The potential for intelligent speed adaptation (ISA) to assist with road safety

June 2024

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NZ Transport Agency Waka Kotahi research report 716
Contracted research organisation – WSP New Zealand

NZ TRANSPORT AGENCY WAKA KOTAHI

Te Kāwanatanga o Aotearoa New Zealand Government

ISBN 978-1-99-106848-4 (electronic)
ISSN 3021-1794 (electronic)

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Tate, F., Frith, B., Thomas, F., Newsome, M., & Malcolm, L. (2023). *Potential for intelligent speed adaptation (ISA) to assist with road safety* (NZ Transport Agency Waka Kotahi research report 716).

WSP was contracted by the NZ Transport Agency Waka Kotahi in 2022 to carry out this research.

Cover image sourced from Starkey et al., 2020, p. 213.

Keywords: crash; intelligent speed adaptation; ISA; safety, speed

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[1] This research was conducted May 2022-May 2023.

Acknowledgements

We would like to thank the following people for their contributions to this research.

The members of the steering group for their knowledge, guidance and input throughout the project:

- Malcolm Menzies, NZ Transport Agency (Research Owner)
- Todd Wylie, NZ Transport Agency
- Irene Zikonda-Kraus, NZ Transport Agency
- Morgan Watkins, Te Manatū Waka Ministry of Transport

Our peer reviewers for their relevant and constructive feedback:

- Samantha Jamson, University of Leeds
- Sam Charlton, Waikato University

The interviewees who contributed their time, knowledge and opinions for this research.

Our technical review and editing team Robert Henderson and Mary Bennett.

Abbreviations and acronyms

ACC	adaptive cruise control
AISA	advisory intelligent speed adaptation
ASD	available sight distance
DISA	differential intelligent speed adaptation
DSA	dynamic speed adaptation
DSI	death or serious injury
EDR	event data recorder
EU	European Union
GPS	Global Positioning System
IILM	Integrated Intervention Logic Model
ISA	intelligent speed adaptation
LKA	lane-keep assist
MISA	mandatory intelligent speed adaptation
NISA	no intelligent speed adaptation
NZTA	NZ Transport Agency Waka Kotahi
PDA	proportion of distance driven more than 5 km/h above the speed limit
SD	sight distance
WoF	warrant of fitness

Contents

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Executive summary

This report discusses the potential for intelligent speed adaptation (ISA) to assist with road safety, including reducing deaths and serious injuries by 40% by 2030 (based on a 2018 baseline).

ISA is one technology in the family of intelligent transport systems, which use advanced information, electronic communications and other technologies for the management and operation of transport networks. The objective of ISA is to keep vehicle speeds within appropriate limits in the interests of safety while providing emissions co-benefits.

There are three categories of ISA determined by the level of intervention involved. Based on information in Waibl et al. (2013), these are:

- advisory – the speed limit is displayed and/or verbally articulated to remind the driver of changes in the speed limit
- voluntary (driver select) – the driver can enable and disable control by the vehicle of the maximum speed
- mandatory (intelligent governor) – the maximum speed of the vehicle is always limited.

This report is designed to be read in conjunction with Waibl et al. (2013) and therefore does not seek to re-traverse ground already covered in that document. It begins with a literature review to cover material published since 2013, moves on to surveyed opinions of ISA users and finishes with a discussion of the benefits and costs of advisory ISA in Aotearoa New Zealand.

Literature review

The main takeaways from the literature review were as follows.

Advisory ISA:

- The results of the studies are generally in line with the conclusions of Waibl et al. (2013) in that users were generally positive about advisory ISA and there was enough compliance to make a useful difference.
- In an advisory ISA fleet, setting incentives works better for those who are already more compliant (rather than those who are non-compliant in other driving areas).

ISA apps:

- Properly configured ISA apps have a demonstrable safety benefit and do not produce adverse distractive effects. The greatest challenge may be encouraging drivers to use them appropriately and consistently.

ISA as part of connected vehicle systems:

- ISA within connected vehicle systems could be a promising application for the future but research to isolate its contribution to such systems is not yet available.

Effectiveness and preference for ISA types:

- Drivers prefer less-mandatory forms of ISA, but conversely, mandatory ISA was more effective in reducing speeds.
- Studies reported 80–97% of drivers perceiving ISA as beneficial for all drivers. In a survey, 80% of drivers preferred restrictive ISA for problematic or frequent speeders and more than half preferred intervening systems like supportive and restrictive ISA for professional drivers and young drivers.
- Mandatory ISA can be effective in a working environment where the driver has no choice but to use it.
- Free ISA provision was preferred but a minority were willing to buy informative or warning ISA at a fair price with respect to a navigation system.

- The more intervening the ISA, the greater market penetration levels were required to induce willingness to install.

Older drivers and ISA:

- ISA systems assist older drivers with speed moderation and lane keeping, but the results gained vary with the system used.
- ISA acts to reduce speeds but may also improve older driver safety by reducing their mental load.

ISA impact on offenders:

- ISA improves the behaviour of recidivist offenders when used in conjunction with rewards and as a control mechanism.

Suitability of speed crash models in the case of advisory ISA:

- Individualised models fit best with the plethora of individual driver decisions that occur with advisory ISA and the subsequent changes in the shape of the speed distribution.
- Therefore, as in Waibl et al. (2013), the Kloeden model is used in the analyses of advisory ISA in this report.

Interviews with ISA users

Individual interviewees believed the ISA system was useful in helping reduce the risk of speeding tickets and to a lesser extent mentioned road safety. However, they reported that systems can be unreliable. This impacts trust in the system and use of the system, with some turning off the system or not using the system during parts of their drive when the system was incorrectly giving speeding alerts.

Both individual and fleet users stated that updating, giving feedback and making corrections on systems is difficult. Other car features such as adaptive cruise control (ACC) were highly regarded and used to help manage speed.

For fleet management systems, data being sent to workplaces impacts driver behaviour more so than in their personal vehicle. There was concern that the fleet monitoring system may increase attention to the vehicle’s speed thus reducing the driver’s attention to other aspects of the road environment.

Benefits and costs of advisory ISA

The study into the benefits and costs of advisory ISA was based on existing data. Using this data, an economic assessment of ISA was undertaken for two scenarios. The first was a natural market-driven implementation of ISA and the second a strategy whereby, once ISA is fitted to 75% of new vehicles entering the fleet, it would be mandated for all vehicles entering the fleet, new or used. The 75% threshold was selected by the project steering group and is in line with the mandating of other vehicle safety features where consideration has been given to potential vehicle supply restrictions and associated cost increases.

The resulting analysis found that, when assessed according to the Monetised Benefits and Costs Manual (Waka Kotahi NZ Transport Agency, 2023a), the benefit-cost ratio for both scenarios was positive (ie, above 1.0, being in the order of 1.7). The big driver and to a certain extent the big unknowns are the costs that are associated with ISA. Even a nominal cost has a major impact on the resulting analysis. Furthermore, there seemed to be essentially no benefit from mandating ISA at such a late stage. Further work is recommended to investigate alternative mandate scenarios.

The crash reductions from Waibl et al. (2013), while based on on-road New Zealand studies, appear low compared to those reported in the international literature. Furthermore, these were conducted prior to the recent moves towards designating safe and appropriate speeds.[2] As a result, in rural areas where 100 km/h was the speed limit, participants may not have been able to exceed the speed limit frequently and therefore the value of ISA would be diminished. The assessment of ISA from a wider dataset using the more recent safe and appropriate speed data from suppliers such as EROAD could greatly improve the validity of the crash reductions and the subsequent benefits of ISA.

Conclusions

These were the overall conclusions of the project:

- The provision of ISA in the New Zealand light vehicle fleet is increasingly driven by overseas mandates. While the costs associated with ISA are assumed to be small if not non-existent, when distributed over the fleet, these mount up. Nevertheless, in a New Zealand context, the provision of ISA has a positive benefit-cost ratio (around 1.7) and the potential to save a total of 5,298 deaths and serious injuries over the next 40 years from 2023 to 2063.
- Given the relatively high proportion of the fleet already fitted with ISA, when the threshold of 75% of new vehicles entering the fleet fitted with ISA is achieved, the additional benefit of mandating ISA for all vehicles from that point forward is minimal. As a result, there seems to be no compelling argument to mandate ISA once it is fitted to 75% of new vehicles entering the fleet, but benefits may accrue from mandating earlier.
- There are several caveats to the above, and further work on the benefits realisation is warranted.

Recommendations

To encourage uptake of advisory ISA:

1. Develop a standard or system to ensure that speed limit information displayed to drivers is accurate.
2. Identify implications for over-the-air updates in the used import second-hand market and the impact of these on ISA adoption.

For fleet managers and providers of ISA systems used in fleet management:

3. Evaluate the impact of additional in-vehicle displays and the role of fleet monitoring and associated protocols on ISA compliance.
4. Provide users with information regarding how their driving data is used and a means to access their personal driving data.
5. Investigate use of fleet systems to increase exposure to ISA (for example, retrofitting of ISA in fleet vehicles for organisations with more than a specified number of employees).

For future ISA research:

6. Further field trials or analysis of data for a wider range of safe and appropriate speeds.
7. Assess the impact of human-machine interface design on compliance.
8. As more post-COVID-19 data becomes available on the proportion of used imported vehicles with ISA, the penetration rate assumptions for used imports should be revisited.
9. A range of alternative mandated scenarios should be investigated.

[2] This is resulting in 80 km/h speed limits in many areas where the limit was previously 100 km/h.

Abstract

This report discusses the potential for intelligent speed adaptation (ISA) to assist with road safety, including reducing deaths and serious injuries by 40% by 2030 (based on a 2018 baseline). ISA is one technology in the family of intelligent transport systems, which use advanced information electronics, communications and other technologies for the management and operation of transport networks. The objective of ISA is to keep vehicle speeds within appropriate limits in the interests of safety.

This report is designed to be read in conjunction with Waibl et al. (2013) and therefore does not seek to re-traverse ground already covered in that document. It begins with a literature review to cover material published since 2013, moves on to surveyed opinions of ISA users and finishes with a discussion of the benefits and costs of advisory ISA in Aotearoa New Zealand.

It makes these overall conclusions:

- The provision of ISA in the New Zealand light vehicle fleet is increasingly driven by overseas mandates. While the costs associated with ISA are assumed to be small, when distributed over the fleet, these mount up. Nevertheless, it would appear that, in a New Zealand context, the provision of ISA has a positive benefit-cost ratio (around 1.7) and the potential to save a total of 5,298 deaths and serious injuries over the next 40 years from 2023 to 2063.
- There seems to be no compelling argument to mandate ISA once it is fitted to 75% of new vehicles entering the fleet, but benefits may accrue from mandating earlier. Further work is recommended to investigate alternative mandate scenarios.
- There are several caveats to the above, and further work on the benefits realisation is warranted.

1 Introduction

1.1 What is ISA

Intelligent speed adaptation (ISA)[3] is one technology in the family of intelligent transport systems, which use advanced information, electronic communications and other technologies for the management and operation of transport networks. The objective of ISA is to keep vehicle speeds within appropriate limits in the interests of safety.

1.2 Types of ISA

ISA comes in many forms, and these are discussed in Waibl et al. (2013). That report delivered an investigation into the deployment of an advisory ISA system in Aotearoa New Zealand, upon which this report builds. The researchers carried out field trials of advisory ISA, which found that it made journey times more consistent and uniform between participants. Driver speeds significantly reduced compared to the baseline condition across a range of road types, although the effects were relatively small. The increase in speed compliance of about 7% was more positive than previous overseas advisory ISA findings, suggesting that New Zealand drivers would respond well to the implementation of advisory ISA. In rural conditions with winding curves, variable advisory ISA significantly improved compliance with advisory curve speed signs. Thus variable ISA offers a proactive and potentially cost-effective solution to a key accident risk in New Zealand.

ISA may be classified into three broad categories determined by the level of intervention involved (Waibl et al., 2013, p. 15):

- Advisory: The speed limit is displayed and/or verbally articulated to remind the driver of changes in the speed limit.
- Voluntary (‘driver select’): The driver can enable and disable control by the vehicle of the maximum speed.
- Mandatory (‘intelligent governor’): The maximum speed of the vehicle is always limited.

Waibl et al. (2013, pp. 15–16) further refine these categories in relation to the currency of the speed limit information:

- Fixed: The vehicle is informed of the posted speed limit.
- Variable: The vehicle is informed of locations where a lower speed limit or advice is recommended or implemented such as pedestrian crossings or sharp bends. In this case, the speed limits or advice may vary spatially.
- Dynamic: In addition, speed limits may vary both temporarily and spatially – lower speeds may be implemented due to weather conditions, in response to incidents or congestion or around schools when students are arriving or leaving.

The terminology used to describe forms of ISA varies around the world.

[3] Also sometimes called intelligent speed assist.

1.3 Report structure

This report is designed to be read in conjunction with Waibl et al. (2013) and therefore does not seek to re-traverse ground already covered in that document.

It begins with a literature review (section 2) to cover material published since 2013, moves on to interviews (section 3) to determine opinions of ISA users and finishes with a discussion of the benefits and costs of advisory ISA in a New Zealand context (section 4).

1.4 Objectives

This project was guided by the research objectives to:

- determine the likely effectiveness and efficacy of different types of ISA to assist with and encourage safe driving behaviour
- discuss the wider costs and safety benefits of ISA based on existing data sources
- establish the uptake of ISA and associated barriers in other jurisdictions, including examples where speed control has been implemented with respect to benefits and disbenefits
- understand the current take-up of ISA, barriers and motivations in New Zealand
- understand the current usage and performance of ISA in New Zealand
- understand the impact of ISA on key driving behaviours
- understand the level of market penetration to realise the safety benefits of ISA
- understand the in-service maintenance requirements of ISA.

2 Literature review

2.1 Introduction

This review relates to literature that has emerged since Waibl et al. (2013) was completed and should be read in conjunction with that report. The sources include literature from a variety of peer-reviewed journals, conference proceedings (both peer reviewed and non-peer reviewed), literature from jurisdictional websites, websites of international governmental organisations and safety-focused non-governmental organisations and other grey literature. Standard search engines (Google and Bing) were used along with a variety of tools available to the WSP information centre and the website SafetyLit,[4] which contains a compendium of safety-related abstracts.

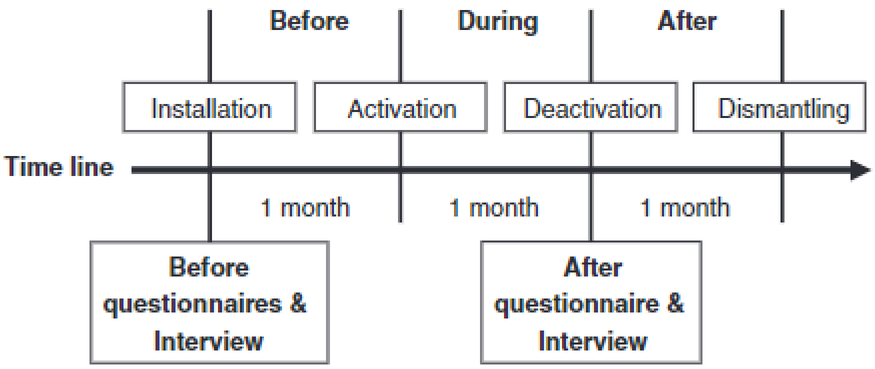
2.2 Advisory ISA studies

A field experiment related to advisory ISA (Ghadiri et al., 2013) was carried out in 2010 in Penang, Malaysia, where 11 drivers – five female (mean age 29.2 years) and six male (mean age 34.8 years) – had their personal vehicles instrumented with an advisory ISA system. The roads driven were described as expressways. The study aimed to evaluate the impact of an advisory ISA on driving speed, traffic safety and driver's attitude, behaviour and acceptance of the system.

The system included a spoken warning message and a text message activated when the driver exceeded the speed limit. The warning was repeated until the driver complied with the speed limit. The vehicles were driven for 3 months on a test road with speed limits of 50, 60 and 110 km/h with the system active. The speed was continuously logged. The warning that occurred when the speed limit was exceeded activated in the second month and deactivated in the third month. The drivers were surveyed and speed surveys were carried out.

The study sequence is illustrated in Figure 2.1.

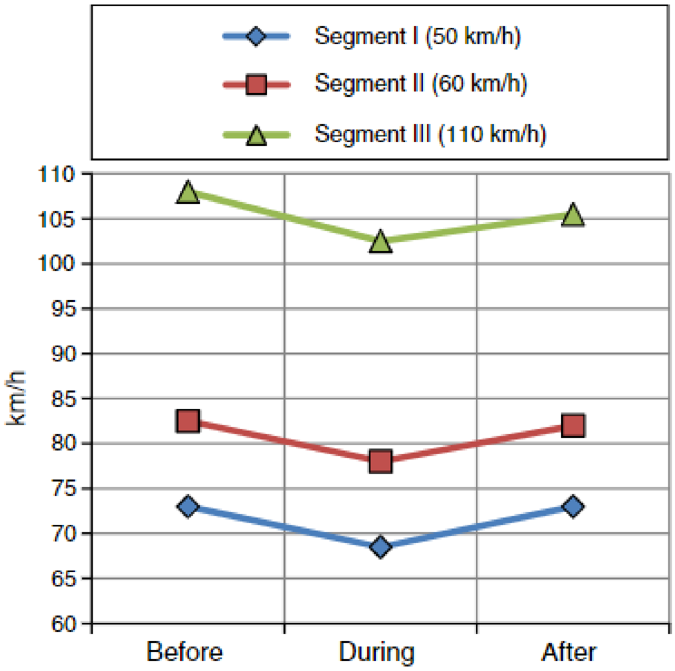
Figure 2.1 Sequential view of the study's procedure (reprinted from Ghadiri et al., 2013, p. 107)



Significant reductions in mean, maximum and 85th percentile speed accompanied use of the system. When the system was deactivated, speeds rose again as depicted in Figure 2.2.

[4] https://www.safetylit.org/

Figure 2.2 The 85th percentile speeds of all test cars when driving with and without the system activated (reprinted from Ghadiri et al., 2013, p. 110)



In a post-trial survey, drivers' responses indicated they felt that the system helped them to follow the speed limit and assisted driving comfort. They preferred the warning system to a driver support system – for example, an active accelerator pedal, which makes the accelerator vibrate and become harder to press, as a warning of excessive speed. However, this preference was not grounded in actual experience as an active accelerator pedal did not feature in the trial. After the trial, most drivers were willing to keep an ISA system.

The safety impact was estimated using Nilsson's power model (Cameron & Elvik, 2008; Nilsson, 1981) using the aggregated speed data for the three time segments illustrated in Figure 2.2. The results are depicted in Table 2.1.

Table 2.1 Expected decreases in serious injury crashes and fatal crashes using the power model (reprinted from Ghadiri et al., 2013, p. 112)

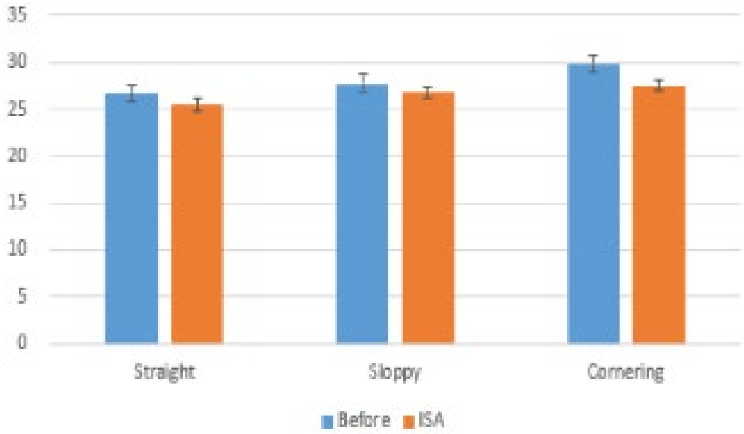
Segment/speed limit (km/h)	Mean speed (km/h)		E1	E2
	V_1	V_2	$(1-(V2/V1)^3)*100$	$(1-(V2/V1)^4)*100$
I/50	62.78	59.18	16%	21%
II/60	54.33	50.95	18%	23%
III/110	94.86	90.59	13%	17%

V1 = Without system , V2 = With system.
E1 = Expected decrease in the number of serious-injury accidents %.
E2 = Expected decrease in the number of fatal accidents %.

Another Malaysian trial of advisory ISA involved 20 buses plying a 1,763 m loop route on the Campus of the Universiti Teknologi MARA in the Malaysian City of Shah Alam (Makhtar & Khameini, 2018). The ISA involved voice commands that the drivers could choose to comply with or ignore. The route was divided into a sloping segment, a straight segment and a segment containing curves.

The average speeds of the drivers over the three segments before and after implementation of ISA were compared using a paired sample t-test. The resulting speed changes are shown in Figure 2.3.

Figure 2.3 Average speed (km/h) (vertical axis) for road segments before and after ISA implementation (reprinted from Makhtar & Khameini., 2018, p. 118)



In all cases, there was a reduction in average speed. The reductions for the sloping (denoted in Figure 2.3 as sloppy) and curved segments were statistically significant. The attitudes of the drivers were also investigated via a questionnaire. Most of the respondents did not consider the speech-based ISA as a distraction or interruption and professed a willingness to reduce their speed in response to the ISA warning – 65% of the drivers preferred the speech-based warnings to other types of sounds. They were familiar with the speech-based warning as that was the warning type used in the trial.

2.2.1 App-based advisory ISA systems

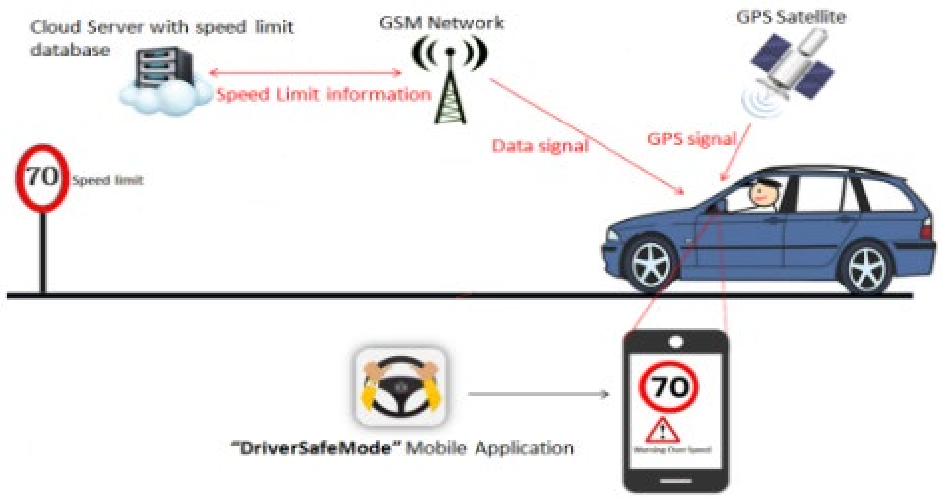
2.2.1.1 Specific ISA apps

The two Malaysian systems described in section 2.2 were bespoke experimental systems that were not application based. An Android app, DriverSafeMode, is described in a Sri Lankan paper (Perera & Dias, 2017). The app uses advisory ISA to warn drivers that they are exceeding speed limits by verbal and visual warnings. The visual warning (which could arguably be a distractor) is shown in Figure 2.4.

Figure 2.4 Visual of when complying with the speed limit (left) and warning when exceeding the speed limit (right) (reprinted from Perera & Dias, 2017, p. 340)

Speed limits in Sri Lanka depend on vehicle type and road type. The vehicle type is supplied to the app by the driver. Google Maps is used to obtain road type by inputting location (longitude, latitude) values continuously. Speed limits are stored in the cloud for each road type and vehicle type. The app connects with the speed limit database during driving mode to access the speed limit for the road type being driven. It compares the real-time speed with the speed limit and warns the driver when the speed limit is exceeded. Figure 2.5 illustrates the process.

Figure 2.5. How the DriverSafeMode app works (reprinted from Perera & Dias, 2017, p. 341)



User impressions of the system were sampled by interviewing 30 test drivers – 10 light-motor vehicle drivers, 10 heavy-motor vehicle drivers and 10 motorised three-wheeler drivers. Their impressions are detailed in Table 2.2.

Table 2.2 User impressions of the system (reprinted from Perera & Dias, 2017, p. 343)

	Light-motor vehicle test drivers	Heavy-motor vehicle test drivers	Tricycle test drivers
Very Effective	8	5	4
Effective	2	4	4
No difference	0	0	0
Ineffective	0	1	2
Very Ineffective	0	0	0
Total	10	10	10

This showed that most of the drivers (80% of light-motor vehicle drivers, 50% of heavy-motor vehicle drivers and 40% of motorised three-wheeler drivers) considered the application very effective, and 90% of the heavy-motor vehicle drivers and 80% of the motorised three-wheeler drivers considered it very effective or effective. Those heavy-motor vehicle and motorised three-wheeler drivers who considered it ineffective did so because traffic noise interfered with hearing the verbal warning. Logically, 'effective' should mean success in controlling speed but the questions used were not disclosed in the paper.

The speeds generated by the system were adequate for the purpose except where the Global Positioning System (GPS) signal from the satellite was disturbed by topographical features such as dense trees and buildings. The system also depends on the existence of cellular networks and wireless internet, which would limit its use in New Zealand as a significant portion of the road network is covered by neither. These limitations could be overcome with improved communication coverage in the coming years.

A New Zealand research team (Starkey et al., 2020) examined the impact of an ISA app on driving performance in a simulator. In the study, 104 participants drove a simulated 26.4 km section of rural road incorporating typical hazards and three speed zones (100 km/h, 80 km/h and 60 km/h). None of the participants reported having used an ISA system previously.

Visual information in the form of speed limit rondels was provided via a smartphone that was mounted on the centre console 12 cm to the left of the steering wheel (see Figure 2.6).

Figure 2.6 The location (left) of the smartphone in the car and the ISA display (right) (reprinted from Starkey et al., 2020, p. 213)

Speeding was defined as at least 4 km/h over the limit for at least 3 seconds. This triggered the main speed rondel flashing on and off until the speed reduced to within 4 km/h of the speed limit. For the audio-visual conditions, a beep synchronised with the flashing. Passive mode meant the ISA display automatically updated to show the new speed limit 7 seconds after entering a new speed zone. In active modes, on entering a new speed zone indicated by speed limit signs at the left and right edge of the road, the participants had to select a new speed limit from the selection of small rondels at the bottom of the screen. Selection of the new speed was confirmed by a beep, and the new speed was displayed in the large rondel. If a new speed was not selected, the ISA reverted to passive mode. Drives were completed with the app in five modes: active audio visual, active visual, passive audio visual, passive visual or no ISA. Another group drove wearing eye-tracking glasses to measure distraction via the measurement of glances. A between-groups design was used with each participant pseudo randomly assigned to a main condition (active audio visual, active visual, passive audio visual, passive visual, control – no ISA) with no participant doing multiple main conditions.

App users complied well with speed limits compared to the no ISA group. The ISA was particularly effective in lower speed limit zones. No significant differences between the four versions of the app were detected. There were relatively few glances at the app, with an average glance duration of 190 milliseconds.

There were no negative impacts on driving performance. Lane keeping was unaffected and overtaking ability was unaffected. When questioned, participants generally rated the app positively.

The authors concluded that the results suggested that properly configured ISA apps have a demonstrable safety benefit and do not produce adverse distractive effects. The greatest challenge may be encouraging drivers to use them appropriately and consistently.

2.2.2 Advisory ISA as part of proprietary navigation/road network information apps

There are already several apps that advise drivers if they are exceeding the speed limit. These apps commonly use either a verbal message or visual message or a combination of the two. An example is Waze,[5] which has a discretionary speed alert system that can be used in conjunction with Apple CarPlay or Android Auto. Waze has received positive reviews (Williams, 2021; Mobile App Daily, 2023). The alerts can be customised as shown in Figure 2.7 from the Google support website.

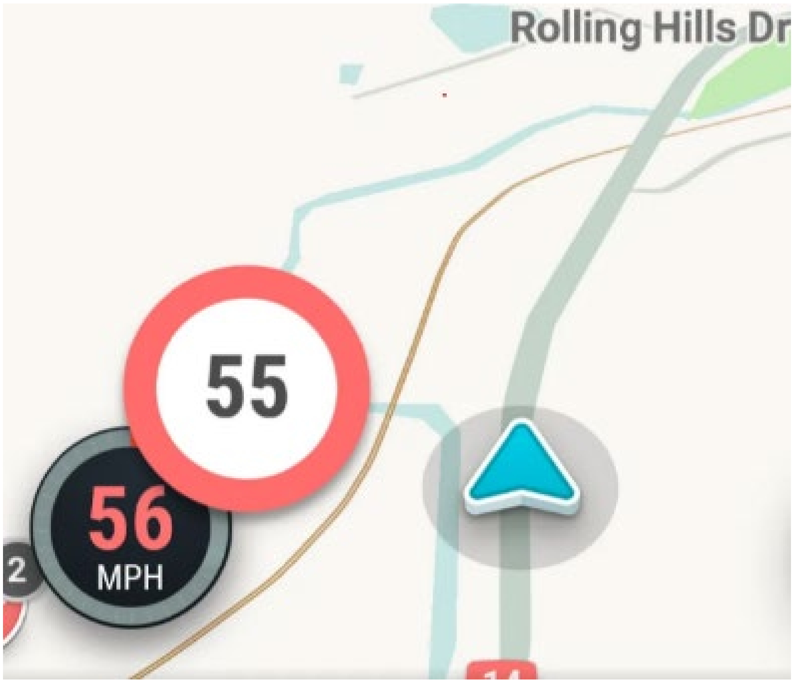
Figure 2.7 Customisation instructions for Waze speed alerts (reprinted from Google, n.d.)

You can customize your alerts using the options under **Speed limit**

1. Tap **Show speed limit** and select an option:
   - Show when exceeding speed limit
   - Always show speed limit
   - Don't show
2. Tap **When to show** to select alerts for when you reach the speed limit or when you exceed the speed limit.
3. Turn on **Play alert sound** to hear a sound alert when the speed limit appears on the speedometer.

Figure 2.8 depicts a Waze mobile phone or navigation system screen featuring a speed limit alert.

Figure 2.8 Mobile phone screen featuring a Waze speed alert (reprinted from King, 2016)



[5] https://www.waze.com

2.2.3 Takeaways

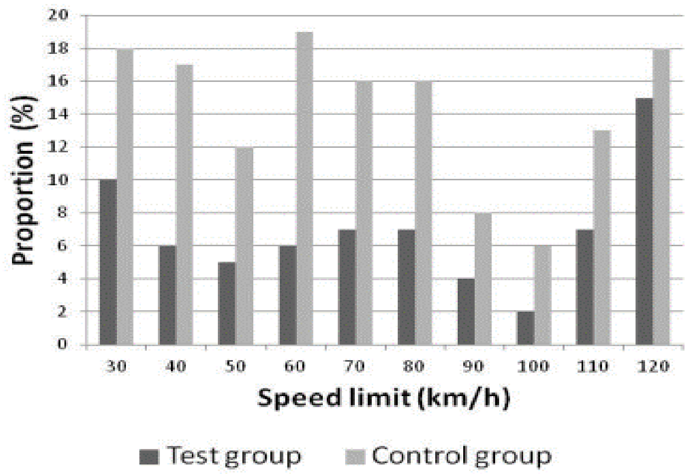
- The results of the studies are generally in line with the conclusions of Waibl et al. (2013) that users were generally positive about advisory ISA and there was enough compliance to make a useful difference.
- Three studies were from countries in Asia (Malaysia and Sri Lanka), which could have different compliance characteristics from New Zealand.

2.3 The role of incentives

2.3.1 Advisory ISA with incentives

Stigson et al. (2014) describe a 1-year pay-as-you-speed trial using advisory ISA with an economic incentive for observing the speed limit. The participants were not restricted in where they could drive. This trial was conducted in Sweden during 2011 and 2012. The ISA system used a GPS receiver continuously identifying the position of the vehicle and was linked to a national digital road network map that included speed limits. Speeding was detected by comparing the speed measured by the GPS to the speed limits stored in the digital map. The incentive was an insurance premium reduction of up to 30% depending on the level of compliance with the speed limit. The participating drivers were private insurance customers. They were randomised into a test group (initial n=152 and final n=128) and a comparison group (initial n=98 and final n=68). The test group drivers received a visual warning of any speed limit violation and could follow their driving behaviour on a personal website. The comparison group received no feedback and received a 20% premium discount irrespective of how they drove. The proportion of distance driven above the speed limit was compared between the two groups. The test group significantly reduced their proportion of distance driven above the speed limit. Overall, the proportion of driving 6 km/h or more over the speed limit was 6% for the test group and 14% for the comparison group and was constant over time. Figure 2.9 illustrates the percentages travelling more than 6 km/h over the speed limit for each group by the posted speed limit.

Figure 2.9 Percentage travelling more than 6 km/h over the speed limit for each group by posted speed limit (reprinted from Stigson et al., 2014, p. 615)



The impact of the ISA increased at higher speeds above the limit. Over 40% of the drivers in the test group drove less than 1% of the total distance illegally. The corresponding figure for the control group was approximately 10%. The lower speeding rate in the test group did not result in any large increase in travel time. Depending on the speed limit, members of the test group on average travelled at the most 1.5 fewer kilometres in an hour than the control group. The authors applied the road accident power model as described in Elvik et al. (2004) and Vadeby and Forsman (2012). This suggested the reduced speeding in the test group would relate to a reduced fatality risk of 20% and reduced risk of serious injury by 5–10%. This work indicates that incentives may be worth considering as a way to improve the operation of advisory ISA.

Agerholm et al. (2012) describe a Danish ISA trial related to commercial drivers. The trial included 26 commercial cars and 51 drivers. Following a 2-month baseline period, the ISA was activated for six 2-month periods denoted as ISA 1 to ISA 6 (see Table 2.3). The drivers could be identified by a personal key (key ID) before driving but such personal identification was compulsory for only some of the drivers. The ISA system used was advisory with verbal warnings supplemented by rewards for not speeding and social control via a website where drivers could compare their results non-anonymously with other drivers within their company who had activated their key codes and anonymously with those who had not and drivers from other companies. The social control, which was intended to involve drivers comparing their performances during their breaks, was ineffective as the discussion that ensued was mainly about technical aspects of ISA rather than individual performance. Similarly, the rewards impact was disappointing as the adherence to speed limits decreased over time during the trial.

Table 2.3 Proportion of distance driven more than 5 km/h above the speed limit (PDA) with and without key ID (reprinted from Agerholm et al., 2012, p. 5)

Speed limit	Key ID	Baseline	ISA 1	ISA 2	ISA 3	ISA 4	ISA 5	ISA 6
Total	With key ID	15%	3%	4%	3%	4%	5%	5%
	Without key ID		10%	10%	12%	12%	15%	13%
50 km/h	With key ID	20%	5%	6%	5%	6%	6%	12%
	Without key ID		13%	14%	19%	15%	17%	16%
80 km/h	With key ID	15%	3%	4%	2%	3%	5%	4%
	Without key ID		10%	8%	12%	11%	15%	13%

Table 2.3 also shows that drivers using key ID were much more compliant with the speed limit than those not using key ID. The PDA without key ID was significantly higher than with key ID. On 50 km/h roads with key ID, PDA increased over time but still remained significantly lower than baseline. For 80 km/h roads with key ID, PDA was low (3–5%) and virtually unchanged over time. Without key ID, the pattern found was similar to that for 50 km/h roads. Use of key ID could be considered a metric of intention to drive in a way where the driver was happy to be open to scrutiny. Table 2.4 shows that this reduced very markedly over time.

Table 2.4 Proportion of distance driven with/without use of key ID (reprinted from Agerholm et al., 2012, p. 5)

	ISA 1	ISA 2	ISA 3	ISA 4	ISA 5	ISA 6
With key ID	65%	67%	49%	43%	33%	27%
Without key ID	35%	33%	51%	57%	67%	73%

Non-key ID users showed almost no change in their pre-ISA behaviour. Statistical modelling also showed that drivers who reduced their speed under ISA sped significantly less in baseline than those who did not. Questionnaires were used to distinguish between green drivers (not positive to speeding) or red (more positive to speeding). Green drivers were found to always use the key ID while red drivers never used it. Sensitivity to ISA and the driver's speeding propensity were highly correlated with green drivers. Hence, ISA was found to impact much more on the already relatively compliant key ID users than the less compliant non-users and to decrease in effectiveness markedly over time as the use of key ID decreased over time.

2.3.2 Advisory ISA with incentives

Reagan et al. (2012) report a 2011 ISA field trial that took place in Kalamazoo, Michigan, with 50 drivers participating for 4 weeks – 40 drove vehicles equipped with advisory ISA systems featuring auditory and visual warnings that were triggered when the travel speed exceeded the speed limit by 5 mph and the remaining 10 drivers were a comparison group who drove vehicles without ISA. Week 1 was a baseline period. The group of 40 drivers (of which 20 were monetarily incentivised) had ISA activated either during week 2 or week 3. Week 4 was a return to baseline. The experimental design is illustrated in Table 2.5.

Table 2.5 Experimental design (reprinted from Reagan et al., 2012, p. 221)

	Week 1	Week 2 (AF On or Off[a])	Week 3 (AF On or Off[a])	Week 4
Incentive (n = 20)	Baseline	Advisory on or off	Advisory on or off	Reversal
No incentive (n = 20)	Baseline	Advisory on or off	Advisory on or off	Reversal
Control (n = 10)	Control	Control	Control	Control

Note. AF = automated feedback.
[a]Within the monetary incentive (MI) and no-MI groups, the advisory was counterbalanced between Weeks 2 and 3.

The monetary incentive was a $25 bonus credit, which declined by 3 cents for every 6-second period driven 5–8 mph above the speed limit. The penalty increased to 6 cents at 9 mph or more above the limit. A visual display provided updated bonus amounts when the ignition was turned on or off. The results showed that the incentive system produced significant reductions in excessive speed and the advisory ISA on its own led to modest reductions. When incentives were in operation, drivers consistently increased the percentage of time driving at or under the speed limit and reduced their average speeds in several speed zones.

Thomas et al. (2022) provide a review of the application of incentives to encourage safe behaviour and choices in the context of an overall safe system approach. The researchers found that safer driving incentives are complex and many factors influence their success. Those targeting younger drivers and fleet schemes show the best results. Layering or multiplying incentives can improve outreach to all groups.

2.3.3 Takeaways

The studies looked at here confirm results from Waibl et al. (2013) and Thomas et al. (2022) that indicate incentives can work well but need to be very carefully designed to do so.

2.4 Advisory ISA as part of connected vehicle systems

Ali et al. (2020) examined the impact of the connected environment on driving behaviour and safety. They used a driving simulator to mimic a connected environment with vehicle-to-vehicle and vehicle-to-infrastructure communication capabilities. One of the communication connections was advisory ISA in the form of speed limit violation warnings. Table 2.6 compares total speed limit violation warnings in a baseline condition with those in a connected environment (perfect communication) scenario. Three baseline conditions are presented: two-lane two-way highway, four-lane two-way motorway and the city environment.

Table 2.6 Baseline speed limit violation warnings compared to perfect communication warnings (reprinted from Ali et al., 2020, p. 12)

Sum of the frequency of exceeding the posted speed limit	Baseline	Connected Environment	Wilcoxon test
Two-lane two-way highway (posted speed limit 100 km/h)	1479	1373	<0.001
Four-lane two-way motorway (posted speed limit 100 km/h)	152	4	<0.001
City (posted speed limit 40 km/h)	763	384	0.004

Table 2.6 records that the connected system (which features warning ISA) is associated with fewer speed limit violations. However, it is not possible to ascertain to what extent the warning ISA contributed to the change vis-à-vis the other connectivity measures.

2.4.1 Takeaway

ISA within connected systems could be a promising application for the future but research to isolate its contribution to such systems is not yet available.

2.5 Curve-based ISA

Several studies describe the successive stages of a project aimed at developing an ISA system based on available sight distance (ASD) on curves rather than the posted speed limit (Bassani et al., 2019; Hazoor et al., 2021, 2022). The system could be deployed in all three ISA configurations (see section 1.2). The rationale for this system is that posted speed limits on a stretch of road do not generally take stopping sight distance (SD) requirements on a particular part of the stretch into account so that, at particular locations, speeds below the posted speed limit may be unsafe.

Table 2.7 depicts the percentage of safe, partially safe and unsafe curve negotiations and driver compensation strategies exhibited by a group of test drivers in a simulator study by Bassani et al. (2019) reported in Hazoor et al. (2021) as they negotiated horizontal curves. Safety was defined as:

- safe: ASD always > SD
- partially safe: at curve entry and exit ASD > SD but ASD < SD at the middle section of the curve
- unsafe: ASD < SD throughout the curve.

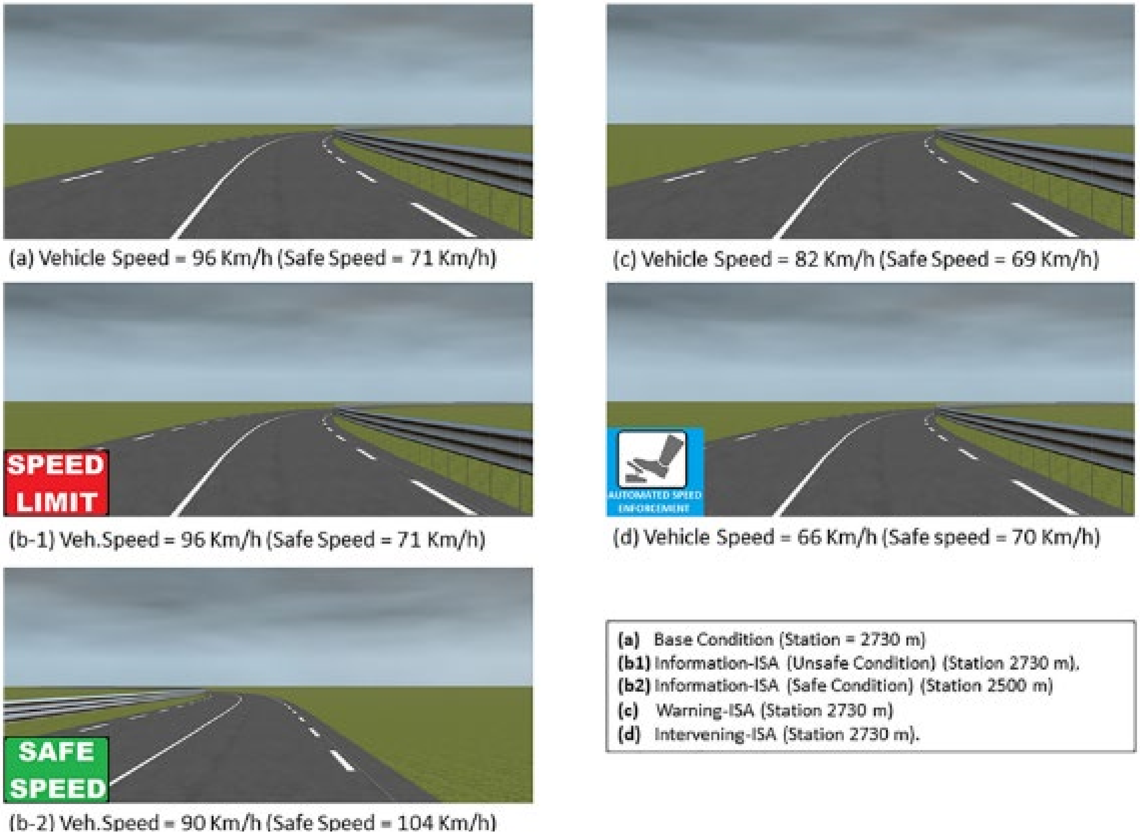
Table 2.7 Driver choice of compensatory strategy combinations considering visibility conditions along curves with limited sight distance available (reprinted from Hazoor et al., 2021, p. 2)

	Strategy			
Visibility condition	Lateral shift (%)	Speed reduction (%)	Both (%)	None (%)
Safe (ASD > SD)	11.5	36.9	3.5	48.1
Partially safe	18.9	40.3	6.6	34.1
Unsafe (ASD < SD)	5.8	49.3	26.1	18.8
Total	14.0	38.8	5.9	41.3

Table 2.7 reveals that, of drivers negotiating curves with a safe level of visibility, 36.9% moderated their speed to reduce their SD, 11.5% moved laterally to increase their ASD, 3.5% did both and 48.1% did neither. On less-safe curves, more drivers (40.3% for partially unsafe curves and 49.3% for unsafe curves) reduced their speeds.

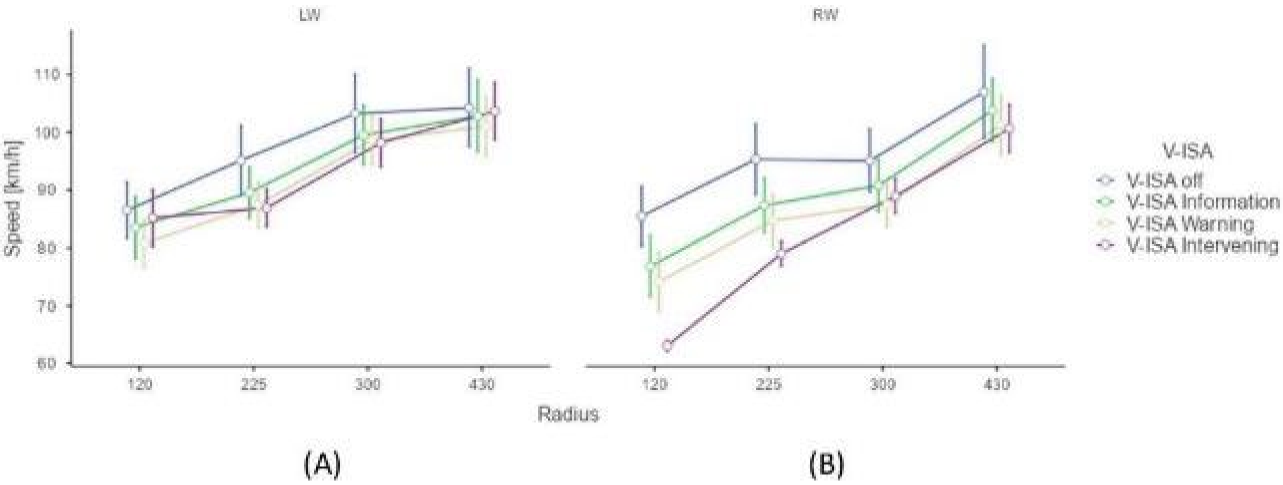
This work was a precursor to the testing of an ISA model across the three ISA types. The model can estimate the ASD with respect to the vehicle's longitudinal and lateral position. The test drivers were given visual information on actual vehicle speed and the recommended safe speed based on the ASD via a display of static images. Some examples are shown in Figure 2.10.

Figure 2.10 Examples of visual information given to the driver for ISA variants under varying safety conditions (reprinted from Hazoor et al., 2021, p. 7)



For the voluntary variant of ISA, a continuous beep sounded immediately when the driver travelled at an unsafe speed. The intervening variant either prevented the vehicle from exceeding the threshold speed limit or decreased the vehicle speed gradually and smoothly from an unsafe speed to the threshold speed limit. Drivers also drove under the base condition with no ISA. Figure 2.11 provides mean speeds by curve radius and direction for left-hand and right-hand curves by the different types of ISA. All forms of ISA resulted in lower speeds than those with no ISA. Additionally, the more intervening the ISA, the lower the speed is generally.

Figure 2.11 Mean speeds by curve radius and direction for left-hand (A) and right-hand (B) curves with error bars (reprinted from Hazoor et al., 2022, p. 8)

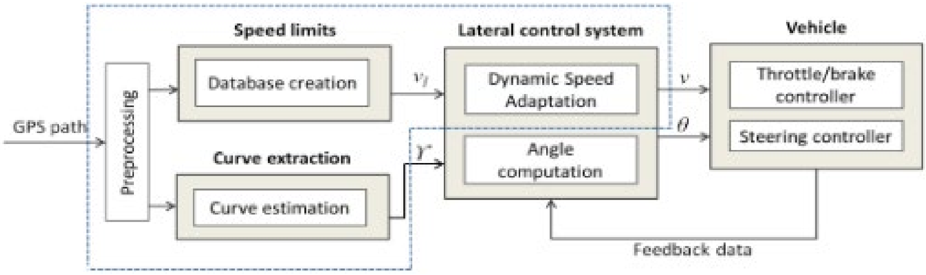


Another paper on the use of ISA on curves relates to dynamic speed adaptation (DSA) – a variant of ISA (Gámez & Ruichek, 2017). An algorithm analyses GPS information offline to identify high curvature segments and estimates the safe speed for each curve. The speed limit for the relevant section is also provided through a speed limit database. DSA uses this information to provide smooth transitions between driver chosen speeds and safe speeds. It does this by detecting upcoming sharp curves and adjusting deceleration to smoothly attain a safe traverse speed. The vehicle's tracking performance is evaluated through lateral errors, given a geographic information system (GIS) road map, including speed limits and safe curve speeds. The process is as follows (Gámez & Ruichek, 2017, p. 2):

- *extract position information of sharp curves and speed limit zones,*
- *compute the recommended speed for each sharp curve,*
- *obtain the speed limits for the path,*
- *analyse the current vehicle position in the travelled GPS path,*
- *compute the triggered distance at which the vehicle needs to start decelerating to ensure smooth speed transitions,*
- *adjust speed during triggered distance to respect sharp curved speed or speed limits,*
- *control the vehicle's speed automatically.*

The automatic control uses a throttle/brake controller and steering controller. Figure 2.12 illustrates the process.

Figure 2.12 Diagram of how the DSA system works (reprinted from Gámez & Ruichek, 2017, p. 3)



This work is still at the experimental stage and the team expressed an intention to investigate further refinements, including:

- detecting the road if GPS is not available
- identifying speed limit signs where no speed limit database is available
- recognising lane markings for road boundary detection and shape estimation
- detecting and recognising arrow markings.

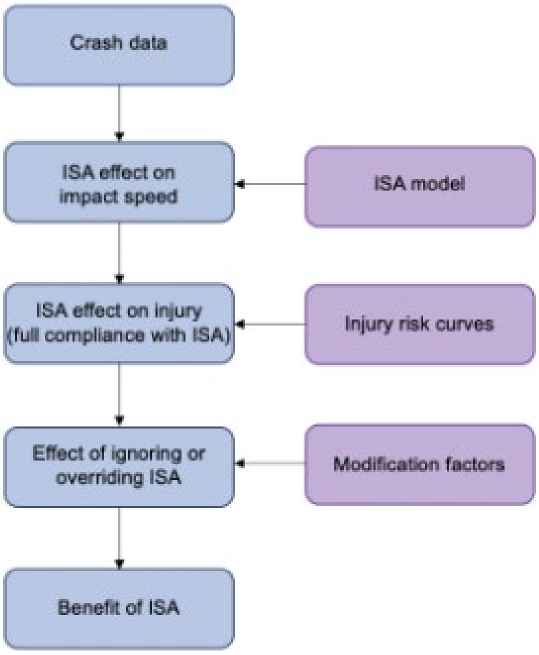
2.5.1 Takeaways

Waibl et al. (2013) discussed ISA at curves in detail and recommended substantial further research on the subject. The studies discussed here add a small increment to the research base but further work is needed.

2.6 Studies relating to more than one form of ISA

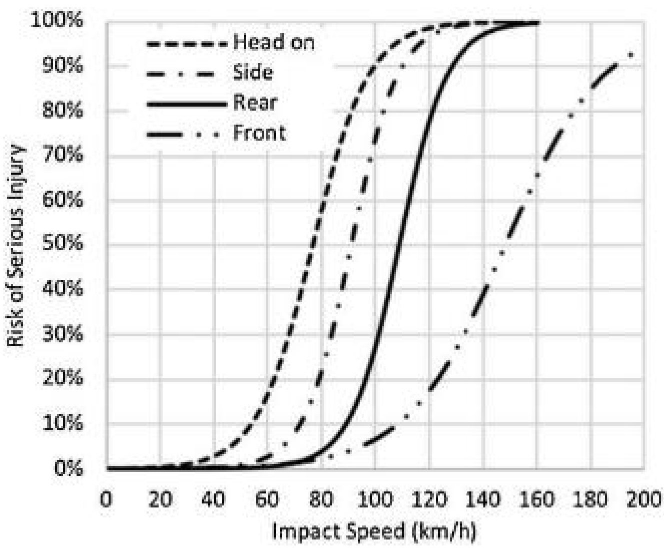
Doecke et al. (2021) report an Australian study to determine ISA's impact on crash severity using event data recorder (EDR) information. The data source was a database combining data from the EDRs of crashed vehicles with matched police crash reports. This meant that pre-crash speeds and speed limit details were known accurately. The impact of ISA was then modelled and combined with the EDR data to produce an estimate of impact speed had ISA been utilised. Changes in the probability of fatal and serious injury crashes were then estimated using risk curves. The methodology is shown in Figure 2.13.

Figure 2.13 Methodology flow diagram (reprinted from Doecke et al., 2021, p. 5)



The injury risk curves from work by Doecke et al. (2020) are shown in Figure 2.14.

Figure 2.14 Curves relating serious injury risk (including fatal) to impact speed, by impact configuration (reprinted from Doecke et al., 2020, p. 9)



The study found sizeable reductions in impact speed associated with ISA and estimated the following changes in Australia-wide serious injury crash numbers if all vehicles were fitted with ISA.

- Limiting (mandatory) ISA: 17.6%, or 7,040 injuries per year
- Supportive (voluntary) ISA: 8.1–12.3%, or 3,240–4,920 injuries per year.
- Advisory ISA: 5.1–9%, or 2,040–3,600 injuries per year.

The authors concluded that voluntary ISA appeared to be the best ISA type for regulation because of strong user acceptance in other studies and moderate safety benefits in this study and previous studies. They also concluded, citing Vlassenroot et al. (2011), that mandatory ISA would be suitable for repeat speed offenders once technical limitations have been overcome. This was because such drivers would benefit most from ISA but are most likely to ignore or override non-mandatory systems.

Spyropoulou et al. (2014) used the Transport Research Laboratory full-scale driving simulator to study driver behaviour changes in 23 participants with advisory, warning and mandatory ISA. Metrics used included driving speed, speed deviation, frequency and magnitude of speeding and speed distribution. The drivers also answered a questionnaire to identify their attitudes towards the systems and how prior expected behaviour compared to measured behaviour. The advisory ISA involved information provided via a 14 cm screen situated in the centre console, which showed the speed limit and its justification (see Figure 2.15).

Figure 2.15 Messages associated with the advisory ISA (reprinted from Spyropoulou et al., 2014, p. 41)

The warning ISA system provided the speed-related information in Figure 2.15 on an in-vehicle screen. There was also an auditory warning when the vehicle speed exceeded the posted speed limit by 2 mph. The warning was repeated three times (0.5 seconds on, 0.5 seconds off) the first time the speed limit was exceeded. A single tone (0.5 seconds) then sounded every 8 seconds the driver continued to exceed the speed limit along with a visual indication on the console screen.

The mandatory ISA prevented the vehicle from exceeding the speed limit by making accelerator pressure ineffective. If a driver entered a speed limit zone too fast, the system decelerated the vehicle smoothly to the speed limit. The system kicked in at 2 mph higher than the posted speed limit. The speed limit was presented via the screen and a warning (0.5 seconds) sounded to signal the intervention.

The simulation involved four drives – one with no ISA and the others with the three different ISA systems in use. The speed limits simulated were highway (60 mph), village area (30 mph) and residential area (20 mph). Each drive covered four highway areas – two village areas and one residential area with village and residential areas constrained not to appear successively. These different areas appeared in different orders in different drives. Each drive was approximately 20 km in length and lasted about 20 minutes. The behaviours under the three ISA conditions are illustrated by the metrics of maximum speed (see Table 2.8), mean speed (see Table 2.9) and standard deviation of speed (see Table 2.10).

Table 2.8 Maximum driving speed (mph) (reprinted from Spyropoulou et al., 2014, p. 42)

ISA system	Base	Informative	Warning	Intervening
Speed limit – 60 mph				
Mean	67.13	68.73	63.97	60.38*
SD	5.01	6.87	6.45	1.00
Speed limit – 30 mph				
Mean	34.09	34.49	33.20	31.11*
SD	4.42	3.54	4.64	0.96
Speed limit – 20 mph				
Mean	28.54	28.00	26.70	21.72*
SD	5.04	4.26	6.26	0.44

* Statistically significantly different from base condition ($\alpha = 0.05$).

Table 2.9 Average driving speed (mph) (reprinted from Spyropoulou et al., 2014, p. 43)

ISA system	Base	Informative	Warning	Intervening
Speed limit – 60 mph				
Mean	62.66	62.71	59.73	59.17*
SD	5.24	4.69	6.09	1.65
Speed limit – 30 mph				
Mean	30.53	31.07	29.48	30.12
SD	3.63	2.61	2.46	1.44
Speed limit – 20 mph				
Mean	24.33	23.39	21.25*	20.95*
SD	4.09	3.00	3.22	0.75

* Statistically significantly different from base condition ($\alpha = 0.05$).

Table 2.10 Standard deviation of speed (mph) (reprinted from Spyropoulou et al., 2014, p. 43)

	Base	Informative	Warning	Intervening
Speed limit – 60 mph				
Mean	2.24	2.97	1.86	0.81*
SD	0.58	2.03	0.96	0.85
Speed limit – 30 mph				
Mean	1.54	1.39	1.47	0.56*
SD	0.68	0.49	0.96	0.46
Speed limit – 20 mph				
Mean	1.46	1.56	1.95	0.36*
SD	0.49	0.70	1.54	0.30

* Statistically significantly different from base condition ($\alpha = 0.05$).

The drivers tended to drive at illegal speeds irrespective of speed limit or ISA system. This is indicated by the mean maximum speed exceeding the speed limit. Warning and mandatory ISA tended to reduce the extent of speeding, but the advisory ISA did not. Speed reductions were statistically significant at 5% level for the mandatory system for all speed limits. The authors considered this reduction to be a direct result of the mandatory ISA. Baseline mean speeds exceeded the speed limit as did mean speeds for advisory ISA. Mean speeds were closer to the speed limit for the warning and mandatory systems. The impact on mean speeds was less than the impact on maximum speeds for all ISA types. Only the mandatory ISA had a significant impact on the standard deviation of speed.

Ando and Mimura (2015a) reported average speed changes related to advisory ISA for a similarly sized group to that in Ando et al. (2014) (see section 2.7), but classification of participants was by personality trait (called factors in the paper) rather than by age. The same simulator was used on a 40 km/h road section, a 30 km/h narrow road section and a 30 km/h wide road section. Results are recorded in Table 2.11.

Table 2.11 Speed changes by driver group under different ISA conditions (reprinted from Ando & Mimura, 2015a p. 143)

Factor	Road section	Average speed (km/h)			
		Usual: First time	Voice information	Picture information	Usual: second time
Aggressive ($n = 16$)	40 km/h	42.0	38.1	38.6	38.5
	30 km/h narrow	31.7	30.8	31.4	31.8
	30 km/h wide	35.3	30.9*	31.1	32.2
Dependence ($n = 15$)	40 km/h	41.0	36.9	37.0	37.1
	30 km/h narrow	31.7	29.7	29.5	29.4
	30 km/h wide	33.8	30.5	31.0	29.9
Random rambling, look aside ($n = 17$)	40 km/h	42.5	38.6	37.7*	38.3
	30 km/h narrow	33.2	31.3	30.0	32.2
	30 km/h wide	34.7	30.7*	30.7*	32.0
Accept violation ($n = 18$)	40 km/h	39.8	37.5	39.0	38.3
	30 km/h narrow	31.2	30.7	31.1	31.4
	30 km/h wide	34.3	31.6	32.6	33.4

Note: significance at 5% level when applying Dunnett's multiple comparisons with the "usual: first time".

The factors in Table 2.11 are stated as meaning (Ando & Mimura, 2015a, p. 139):

- *aggressive factor. e.g. getting angry with the action of the car just ahead for being slow, or feeling unhappy when overtaken by someone …*
- *dependence factor. e.g. turning left or right just following the car ahead or not feeling nervous when changing lane because of thinking other cars will give way …*
- *random rambling, looking aside factor. e.g. looking aside sometimes during driving or being careless sometimes even during driving …*
- *accept violation factor. e.g. considering all drivers are in the same boat in the sense that driving may bother someone or a traffic accident means no luck or not being dangerous when driving at the speed that is about 10 km/h over the speed limitation.*

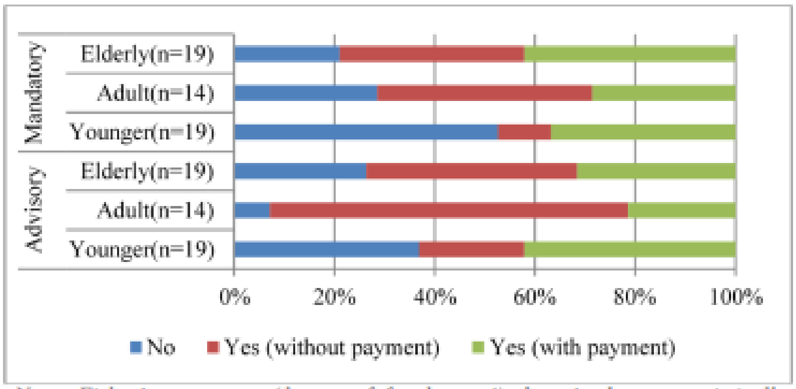
In the table, 'usual' means no ISA, 'first time' means pre-ISA and 'second time' means post-ISA.

For all groups, average speeds reduced by varying amounts during advisory ISA and tended to go up again after ISA was discontinued. The aggressive group tended to increase the most under discontinuance of ISA.

The drivers were asked to evaluate ISA on a 5-point scale. Generally, the drivers preferred advisory ISA to the mandatory version, and the older drivers rated it more highly than their younger counterparts.

The older drivers appeared more willing to pay for mandatory ISA than the younger groups, but no differences were significant (see Figure 2.16). All the age groups considered that ISA should be promoted, whether mandatory or advisory.

Figure 2.16 Driver willingness to pay for ISA by age group (reprinted from Ando & Mimura, 2015b, p. 370)



Note: Fisher's exact test (degree of freedom= 4) doesn't show a statistically significant difference.

The authors concluded that acceptance of both forms of ISA was generally high for older drivers on community roads (one-lane two-way local roads, uncommon in New Zealand but the norm in Japan). As well as reducing speeds, ISA may also improve safety by reducing mental load. This was ascertained by surveying drivers on their experience of six mental load categories – panic, uneasy, nervous, tiring, anxious and impatient – using a 7-point Likert scale ranging from much disagree to much agree. For mandatory ISA, all age groups tended towards positive results. For advisory ISA, older drivers tended to show lower mental loads than younger drivers, particularly on community roads. Mandatory ISA was less accepted than advisory ISA meaning ISA should be introduced through advisory ISA, and given Japan's ageing population, acceptance by older drivers is a critical factor.

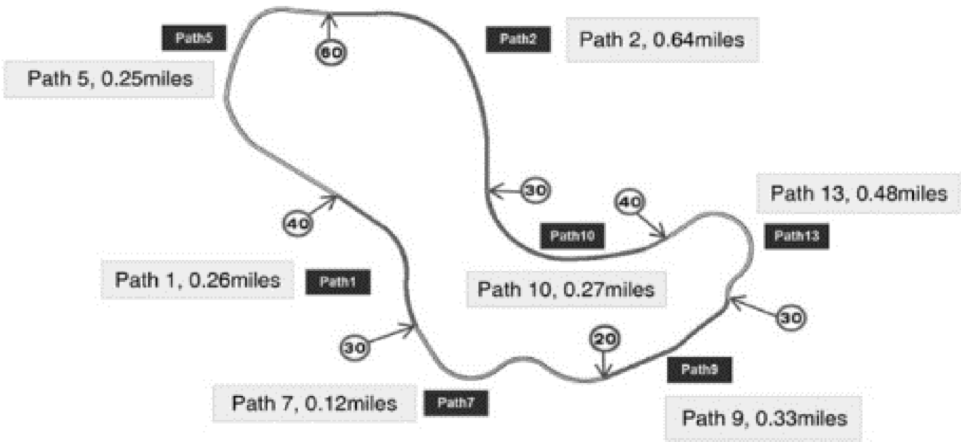
2.6.1 Takeaways

Not unexpectedly, drivers preferred less-mandatory forms of ISA, but conversely, the more-mandatory types were more effective in reducing speeds.

2.7 Studies principally related to older drivers

Guo et al. (2015) carried out a simulator study investigating the extent to which ISA in three forms can assist older drivers to maintain an appropriate vehicle speed in an area with a 30 mph speed limit. The study used an experimental group of 26 drivers aged over 60 along with a comparison group of 16 experienced drivers aged under 60. All drivers completed four driving tasks in a driving simulator with and without ISA. The experiment used a simulated circular road map with seven road segments connected by seven nodes. The road layout was a single carriageway with a lane in each direction and several speed limit changes. The length and speed limit of each segment are shown in Figure 2.17.

Figure 2.17 Simulated road map (reprinted from Guo et al., 2015, p. 345)



Four scenarios were used:

- No ISA (NISA).
- Advisory ISA (AISA): A speed limit sign (blue background) was placed on the lower left corner of the windscreen to remind the driver of the limit, and a 3 second audible warning of a speed limit change was provided 5 seconds before entering the new zone to provide a 2 second reaction time.
- Differential ISA (DISA): The background colour of the speed limit sign changed from blue to red on exceeding the speed limit with an audible message asking the driver to slow down. This comes within this document's definition of voluntary ISA.
- Mandatory ISA (MISA): An automatic braking system was activated if the driver exceeded the speed limit and the steering wheel started to vibrate. There was no warning about speeding.

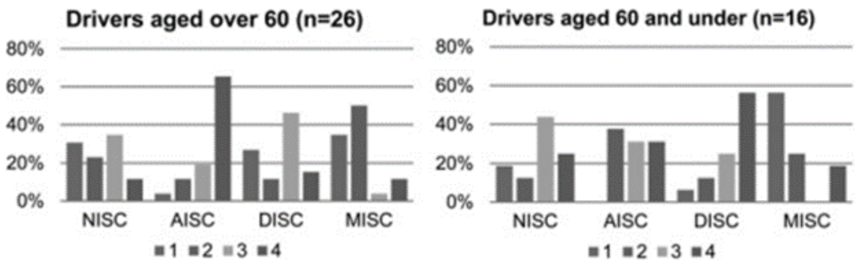
Driving performance was then examined for each scenario using the simulated paths shown in Table 2.12.

Table 2.12 Paths used to examine driving performance per scenario (reprinted from Guo et al., 2015, p. 346)

Path	Scenario NISA	Scenario AISA	Scenario DISA	Scenario MISA
1	no	yes	no	yes
9	yes	yes	yes	no
10	yes	no	yes	yes

The participants drove through their paths under free-flowing traffic condition with no junctions and no overtaking. This was to isolate the ISA as the only source of distraction or cognitive overload. Lateral lane keeping and vehicle speed were examined with and without the ISA systems. The analyses were carried out on a scenario-by-scenario basis for each participant. The rankings are summarised in Figure 2.18.

Figure 2.18 Drivers' lane-keeping rankings (1 = worst, 4 = best) (reprinted from Guo et al., 2015, p. 347)

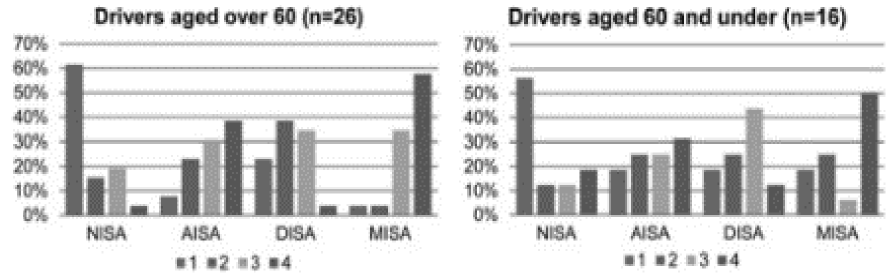


Changes in speed and lane-keeping performance varied with type of ISA and driver age. The authors also considered that training in effective use of ISA is needed for all drivers irrespective of age.

Most older drivers performed best with the AISA system (over 65% of drivers rated 4) while more than half of the drivers aged 60 and under performed best with the DISA system. Differences between ISA systems were statistically significant for the older group but not for the younger group. This is evidence of the older group's lane keeping being impacted by ISA, in particular the AISA system. This is not true of the younger group.

Speed compliance was ranked in a similar way to lane keeping and is summarised in Figure 2.19.

Figure 2.19 Drivers' speed compliance rankings (1 = worst, 4 = best) (reprinted from Guo et al., 2015, p. 349)



Exceeding the 30 mph speed limit was common among the participants. The older group performed better in the MISA system (58% of drivers rated 4) and the AISA system (38% rated 4) than in the NISA and the DISA systems (only 4% rated 4 in both). In the younger group, the pattern was similar, but their mean speeds were closer to the limit than those of the older group. However, conversely, the younger group exceeded the limit more often. For both the younger and older group, lane-keeping performance deteriorated with the MISA. This was possibly related to lack of experience with the autonomous braking system, which indicated to the authors a need for prior education for the drivers on how such a system works.

The authors concluded that:

> *ISA can play a role in helping older drivers stay safely on the road for longer by assisting with lane-keeping and speed performance under free-flow traffic conditions in built-up areas with low road speed limits.* (Guo et al., 2015, p. 350)

They also considered that lane keeping benefits most from AISA, which has least interventions. As AISA also assists in speed maintenance, they considered the system most suitable for more widespread use at the time of writing.

Researchers led by Japan's Toyota Transportation Research Institute have produced a suite of simulation results about the impact of advisory and mandatory ISA on lower speed limit roads (50 km/h and under). Ando and Mimura (2015b) used a simulator to look at how older Japanese drivers accept both advisory and mandatory ISA. The roads simulated and their speed limits are shown in Table 2.13. (Community roads are one-lane two-way local roads, uncommon in New Zealand but the norm in Japan).

Table 2.13 Road types simulated (reprinted from Ando & Mimura, 2015b, p. 365)

	Road type	No. of lanes	Lane width	Shoulder width	Sidewalk width	Width of road	Speed limit	Class of roads
Trunk roads	4-lane	4	3.25	0.50	3.00	20.0	50km/h	Type 4, Class 1
	2-lane	2	3.25	0.50	3.00	13.5		Type 4, Class 1
Community roads	Wide	1	5.50	0.50	None	6.50	30km/h	Type 4, Class 3
	Narrow	1	4.00	1.25	None	6.50		Type 4, Class 3

Note: unit of width=m

The study used 52 participants – 19 were 65 years and older, 14 were 30–64 years and some were under 30. The road types in Table 2.13 were driven under the following conditions:

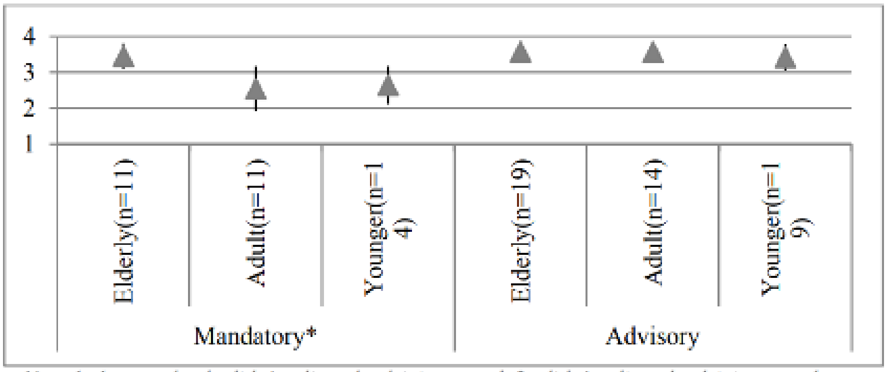
- No ISA with no speed limit signs.
- No ISA with speed limit signs.
- Mandatory ISA with speed limit signs followed by mental load questions.
- Advisory ISA with speed limit signs followed by mental load questions.

After the drives, participants were questioned about their impressions of the different forms of ISA. Mental load was classified into six categories described as panic, uneasy, nervous, tiring, anxious and impatient. All loads are measured by 7-point scale described as much agree (-3), agree (-2), a little agree (-1), no opinion (0), a little disagree (1), disagree (2) and much disagree (3). Thus, positive choices relate to positive responses and vice versa (Ando & Mimura, 2015b).

For mandatory ISA, results differed by age group. Younger drivers felt less mental load on trunk roads while older drivers felt less mental load on community roads. For advisory ISA, all age groups tended to feel uneasy irrespective of the road, but the younger drivers tended to be more uneasy than their older counterparts although the differences were not statistically significant. Overall, the older group exhibited less mental load especially on community roads.

The drivers were also questioned about their compliance with ISA based on a 4-point scale – 1 (completely didn't adjust the driving speed), 2 (didn't adjust the driving speed), 3 (tried to adjust the driving speed) and 4 (did best to adjust the driving speed). The results are depicted in Figure 2.20.

Figure 2.20 ISA compliance by age group (reprinted from Ando & Mimura, 2015b, p. 369)



Note 1: 1=completely didn't adjust the driving speed, 2=didn't adjust the driving speed, 3=tried to adjust the driving speed, 4=did best to adjust the driving speed; Note 2: One-way analysis of variance (=5%, **=1% significant).*

Older drivers stated that they tended to adjust their speeds much more than the younger groups. For advisory ISA, no significant difference existed between groups. All drivers tended to adjust their driving speeds. The older drivers changed their speeds similarly for both types of ISA. The authors speculated this might be because they treated both ISAs the same while the younger drivers realised that mandatory ISA changed their speeds for them.

Another paper (Ando et al., 2014) reported actual average speed changes associated with different types of advisory ISA. These are illustrated in Table 2.14.

Table 2.14 Average speeds before, during and after advisory ISA for voice and picture information (reprinted from Ando et al., 2014, p. 280)

	Section		Usual: first time	Voice information	Picture information	Usual: second time
Elder	40km/h	Average speed	38.48	38.72	39.07	37.65
		T-value		0.12	0.22	0.45
	30km/h narrow	Average speed	32.00	32.07	31.12	31.92
		T-value		0.04	0.40	0.05
	30km/h wide	Average speed	34.71	31.12	32.69	32.41
		T-value		3.08**	1.35	1.25
Younger	40km/h	Average speed	44.68	38.27	38.05	39.47
		T-value		3.91**	4.18**	4.67**
	30km/h narrow	Average speed	33.91	30.46	30.37	31.88
		T-value		1.80*	1.75	1.60
	30km/h wide	Average speed	36.03	31.48	30.12	33.05
		T-value		2.50*	2.77**	2.40*

※T-value: calculated by the statistical test of the differences with that respective for the usual drive: first time;
※significance level **: 1%、*: 5%.

In the table, ‘usual’ means no ISA, ‘first time’ means pre-ISA and ‘second time’ means post-ISA.

Older drivers reduced their speeds significantly on wide 30 km/h roads with voice information, and there was also a reduction with picture information. Younger drivers reduced their speeds significantly with voice information on both types of 30 km/h roads and with picture information on 30 km/h wide roads. Speeds always dropped post-ISA compared to pre-ISA but the only significant changes were for the younger group. To summarise, voice information performed better than picture information, and the ISA had more impact on younger drivers possibly because they were driving faster in the first place.

2.7.1 Takeaways

- ISA systems assist older drivers with speed moderation and lane keeping but the results gained vary with the system used.
- Mandatory ISA with automatic braking was associated with deteriorating driver performance, possibly due to driver unfamiliarity with the system.

2.8 Studies related only to mandatory ISA

Greenshields et al. (2016) report the trialling of a propriety mandatory ISA system on two London bus routes. The ISA system, supplied by Zeta Automotive Ltd, intervened by using GPS data matched against an on-board map and speed-limit database to prevent the equipped vehicle from breaking the speed limit by controlling its acceleration. The system did not apply the brakes or stop a driver from applying them, and the driver could use the accelerator normally until the speed limit was reached. Drivers could override the system only in an emergency. Before the ISA system was turned on, the main evidence of speeding by buses was between the bus depot and the start and end of the routes and in 20 km/h zones. The ISA system successfully limited bus speeds except for occasional downhill instances where gravity was a factor. With ISA operating, the percentage of time buses spent over the speed limit (depending on the bus route) reduced from 14.9–17.8% to 1–3.3% in 20 mph zones and from 0.5–3.3% to 0–1.1% in 30 mph zones. There was a slight increase in average journey times, which could operationally require extra buses if ISA was implemented. There was no detectable change in fuel use. Passengers knew nothing of the ISA but most had positive reactions on it being explained.

Drivers initially felt predominantly negative to the ISA mainly due to set-up and calibration issues. Later impressions were more positive with perceptions of holding up other drivers in off-peak, lower-traffic periods being the main concerns.

The authors considered using models to estimate crash changes from the speed changes but decided not to due to perceived difficulties in applying the models derived for light vehicles to buses. The crash changes, however, do not look to be potentially large in absolute numbers.

This is because a search of official road crash data for London for the calendar years 2012–2014 found only 11 cases of a bus with a causal factor of speed more than the speed limit resulting in injury from nearly 6,000 vehicle injury cases involving buses. As of June 2021, Transport for London expected to have ISA rolled out over its entire bus operation by 2032 (London Assembly, 2021).

2.8.1 Takeaway

Mandatory ISA can be effective in a working environment where the driver has no choice but to use it.

2.9 Studies primarily aimed at offenders

Stephan et al. (2014) trialled an advisory ISA programme to help recidivist speed offenders in Victoria to reduce speeding. The trial was conducted on road to assess the effectiveness of an advisory ISA in reducing the recidivists' speeding. The trial was undertaken with and without demerit point removal. Of the 86 recidivists who participated, 40 (speed alert group) were exposed to advisory ISA in their everyday driving for 12 weeks and monitored with a data logger for 8 more weeks and another 46 (speed data group) were not exposed to ISA but monitored for 20 weeks. Around half were selected at random to have 3 demerits points removed from their last speeding offence post-trial. They were aware that this would happen.

When ISA was active, the exposed group's mean speed reduced significantly (see Figure 2.21) as did the proportion of time exceeding the speed limit (see Figure 2.22) and return time to the speed limit when it was exceeded (see Figure 2.23) compared to the group not exposed. There was no pre-ISA period recorded so the study does not tell us anything about how they would have driven before being exposed to ISA.

Figure 2.21 Mean speed (standard error) for each ISA group by period (reprinted from Stephan et al., 2014, p. 6)

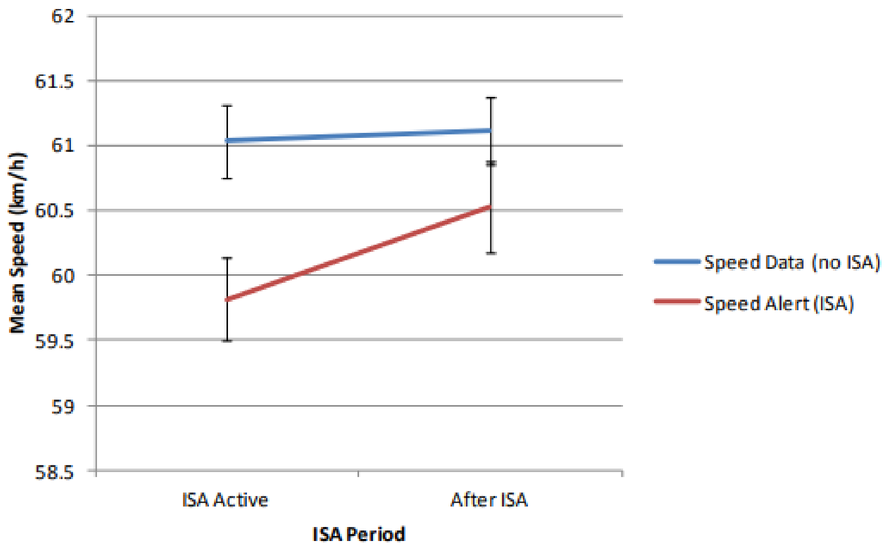


Figure 2.22 Mean (standard error) proportion of time spent travelling over the speed limit by period (reprinted from Stephan et al., 2014, p. 7)

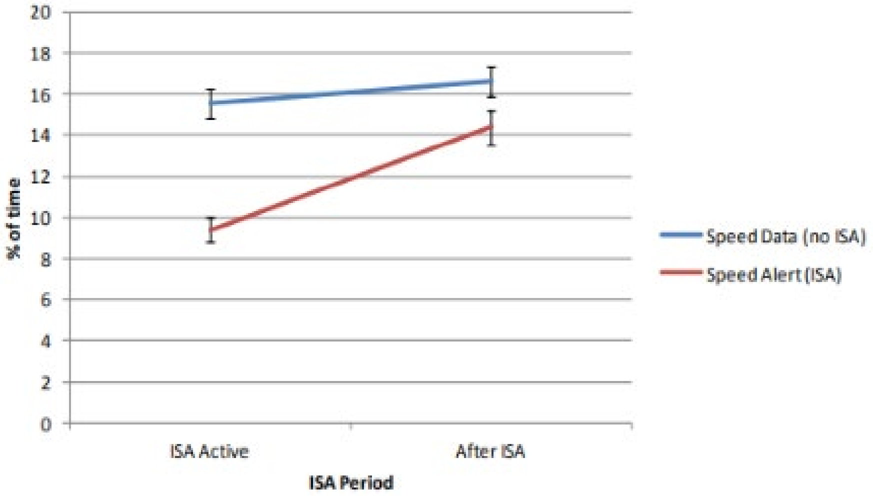
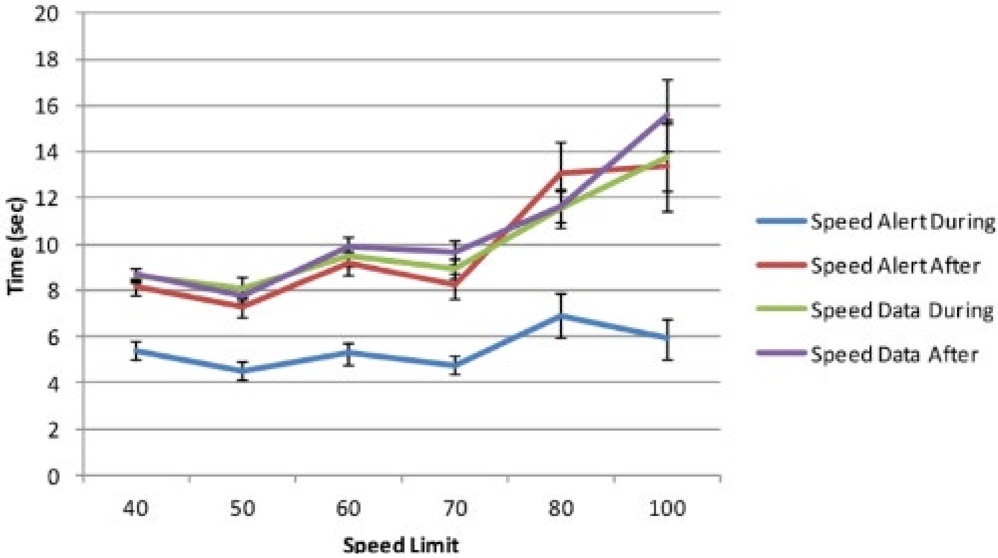


Figure 2.23 Mean (standard error) time to return to the speed limit for each ISA by speed zone and period (reprinted from Stephan et al., 2014, p. 8)



Without ISA, the two groups behaved similarly regarding speed. Demerit point removal did not impact ISA effectiveness.

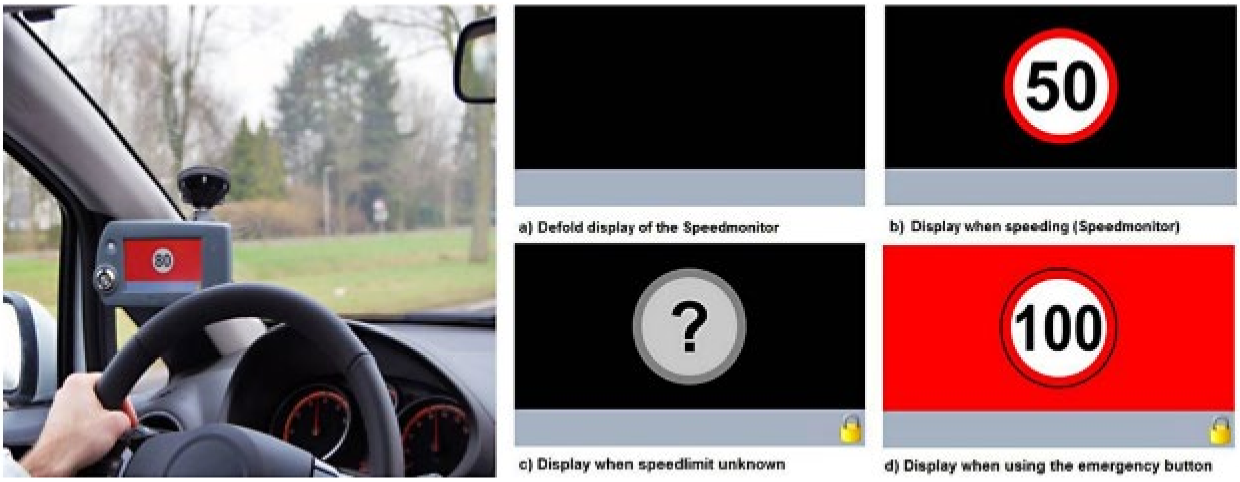
A report by van der Pas et al. (2014a) discusses a field trial carried out by the Dutch Ministry of Infrastructure and the Environment using ISA as a penalty system for serious speed offenders.

Two ISA systems were trialled:

- Speedlock is a form of mandatory ISA that prevents a vehicle from exceeding the speed limit plus a tolerance. The tolerance depends on the speed limit – 3 km/h for limits below 60 km/h and 5 km/h for limits 60 km/h or above.
- Speedmonitor is a form of warning ISA that warns when the speed limit is exceeded and notes how often it is exceeded. Based on time spent speeding, speed limit, number of km/h above the speed limit and previous behaviour, Speedmonitor can autonomously implement a temporary Speedlock.

Both systems feature an emergency button that lets drivers override the speed limit for 15 seconds. At the end of the 15 seconds, Speedlock reactivates if the vehicle speed is below the limit. If above the limit, the system emits a loud high beep every 2 seconds. If the vehicle speed drops below the speed limit or a maximum of 1.5 minutes passes, Speedlock becomes active again. If the limit is still exceeded, Speedlock immediately redeploys. Figure 2.24 depicts screenshots of some of the visual displays used.

Figure 2.24 Screenshots of some of the visual displays used (reprinted from van der Pas et al., 2014a, p. 80)



In total, 51 drivers participated fully in the trial, which lasted for 3 months before measurement, 3 months with the system active and 2 months after measurement (see Figure 2.25). Of these drivers, 23 were judged to be serious speed offenders as exhibited by their behaviour in the before part of the trial. The behaviour of all participants was analysed as was the subset of serious offenders.

Figure 2.25 Temporal set-up of the trial (reprinted from van der Pas et al., 2014a, p. 80)

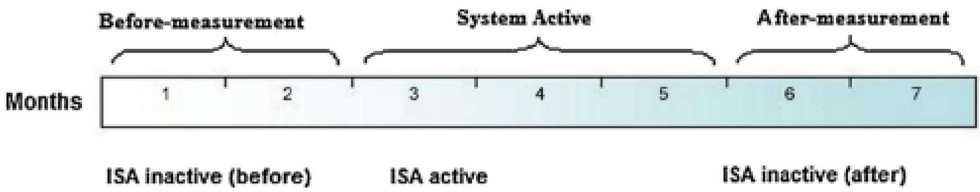
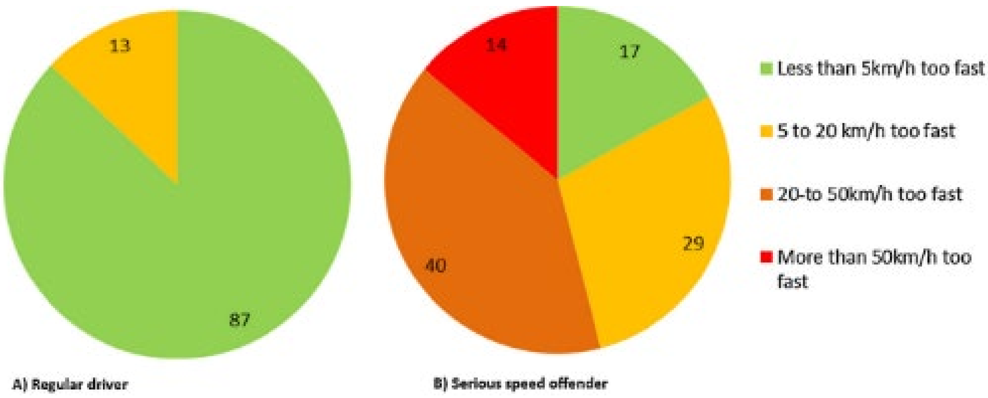


Figure 2.26 compares speed profiles of regular drivers and serious speed offenders in the before period.

Figure 2.26 Comparison of speed profiles of regular drivers and serious speed offenders in the before period (reprinted from van der Pas et al., 2014a, p. 82)



Measurements were taken with and without Speedmonitor and Speedlock for all drivers and serious offenders. In all cases, there was marked improvement under both ISA systems followed by marked regression in the after period. As examples, Figure 2.27 and Figure 2.28 depict kilometres travelled by serious offenders under and above the speed limit on motorways before the trial, with Speedmonitor (see Figure 2.27) and Speedlock (see Figure 2.28) active and after the trial. For the after scenario in both figures, the participants had previously used one or other of the ISA systems in the system active phase of the trial.

Figure 2.27 Kilometres travelled by serious offenders under and above the speed limit on motorways (Speedmonitor) (reprinted from van der Pas et al., 2014a, p. 86)

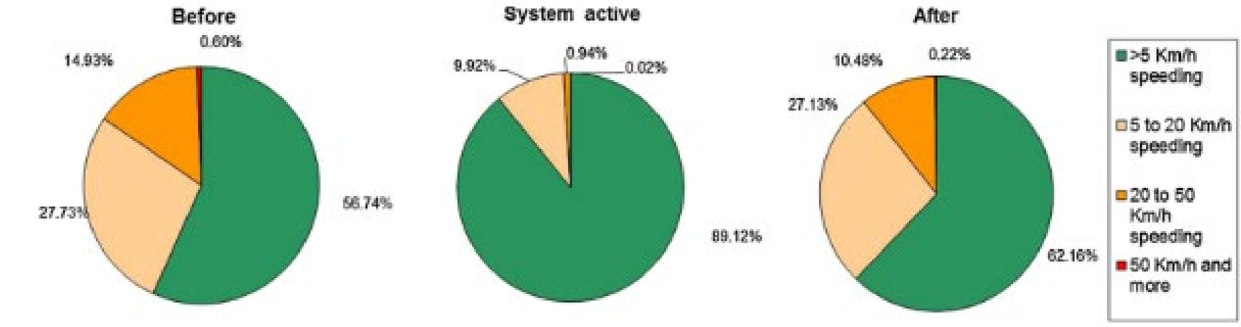
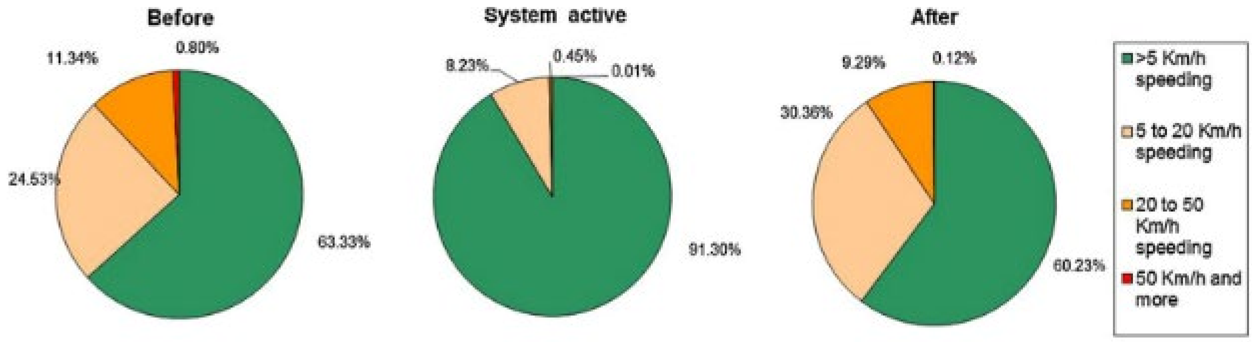


Figure 2.28 Kilometres travelled by serious offenders under and above the speed limit on motorways (Speedlock) (reprinted from van der Pas et al., 2014a, p. 86)



The authors transformed these speed change results into estimates of percentage crash reductions using the models of Elvik (2009) and Kloeden et al. (2002). These estimates are depicted in Table 2.15, where SL relates to Speedlock and SM relates to Speedmonitor. The authors advise caution in the use of these estimates, which are based on mean speed changes and may not properly take into account other issues like possible distractive impacts of the systems.

Table 2.15 Estimated crash reductions related to use of Speedlock and Speedmonitor (reprinted from van der Pas et al., 2014a, p. 90)

	Elvik (2009)		Kloeden et al. (2002)
	% reduction in chance of being involved in a serious accident[a]	% reduction in chance of being involved in a fatal accident	Relative risk of being involved in an accident with casualties[b]
SL	7%–25%	11%–36%	0.4–0.9
SM	3%–33%	4%–47%	0.5–0.9

[a] Accidents with seriously injured and fatalities.
[b] This is expressed as a reduction compared to the old risk (so 0.7 = 70% of the old relative risk).

The results show that the two types of ISA systems that were tested had a large impact on driver behaviour and have the potential to improve road safety by reducing mean speed as well as speed variation.

However, the users showed little sign of learning after the systems were turned off. Moreover, the serious offenders frequently used the emergency button to override the system, which might seriously affect the efficacy of the system.

A related paper reported that participating drivers self-reported positive impacts on their driving behaviour, claiming that:

> *they are less aggressive, tailgate less, brake less aggressively, accelerate less aggressively, anticipate more, and drive less in the left lane*[6] *when it is not necessary.* (van der Pas et al., 2014b, p. 171)

However, increased tailgating and overtaking of study cars by other cars was also reported.

Overall, both the systems produced very encouraging speed changes, which faded very rapidly after the system was turned off. Use of the emergency button was a concern – 10 frequent users accounted for 80% of the total use of the emergency button. Of these, eight were serious speed offenders. Fisher's exact test shows that serious offenders were statistically significantly more inclined to use the emergency button (P = 0.016). Overuse of such a button would impact negatively on an operational ISA system. However, it was not clear from the article whether the emergency button was needed just for the purposes of the trial (used when the speed limit was information was inaccurate) or whether the authors considered it necessary for a practical ISA system.

Other concerns were the large size of back-office systems required to run the system and that, in its tested form, it could be overridden by use of cruise control.

2.9.1 Takeaways

- ISA improves the behaviour of recidivist offenders both when used in conjunction with rewards and as a control mechanism.
- Behaviour returns to pre-ISA levels quickly after removal of controls.
- Where ISA is mandatory, participants tend to use an emergency button excessively to disable it if such a button exists.

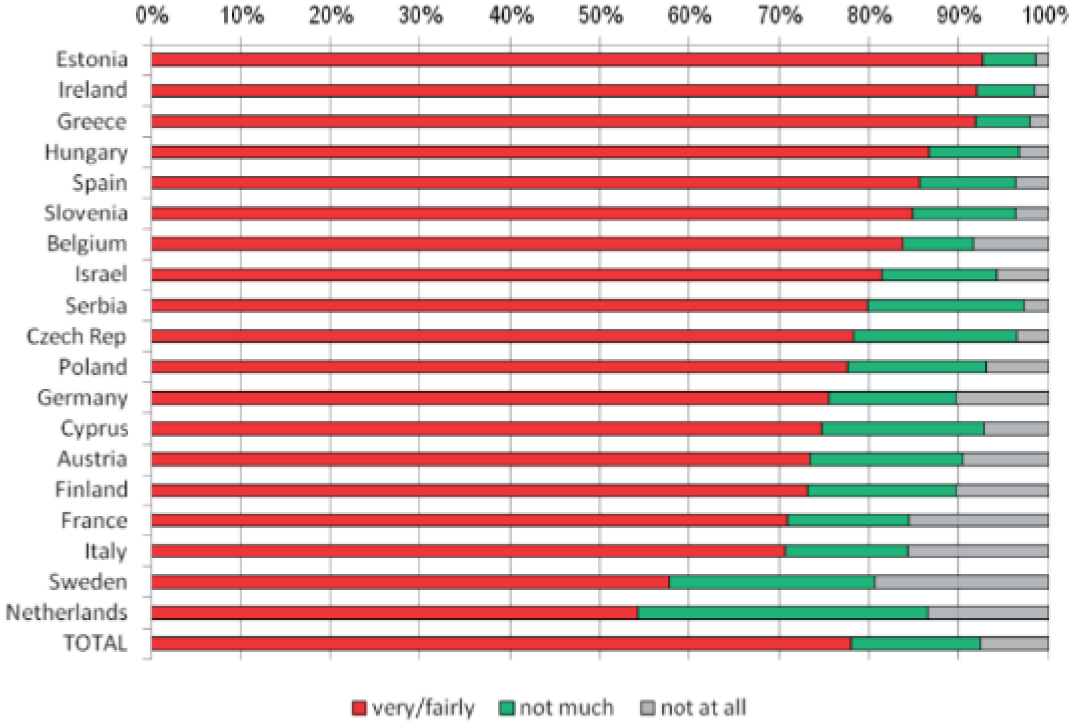
2.10 User acceptance of ISA

Acceptance by the driving public is of paramount importance if governments are ever to introduce ISA on a wide scale.

Antov et al. (2011) surveyed drivers in 19 countries (all European except Israel) using the question: How much would you be in favour of using speed limit devices in cars? The results are illustrated in Figure 2.29. Overall, the acceptance was a little under 80%, with Sweden and the Netherlands noticeably lower than other countries. The question was not explicit enough to differentiate between the different levels of ISA so it does not, for instance, tell us how acceptable a mandatory ISA would be. In the case of offenders, a choice between ISA and licence loss increases acceptance considerably (van der Pas et al., 2014b).

[6] Right lane in New Zealand.

Figure 2.29 How much would you be in favour of using speed limit devices in cars? (reprinted from Antov et al., 2011, p. 272)



Vlassenroot (2011) reports a web survey carried out in 2009 that gained 6,370 respondents from Belgium and 1,158 from the Netherlands. The survey was arranged through the Flemish and Dutch motoring organisations so it can be expected that most respondents would be members of those organisations.

Of these, 5,599 responses from car drivers were considered useful for further analysis. The sample underrepresented drivers younger than the age of 34 and overrepresented the age group 45–64 for licence holders in Belgium and the Netherlands.

The respondents were asked about their perceptions of the effectiveness of various speed controls and what ISA system they preferred. The percentages who perceived various controls to be effective were police controls (81%), speed cameras (78%), technology in the vehicle (69% – this would include ISA), speed bumps (48%) and road safety campaigns (15%).

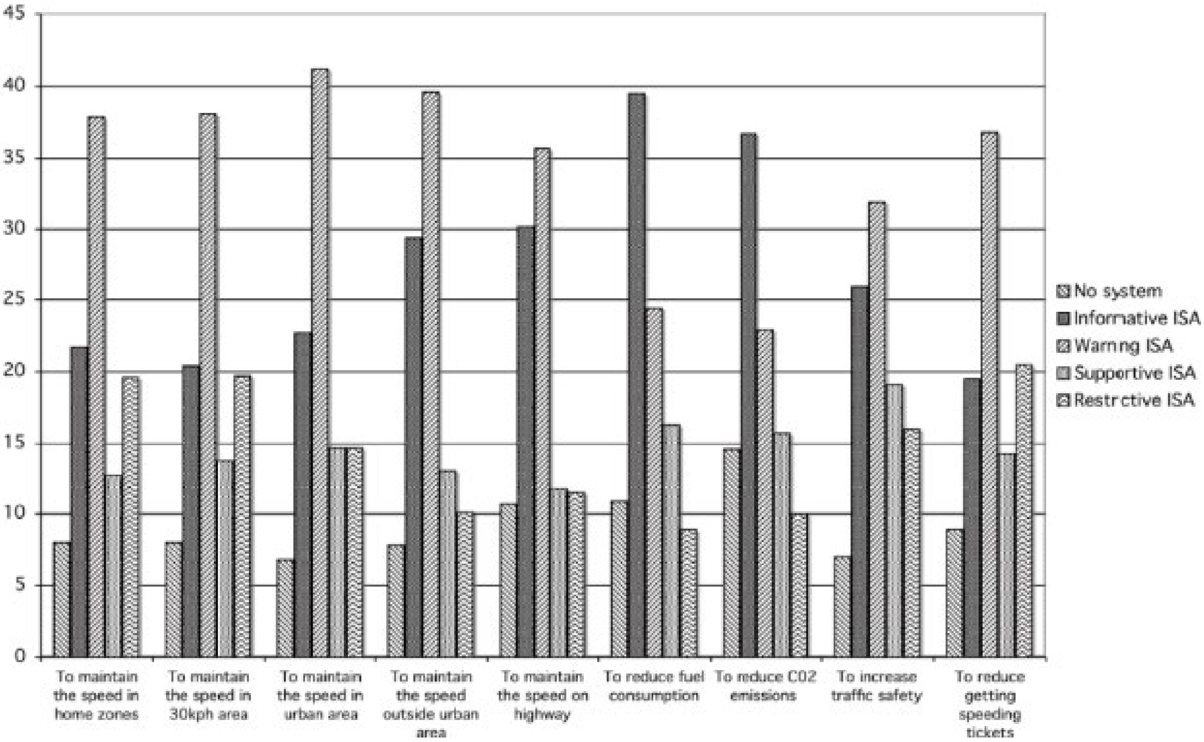
The respondents were also asked which ISA system they preferred and were presented with four different ISA systems:

- Informative ISA (information about the speed limit) – 30% were in favour.
- Warning ISA – 38% were in favour.
- Supportive ISA (driver able to override active accelerator pedal) – 12% were in favour.
- Restrictive ISA – 15% were in favour.
- No ISA – 5% were in favour.

In total, 27% preferred a more intervening type of ISA over an informative one.

Figure 2.30 looks at the percentage of the sample who perceived different types of ISA as being most effective for maintaining appropriate speeds in various areas and for improving safety and reducing likelihood of receiving speeding tickets.

Figure 2.30 Perception of effectiveness of different types of ISA in situations (reprinted from Vlassenroot, 2011, p. 107)



Warning ISA was perceived most effective at maintaining speeds in all speed zones. In higher speed zones, less-intervening systems were favoured. Restrictive ISA was better supported in lower speed zones than in higher speed zones. An informative system was perceived most effective at reducing fuel consumption (40%) and CO_2 emissions (37%). Warning ISA would increase safety best (32%) and reduce exposure to speeding tickets.

Respondents' opinions on usefulness and satisfaction have been compared (see Figure 2.31). The scales used are not stated, but in both cases, the respondents were only asked to evaluate their preferred system – for example, the points on the chart for supportive ISA relate to the opinions of those who preferred that system. In the chart, the term closed ISA is used to describe mandatory ISA. Preferring a particular ISA does not necessarily mean enthusiasm for it, just that the respondent chose not to prefer no ISA. Drivers who chose closed (mandatory) ISA found it more satisfying than other respondents found their preferred systems. Those who preferred a warning ISA found it more useful. Choosers of the supportive system found it less satisfying and useful than the choosers of other systems found their systems.

The study author commented:

> *It is assumed that it would be more difficult to evaluate a supportive system because it is far more difficult to imagine how it would work, or how it would feel.* (Vlassenroot, 2011, p. 108)

Figure 2.31 Driver opinion of ISA usefulness and satisfaction (reprinted from Vlassenroot, 2011, p. 108)

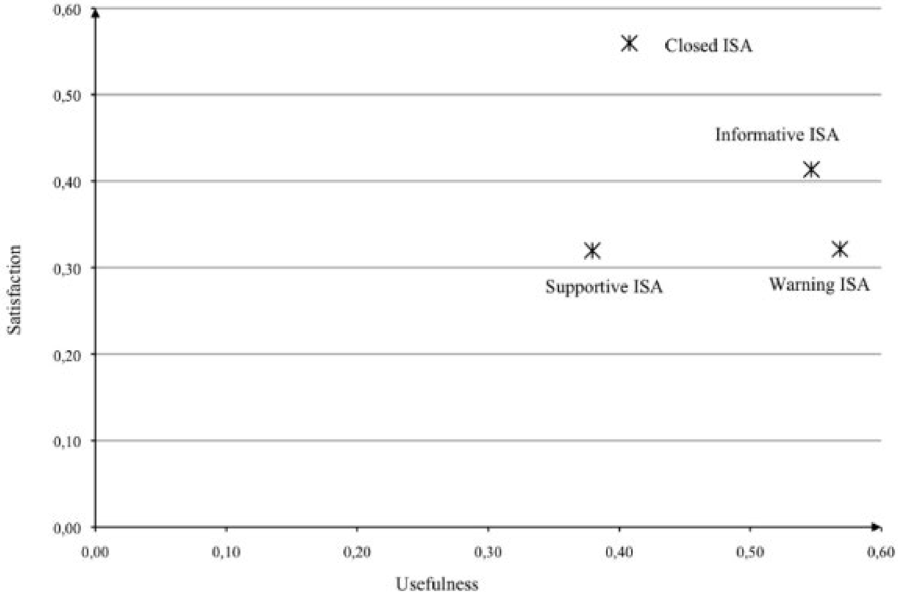


Figure 2.32 depicts the market penetration level needed to induce a participant to install ISA in their vehicle by type of ISA. The more intervening the ISA, the greater market penetration levels required.

Figure 2.32 Level of penetration that would influence the driver's choice on a certain ISA system (reprinted from Vlassenroot, 2011, p. 109)

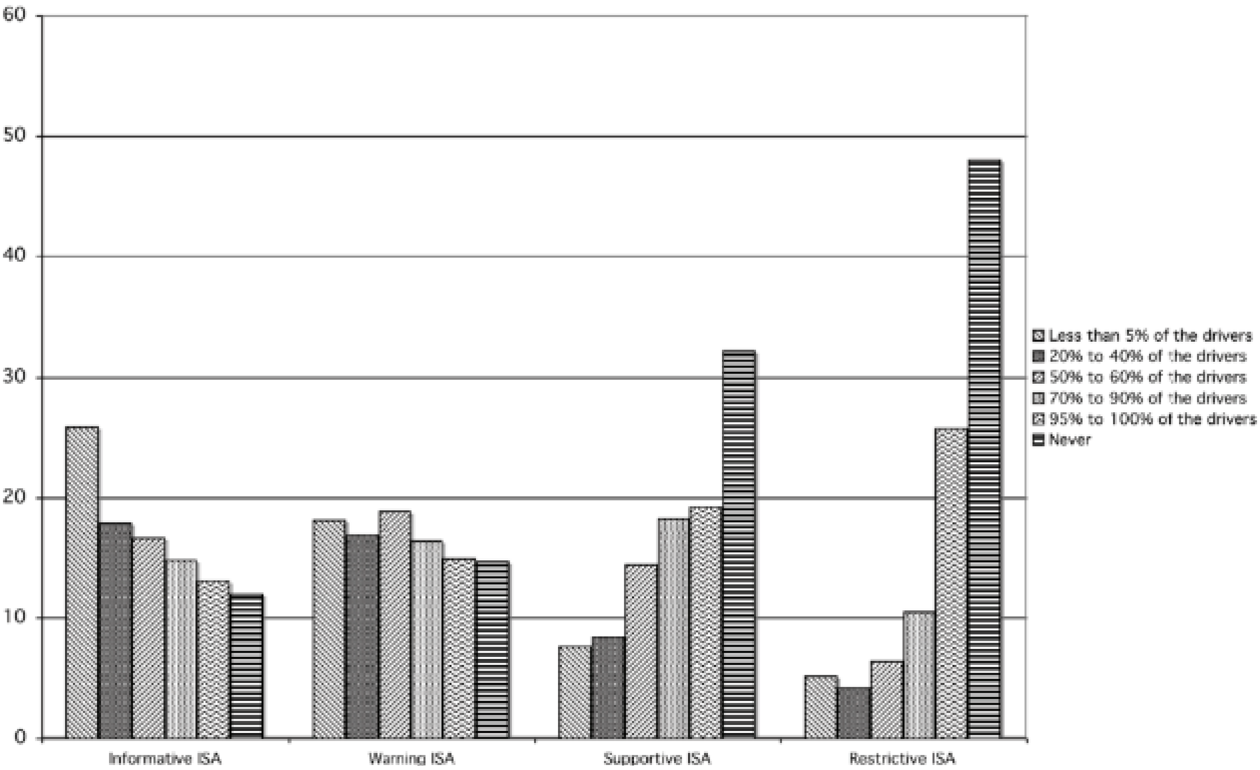


Figure 2.33 depicts perceptions of which driver types using different types of ISA would receive greatest benefits – 80% perceived that problematic or frequent speeding drivers should be using restrictive ISA. More than half of respondents thought professional drivers and young drivers should be using intervening systems like supportive and restrictive ISA, while 97% perceived that some form of ISA would be beneficial for all drivers – 24% informative ISA, 42% warning ISA, 18% supportive ISA and 12% restrictive ISA.

Figure 2.33 Perceptions of which driver types using different types of ISA would receive greatest benefits (reprinted from Vlassenroot, 2011, p. 109)

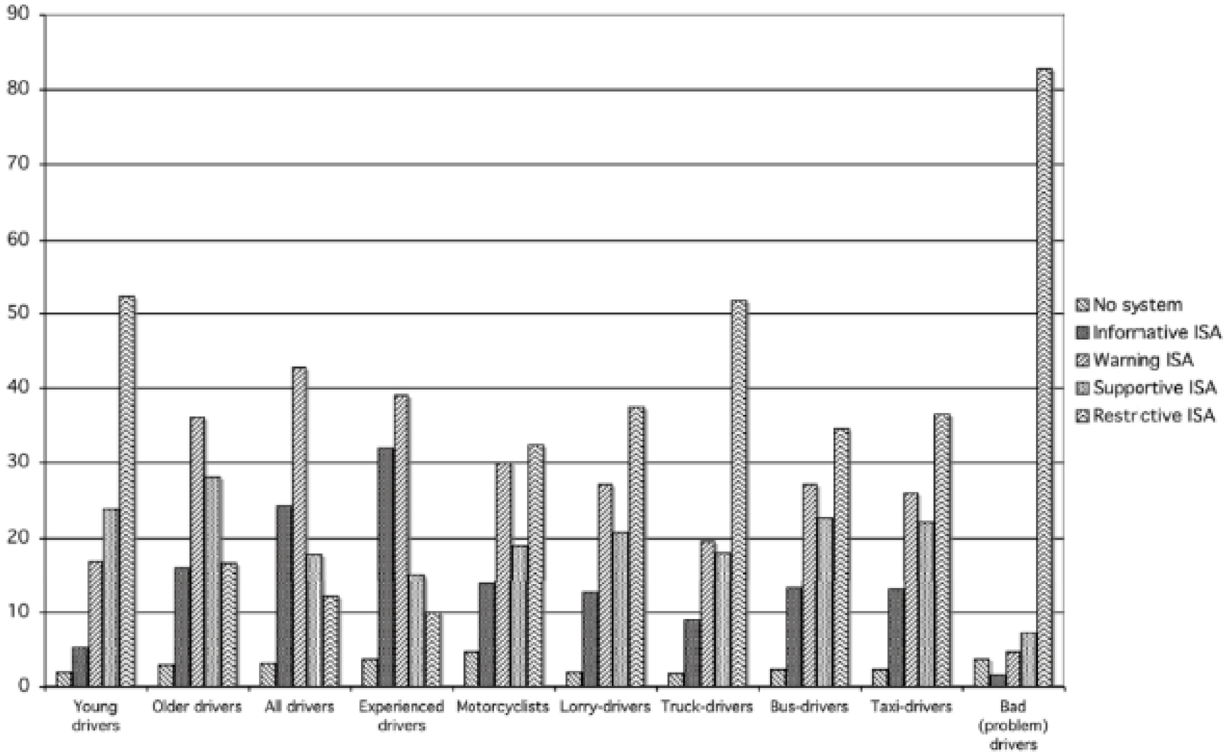
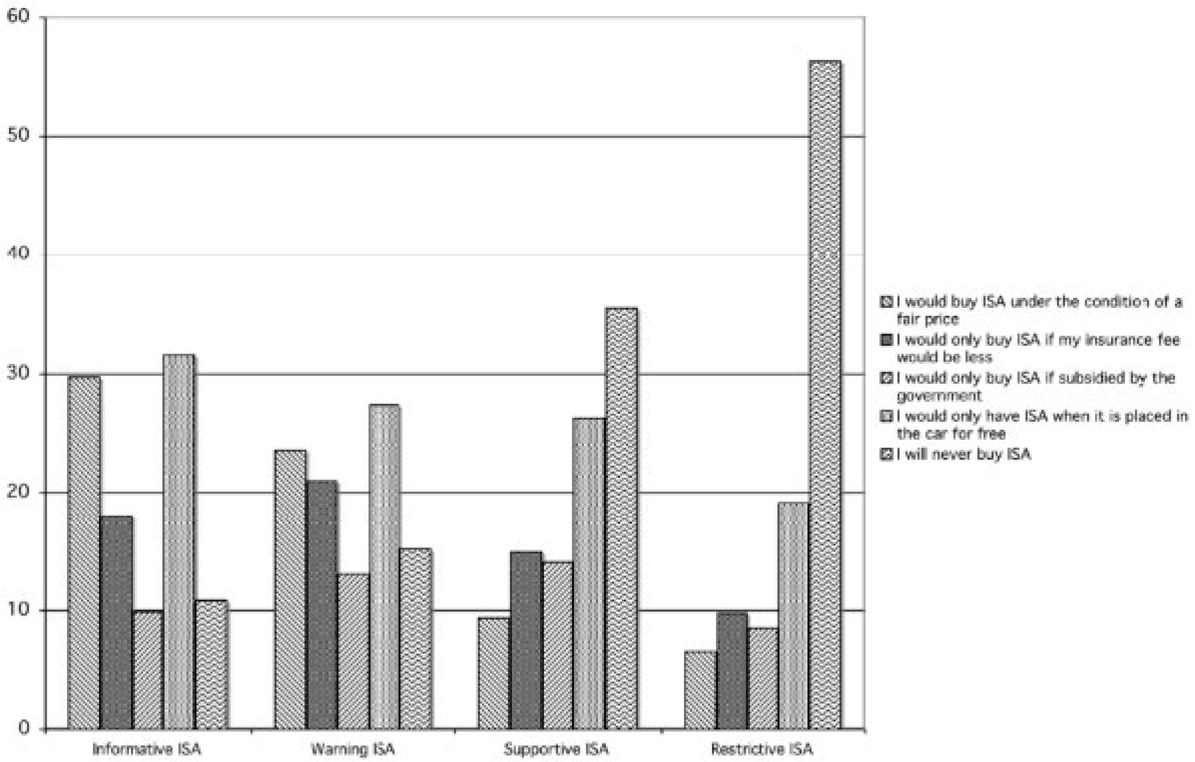


Figure 2.34 illustrates the financial circumstances under which different types of ISA would be acceptable to participants.

Figure 2.34 Financial circumstances under which different types of ISA would be acceptable (reprinted from Vlassenroot, 2011, p. 110)



Free provision is most preferred for informative and warning ISA. Some respondents were willing to buy informative (30%) or warning ISA (24%) at a fair price compared to the price of a standard navigation system, 36% would never buy supportive ISA but financial incentives could induce 29% to install it. Restrictive ISA would be accepted free by 19% but over half of drivers would never buy it.

2.10.1 Takeaways

- Less-restrictive forms of ISA were generally preferred.
- Free ISA provision was preferred but a minority were willing to buy informative or warning ISA at a fair price with respect to a navigation system.
- For problematic or frequent speeders, 80% of drivers preferred restrictive ISA, and more than half preferred intervening systems like supportive and restrictive ISA for professional drivers and young drivers.
- Some form of ISA was perceived as beneficial for all drivers by 97%.
- The more intervening the ISA, the greater the market penetration levels required to induce willingness to install.

2.11 The EU ISA regulation

The European Union (EU) is the only jurisdiction to have mandated ISA. The EU has adopted a draft regulation – the Vehicle General Safety Regulation (EU) 2019/2144 (EUR-Lex, 2019) – which paves the way for ISA systems along with other advanced crash avoidance systems to become compulsory equipment on cars sold in the EU.

The regulation sets out the technical requirements and test procedures needed for an ISA system to be approved. From 6 July 2022, ISA became mandatory for new models/types of vehicles introduced on the market, and from July 2024, ISA will be mandatory for all new cars sold.

The systems used must be easily overridden by the driver at any time. Therefore, they are all basically voluntary. The wording of the minimum requirements is thus:

> *(a) it shall be possible for the driver to be made aware through the accelerator control, or through dedicated, appropriate and effective feedback, that the applicable speed limit is exceeded;*
>
> *(b) it shall be possible to switch off the system; information about the speed limit may still be provided, and intelligent speed assistance shall be in normal operation mode upon each activation of the vehicle master control switch;*
>
> *(c) the dedicated and appropriate feedback shall be based on speed limit information obtained through the observation of road signs and signals, based on infrastructure signals or electronic map data, or both, made available in-vehicle;*
>
> *(d) it shall not affect the possibility, for the drivers, of exceeding the system's prompted vehicle speed;*
>
> *(e) its performance targets shall be set in order to avoid or minimise the error rate under real driving conditions.* (EUR-Lex, 2019, p. 11)

A media release gives a summary of the types of ISA systems this would imply in practice (European Commission, 2022):

1. Cascaded acoustic warning.

2. Cascaded vibrating warning.
3. Haptic feedback through the acceleration pedal.
4. Speed control function.

The first two options only provide warnings, starting with a visual warning. If the driver does not respond, a short audio/vibratory warning is given. The third uses the accelerator pedal to push the driver's foot gently back to give the message to slow down. The driver can ignore it by pushing slightly harder on the accelerator pedal. The fourth involves the car speed being gently reduced automatically with override by gently pushing the accelerator pedal.

2.12 Other ISA approaches

While ISA will be mandatory for new vehicles in the EU from 2024, there is a variety of ways in which ISA is either already present in current vehicles or can be added retroactively (some options have been discussed previously in this report) such as:

- map-based apps on mobile phones
- dedicated map-only systems (commercial and consumer level)
- map and visual dash cam systems (commercial and consumer level)
- map-based systems that are part of a vehicle's information system (either present at manufacture or added by over-the-air updates)
- retrofitted full-vehicle systems capable of controlling vehicle speed.

The cost of these various options ranges greatly from free for apps (though a phone is required) to several thousand dollars. The requirements for these options also vary greatly with full-vehicle systems requiring a modern controllable vehicle.

It should be noted that virtually every ISA-based system outlined above is incorporated as part of an overall package of systems and is not, for the most part, offered as a stand-alone feature. For instance, mobile phone apps that have an ISA component are generally part of a navigation application, commercial-based systems that have ISA are part of an overall fleet management system and full-car systems include other driving assistance aids such as lane-keep assist (LKA) and lane departure warning.

While it may be possible for a purely ISA-oriented commercial product to be produced from an existing multifunction offering, there would need to be a sound business case for this to happen. For instance, it would make commercial sense to produce a stand-alone product if there was a government requirement for all vehicles on the New Zealand road network to have an ISA system installed.

The way ISA is implemented within the current New Zealand fleet as a retrofitted option would have a significant effect on the per-unit cost. A compulsory roll-out would have the lowest per-unit cost as the industry could be guaranteed the demand for a large number of units, lower insurance costs, a government fitting subsidy and so on. Voluntary implementation would have the next lowest cost, while a purely voluntary implementation with little to no incentivising or subsidisation would most likely be too cost prohibitive to implement both from an industry and end user point of view.

2.13 Speed crash models and their application to ISA

It has been well established that highway travel speed is linked to road trauma in such a way that, in most circumstances, increased travel speed will lead to increased road trauma. Elvik et al. (2004) reported a study that involved the meta-analysis of many studies of speed changes.

Its conclusions were unequivocal:

> *Speed has been found to have a very large effect on road safety, probably larger than any other known risk factor. Speed is a risk factor for absolutely all accidents, ranging from the smallest fender-bender to fatal accidents. The effect of speed is greater for serious injury accidents and fatal accidents than for property damage-only accidents. If government wants to develop a road transport system in which nobody is killed or permanently injured, speed is the most important factor to regulate.* (Elvik et al., 2004, p. 29)

ISA can change the shape of the speed distribution. This suggests, therefore, that speed distribution shape is an additional criterion for the study of ISA.

Some useful studies on speed and casualty rates were not included in that meta-analysis because they did not fit the study's criteria or because they were not available at the time. The Accident Compensation Corporation and Land Transport Safety Authority (2000) discussed some of the same studies included in the Elvik et al. (2004) meta-analysis and some other studies that were not included.

These other studies included Kloeden et al. (1997) and Kloeden et al. (2002) who used a case-control study to quantify the relationship between actual observed free-travel speed[7] and the risk of involvement in a casualty crash in a 60 km/h speed limit zone. Kloeden et al. (2002)) found the risk of involvement in a casualty crash doubled with each 5 km/h increase in free-travel speed above 60 km/h. In a similar case-control study of crashes on rural roads in Australia with speed limits of 80 km/h and above, Kloeden et al. (2001) found an increased risk of involvement in a casualty crash for vehicles travelling at speeds above the mean control (non-crash involved) vehicle speed. Specifically, the risk of involvement in a casualty crash was found to be twice as high for vehicles travelling 10 km/h above the mean control speeds and nearly six times as high when travelling 20 km/h above the mean speed.

2.13.1 Application to ISA

Interventions like ISA are aimed at increasing compliance with road authority speed requirements. This involves reducing speeds and may involve changes to the speed distribution. To assess the impact of these changes in speed, models that relate speeds and their distribution to crashes are required. Waibl et al. (2013) discussed in detail the speed crash models available and their merits in assessing the impacts of various types of ISA.

The individual risk model of Kloeden et al., by its very nature, fits best with the plethora of individual driver decisions that occur with advisory ISA and the subsequent changes in the shape of the speed distribution. Therefore, as in Waibl et al. (2013), the Kloeden model is used in the analysis of advisory ISA in this report.

2.13.2 Takeaways

- Individualised models fit best with the plethora of individual driver decisions that occur with advisory ISA and the subsequent changes in the shape of the speed distribution.
- Therefore, as in Waibl et al. (2013), the Kloeden model is used in the analyses of advisory ISA.

2.14 The impact of fleet penetration on the effectiveness of ISA

It has been suggested that the relationship between the proportion of the operating fleet using ISA and the effectiveness of ISA is not directly proportional. Liu and Tate (2004) quote previous research (Liu et al.,

[7] Free-travel speed is the speed of a vehicle unimpeded by other traffic.

1999) suggesting that, on a simple two-lane rural road, speed was managed when 60% of the vehicles were treated. For this to occur, there must be sufficient traffic volume on the rural road for vehicles to interact. Unfortunately, the volumes using the simulated road were not published.

However, it is typically assumed that a vehicle will travel at the driver’s desired free speed when travelling in isolation or travelling more than 6 seconds apart. Somewhat crudely, this would suggest traffic volumes of less than 6,000 per day.

Looking at the picture of New Zealand crash outcomes for the past 5 years (2018–2022) using data retrieved from the NZTA Crash Analysis System in April 2023, 53% of deaths or serious injuries (DSIs) occur on roads with rural speed limits, and of these, 36% occur between the hours of 6 pm and 6 am when traffic volumes are generally low. This would suggest that similarly, at most, 36% of DSIs might occur under the sort of conditions modelled by Liu et al. (1999).

An older alternative dataset held by the research team using crash data from 2013–2018 indicates 70% of DSIs on rural roads (speed limits > 70 km/h) occur on roads carrying fewer than 6,000 vehicles per day.

It is clear from the available data and assumptions above that little is known about the relationship between speed and the proportion of the operating fleet using ISA and the impact on the traffic stream as a whole. It could well be that speeds can be fully managed with less than 100% of vehicles operating ISA.

3 User interviews

To understand the current usage and performance of ISA, the barriers and motivations of users, the impacts of ISA on key driving behaviours and the in-service maintenance requirements of ISA in New Zealand, eight semi-structured interviews were conducted. These were held via phone and video calls with five individual users who have ISA systems in their personal vehicles, two individuals who used vehicles that had fleet monitoring systems installed and one ISA maintenance expert.

3.1 Interviews with individual users with an in-vehicle ISA system

The individual interview questions focused on the type of ISA the interviewees were currently using, their understanding of the technology, their use of their ISA system especially in relation to different driving environments (fixed speed limits, advisory speed limits, temporal speed limits) and any areas where the system had limitations or inaccuracies. Communications were sent inviting people who had an ISA system in their personal vehicle to participate in an interview. Convenience sampling was used and included emails to individuals in WSP offices and posts on social media community pages.

Five interviews were conducted with individual users. Participant ages ranged from 20 to over 70 years. All had been driving since their late teen years and drove their vehicle regularly. The individuals were asked about their current vehicle. Their vehicles ranged in age from 2016 to 2022, with ownership of their vehicle varying between a few months to 4 years. Additionally, three of the interviewees mentioned having prior experience with ISA systems in a previous vehicle. Individuals' vehicles also had other high-tech systems and features such as ACC and LKA. Table 3.1 details the interviewees' vehicle model, the ISA system in the vehicle and the individuals' use of their vehicle's ISA system.

Table 3.1 Vehicle models of those interviewed, including the ISA system type and use of the in-vehicle system by the interviewee

Participant number	Vehicle information	ISA system	Use of in-vehicle ISA system
P1	2016/17 Tesla Model S P85	Advisory GPS data/camera recognition dependent on the software installed	Yes
P2	2018 Subaru XV Premium	Advisory GPS sign alerts	No
P3	2021 Toyota C-HR Hybrid	Advisory Camera recognition	Yes
P4	2022 Polestar 2	Advisory Camera recognition	No (uses Waze app)
P5	2022 Audi Q8	Advisory Camera recognition	Yes

In relation to use of their vehicle's ISA system, three of the interviewees said their ISA system was always or almost always turned on. The two interviewees (P2 and P4) who did not use their vehicle's ISA system had other means of ensuring they were not speeding. One individual (P4) used the Waze app (see section 2.2.2), which they downloaded and displayed through their vehicle's navigation panel (ie, Apple CarPlay, Android Auto). The interviewee believed the app was more accurate than their in-built ISA system and they liked the advantages of the app's social network. Drivers using the Waze app are able to communicate with each other and receive updates on road information such as hazards, police stops and upcoming speed cameras.

While the app has its advantages, the participant also mentioned that it can be slow to display the new speed limit when transitioning between speed zones.

The other individual (P4) who reported not using their vehicle's ISA system said that they manually entered the speed limit into their ACC as they drove. Due to this driving behaviour, they felt they did not need the speed alerts as their speed was limited by the ACC.

> *I don't need the alerts because I don't speed … I realise speed is important. I have an obligation to drive in a safer manner.* (P4)

None of the individuals reported ISA being a feature that influenced their vehicle selection. Other features such as ACC and LKA were considered influencing factors during vehicle selection by those interviewed. In new vehicles, ISA is just one of many features.

> *I only knew that [ISA] existed. No more so than the heated seats or the steering wheel or the mirror defoggers. It was just one in the list of features – they didn't mention the camera recognition technology – I had to find this out myself.* (P5)

Sales people often did not discuss the ISA systems when the interviewees were purchasing their vehicle. Rather, the emphasis was focused on the features the buyer indicated interest in during the conversation (such as ACC and LKA). For one individual, it was apparent that the salesperson only noticed the vehicle had an ISA system during the test drive.

> *When [the salesperson] did the test drive, they noticed [the ISA system]. It was not something that was considered when looking into the vehicle.* (P3)

Two of the interviewees mentioned the ISA speed alerts were already set up and active when they purchased their vehicle (P3 and P5). As these systems were not closely covered in the sales process, both were not aware how to turn the system off. One mentioned that they had to search for information about their ISA system online and use a trial-and-error approach, whereas the other individual was still unsure when the interview was being conducted if they could turn their system off.

> *I do have [ISA speed alerts] on, it's helpful when speeding … it was all set up automatically from the previous vehicle owner … I'm not sure if you can turn the system off.* (P3)

In relation to the alert settings, all interviewees were aware how to change their ISA system's notification settings and the alert thresholds. In-built ISA systems use a speedometer and provide notifications when the vehicle speed is exceeding the set threshold. It is worth noting that most speedometers are designed to overestimate the vehicle speed. With this knowledge, two of the interviewees mentioned they accounted for this overestimation when setting their ISA alert thresholds by having a higher threshold.

> *I set [ISA alerts] for 10 km/h over the limit as that's with knowledge that my speedo reads 4 km under the limit … It would piss me off travelling at 96 km [rather than 100 km] just because I don't like wasting time.* (P2)

3.1.1 When ISA is useful

Interviewees reported that ISA was a tool that allowed them to focus less on speed and more on the road. Four of the five individuals regularly or always had speed alerts turned on when they were driving. The main motivation mentioned was the avoidance of speeding fines, while safety was mentioned to a lesser extent.

> *I don't like getting [speeding] tickets … ensures I am travelling at a safe speed – I don't have to think about it.* (P1)

For interviewees with high-tech vehicles, other systems were also being used in addition to ISA alerts such as ACC and LKA. Individuals often spoke highly of these other vehicle features and their contribution to safety. For example, one individual believed ISA was useful as an alert system, but they did not consider it a safety feature. They then discussed the advantages of ACC in the event of a considered crash.

> *Great warning system for not getting tickets … the system is useful in the way that heated seats are useful. I don't consider it a safety feature. I consider it an alert feature in case I do miss a road sign … In my mind, [ACC] is multitudes, 20 times better than the speed recognition part … the distance warning and the crash alerts and the auto-stopping in the event of a considered crash are in my mind far, far more important features than this intelligent recognition system.* (P2)

Interviewees were asked when they found the ISA speed alerts particularly useful, with longer journeys and unfamiliar roads being the most reported. In line with this, alerts on shorter trips were considered less helpful and even regarded as an annoyance by some. Further, the interviewee who reported not setting speed alerts found it useful that the navigation panel displayed the speed limit sign for when they may have missed seeing a sign when driving.

3.1.2 Improvements

Interviewees mentioned that ISA systems needed improvement in multiple areas. In speed areas such as 30 km/h or lower, speed alerts may not be helpful – two interviewees mentioned that their systems only worked for speeds above about 30–35 km/h. This might pose issues for safer speed areas and road works where speed limits of 30 km/h are common in New Zealand.

Interviewees also reported that the systems typically had issues detecting the correct speed limit for:

- signs that warn of speed limits ahead – this can result in a speed warning starting prematurely before the actual speed change sign (see Figure 3.1)
- variable speed signs – as the speed limit is changed based on the road conditions, these changes can go undetected (see Figure 3.1)
- speed limit signs for school zones – these have enforced timeframes that are not factored into the system's alert notification (see Figure 3.1)
- off-ramp speed signs on motorways – for ISA systems that use cameras, the speed limit signs on exits and adjacent roads can be incorrectly detected (see Figure 3.2)
- temporary road works speed signs – this information can be updated in the system and assumed to be present even after signs have been removed (see Figure 3.3).

Figure 3.1 Examples of advance warning sign (left) (reprinted from Waka Kotahi NZ Transport Agency, n.d.a), variable speed sign (middle)(reprinted from Waka Kotahi NZ Transport Agency n.d.c), school zoned speed sign (right) (reprinted from Waka Kotahi NZ Transport Agency, n.d.b)

Figure 3.2 Example of adjacent roads where a speed sign could be incorrectly detected if travelling on the road to the right (reprinted from Waka Kotahi NZ Transport Agency Wellington, 2021)

Figure 3.3 Example of temporary speed signs for road works (photo supplied by F. Thomas, April 7 2022)

Further, interviewees reported that the system does not account for the road conditions such as poor visibility and bad weather such as heavy rain or high winds. The posted limit may be too high and a lower speed might be more suitable given the road conditions. The driver must use their own discretion to drive at a safe speed. Additionally, under certain conditions such as heavy rain and glare, the camera recognition-based ISA systems can fail to detect speed signs.

Interviewees noted that the system was useful when the data was accurate and reliable. When false positives occurred (a speed alert when not exceeding the limit), individuals mentioned they ignored the speed alert. If the alert continued over an extended period of road, they would consider turning the system off. It was noted that the in-built systems have no way to report incorrect information. One improvement suggested by the interviewees was to allow users to submit feedback and corrections to the system when necessary (this feature is currently available on the Waze app).

For ISA systems that use camera recognition to detect speed limits, one individual raised several concerns, including the need for the data to be vetted as people can tamper with the signage. Further, camera recognition systems can update the GPS map data with the temporary speed limits placed at temporary traffic management sites. These temporary speed limits can be held on the GPS map and be updated on the system and displayed to users after the physical signage has been removed.

> *The validity of the system is only as good as the data. What is to stop someone from putting a 100 sign in a 30 zone? It would be easy to nick a sign … and road works one is a major. [ISA systems] might need the road works sign to be replaced by another sign with the correct speed limit for a period of time so that the systems are up to date. [The] data would need to be vetted.* (P2)

Overall, most interviewees used the ISA speed alerts in their vehicle and believed the systems reduced their risk of speeding tickets. Safety was mentioned to a lesser extent. Individuals did not consider ISA systems as an important feature when selecting their vehicle, and this feature was not covered in detail by the salesperson. Issues with the reliability and accuracy of the system were common concerns and can result in users ignoring the alerts or turning off the ISA system. Additionally, users who were aware that their vehicle's speed was overestimated set higher thresholds for the speed alerts to account for this overestimation. Opportunities for improvements to the ISA systems were identified such as creating channels that update speed limit data in a timely manner and ensuring a vetting process so that information is correct.

3.2 Interviews with fleet users

For commercial fleet interviews, the focus was on the perceived barriers and incentives around uptake for advisory and regulated approaches to ISA.

Two interviews were carried out with WSP employees who regularly used fleet vehicles. WSP has a fleet management system installed in its work vehicles to help ensure compliance and safety of its employees when using company vehicles. The system collects data such as the vehicle's speed, sharp cornering and harsh braking. Unlike ISA in personal vehicles, the fleet monitoring system cannot be turned off by the driver and the information is reported to the user's workplace.

The fleet data is used to intervene managerially when speeding events and other poor driving behaviours occur. WSP has also implemented a ranking system to recognise drivers' performance and reward positive behaviour. An annual award for best driver is presented each year for the highest-ranking driver.

A WSP company-wide email included the following rationale for how the rankings are calculated.

> *The Leaderboard applies to our drivers who have driven at least 200 km in the past 28 days. The leaderboard ranks drivers on the frequency and severity of: Speeding events, the total distance driven in the period, harsh braking and sharp acceleration events.*

The two interviewees were selected to share their view on the system. These interviewees were selected based on their driver rankings – one higher-ranked (HR) individual (good performance) and one lower-ranked (LR) individual (poor performance).

Interviewees had a company vehicle as part of their work contract, which they were permitted to use for work and personal use. The two interviewees were able to describe the basic elements of how the fleet monitoring system worked, and each had further detailed understanding of the system from their personal experiences.

One of the individuals was on the committee involved when the fleet monitoring system was introduced and discussed the reduction in speeding events because of their installation.

> *[Fleet monitoring systems] were all installed in the vehicles for the first month or 6 weeks … The screens were dead [inactive] but the system was still gathering data just to sort of get a baseline … And the first month of [the fleet monitoring system] being live, it's [over-speed events] tapered down.* (LR)

There were positive aspects of the fleet monitoring system such as the system makes drivers more aware of the speed limits, it can be used to locate vehicles when necessary (such as emergency situations) and the system monitoring the kilometres travelled makes it easier for administration staff to make road user charges payments for the fleet vehicles. Both interviewees reported that they understood the need for the system in the fleet vehicles. However, both had concerns, including the reliability of data and the potential for the system to be used as a 'big brother'.

> *When [the fleet monitoring system] is working well, it provides constant feedback on the speed limit. It also provides constant feedback on deviation … cornering, braking and acceleration … It's really the reliability of the data … The basic principle with a perfect [fleet monitoring system] I don't have an issue with.* (LR)

> *It seems a bit big brotherish, but I understand why we need it.* (HR)

The fleet monitoring system has resulted in changes to driver behaviour.

> *I have slowed down in the company vehicle … I would speed up to 110 km/h to pass someone [in my personal vehicle], I can't do that now. Well, you can do it, but you are going to have to talk to someone about it … also, [I'm] more conscious about slowing down when coming into speed signs.* (LR)

The individual who had good performance as assessed by the fleet monitoring system had no issues with the discussions surrounding their driving performance from the system.

> *The [fleet monitoring system performance discussions] I have had to do myself I am quite happy with. I don't really know what happens when management needs to get the big stick out with some people … I am aware that there are people that have to have interviews with their manager about repeat offences or big, high numbers.* (HR)

The individual poorer performer was limited in what they were allowed to disclose about the process but believed the existing process of overspeeding was unpleasant.

> *I would describe them as uncomfortable ranging through to unpleasant … there are some conversations you don't want to have with your manager.* (LR)

One interviewee mentioned that several employees expressed interest in being able to access their own driving data. The possibility of an app to allow for this could be considered, providing more transparency of the information collected and allowing users to be aware of areas for improvement in their driving and to identify inaccurate information. There was some discussion about the potential of an app to allow individual drivers to view their driving data.

There were concerns that the fleet monitoring system makes drivers pay less attention to the road and may be a distraction in critical driving situations, with a perception that more attention is given to the system as the drivers are aware that overspeed events are sent to their managers.

> *I was previously aware of speed limits. Now I think I am overly aware of speed limits. So the focus of my driving … particularly in relation to speed is on what the [fleet monitoring system] is doing.* (LR)

As the information is sent to the driver's workplace, this would influence speeding events more so than just the presence of speeding alerts. For private use cases, the information sent to the workplace can prove useful during incidents where the exact address of a driver was not known, but there were concerns about the system becoming a big brother as the location of the vehicle enables to the company to note if people are taking the work vehicles home when they should not be.

> *Taking the vehicle home at night without the right authorisation will get picked up by [the fleet monitoring system]. [Work vehicles] are supposed to be parked in the office car park overnight, and the big thing to worry about there is fringe benefit tax.* (HR)

The interviewee with the low driver ranking commented on their personal testing of the fleet monitoring system. They determined that their ranking was lowered due to the limitation and inaccuracies of the system.

> *I've been driving along a straight section of road, and it will randomly tell me that I've had harsh braking … they are certainly not perfect devices … the Waikato Expressway opened with an increased speed of 110 km/h so very deliberately the next night after it opened I went for a drive down the [Waikato] Expressway and wanted to see what [the fleet monitoring system] would do, and I got 37 overspeed events along a 20 km section of road so [the fleet monitoring system] had some 110 [km] data in there and some not.* (LR)

The interviewee also observed that the system was not consistent with its alerts and had inaccuracies such as occasionally having a sharp cornering warning when driving on a straight road. They further mentioned that the system does not account for instances where harsher braking is an appropriate response for poor performance of other drivers (such as another driver pulling in front of your vehicle when they do not have right of way or the vehicle in front braking suddenly). They also believe the alerts during these critical driving situations could serve as a distraction to drivers.

3.2.1 Improvements

Despite positive aspects of the fleet monitoring system, issues were also apparent. When the fleet monitoring system is not up to date, the information for speed limits can be incorrect. Supporting the comments of individual private users, the use of ACC to help reduce speeding events was also mentioned by a fleet interviewee who had concerns about the system's data.

> *I have concerns about the reliability of [the fleet monitoring system]… I use adaptive cruise control a lot when I'm driving as I see the speed limit change, I flick in the speed limit on the adaptive cruise control.* (LR)

Additionally, trying to correct the speed limit information in the system was described as difficult by both individuals. One interviewee expressed that the system could be improved by being able to report this information directly to the system supplier.

> *… there's a particular corner where [the fleet monitoring system] has the wrong speed limit information … I brought this to the attention of my manager … rather than me… being able to submit something simple through an organisational system. It's a pain.* (LR)

Care should be taken when reports are made to the system supplier so they can be dealt with appropriately, as it is frustrating for users when this does not occur.

> *Last time I got pinged, I told the boss that I wasn't going to file an incident form for it because I was pinged for doing 59 km/h in a 30 km/h zone but there were no 30 km/h signs up so they can't enforce that and I told the boss. I also informed [the fleet monitoring company] and they gave me some silly reply, but never mind … my manager has been over the bridge the week before and agreed with me that there were no signs so that was all right.* (HR)

Further, the alert notification settings on the fleet monitoring system are not editable by the driver. One of the interviewees believed the thresholds on the system were inappropriate. They suggest changing the alerts to be based on relative risk (ie, 5 km/h over the speed limit in a 50 km/h speed zone has more risk than being 5 km/h over in a 100 km/h speed zone) rather than the use of alerts for exceeding 5 km/h in all speed zones.

> *From a road safety perspective … the thresholds in [the fleet monitoring system] I think are inappropriate, so in a 50 km/h area, you have the orange from 50–60 km/h, and then if you exceed 60 km/h, it goes red and you get the tone … from a risk perspective at those lower speed limits, I think the threshold should be less. Use the United Kingdom speed enforcement as an example … they had a 10% plus rather than the blanket risk. It recognises the relative risk.* (LR)

Both individuals mentioned that aspects about the fleet monitoring system and the organisation's responses were unclear, and they did not feel fully informed on how the data was being used and how their driver performance rankings are calculated. There was also interest in having their personal driving data viewable so they can make improvements or corrections.

> *I'm aware the managers get the speed infringements … fed through to the company's incident reports. I'm not sure if we do anything with sharp cornering or heavy braking … we certainly don't hear about it, but I believe the data does get fed through … Incidents where there is speed exceeding 10 [km/h] over 250 m then that is sent to our supervisor via email … the incidents over 10 [km/h] and those over 20 [km/h], the organisational responses are different.* (LR)

Overall, the interviewees understood the advantages of having driver monitoring systems in commercial fleet vehicles. However, there were concerns related to the reliability of the system's data. There is a need to be able to easily update the speed sign information when appropriate. Unlike personal ISA systems, fleet monitoring systems are unable to be turned off by the driver and the information is sent to the workplace managers. This can result in fleet drivers paying more attention to their speed than they would in their personal vehicles, and there were concerns that the system may take attention off the road, negatively impacting road safety. It may also be important to increase transparency of the system and the use of the data with potential to allow drivers to view their data.

3.3 In-service requirements

The interview with the ISA expert focused on any in-service maintenance requirements beyond standard vehicle servicing requirements that could impact on resources, costs or reliability of the systems in New Zealand.

3.3.1 In-service requirements for map-based systems

For map-based systems to maintain their usefulness, the expert identified that there is a requirement for a national database of all posted speed limits in the country and that it is machine-readable, regularly updated and freely accessible. It was noted that such a machine-readable database does exist in the form of the National Speed Limit Register (Waka Kotahi NZ Transport Agency, 2023b). While the speed limit data is available in a variety of forms the level of use is unclear; some of the potential users spoken to were unable to specifically identify their data sources, while others suggested that the downloads may not be as useful as they could be as the downloads encompass the entire data set rather than updates only. While repeated processing of the entire dataset may be time consuming, such issues could be overcome in future by preprocessing to produce the changes-only data set. The data could also be pushed to commercial offerings like the HERE ISA Map.[8]

3.3.2 In-service requirements for vision-based systems

Irrespective if the visual system was fitted to the vehicle at the manufacturing stage or as an after-market piece of equipment, the expert reported that a camera-based system should not require maintenance during its lifetime. However, while the camera and its supporting systems would not require maintenance, the system relies on speed limit signs on the roading network to be intelligible so there is a maintenance requirement in that the signs need to be kept clean and in good order for the cameras to read them.

While it is not considered a maintenance activity, ISA systems that can implement over-the-air updates can receive software improvements or corrections past their base install period. This could include updates for new sign designs or corrections for incorrectly reading non-speed limit signs. This is important if it is discovered there are signs unique to the New Zealand road network that may confuse camera-based systems that have been configured against signs that conform to the Vienna Convention on Road Signs and Signals. For instance, the advance warning sign shown in Figure 3.1 may be interpreted by a camera-based ISA system as meaning the vehicle has entered a 50 km/h zone when it only indicates that a 50 km/h zone is further ahead.

While these camera-based systems should not require any maintenance over their lifespan, there are situations where the system would be required to undergo calibration such as when a windscreen or some component of the ISA system is replaced. This calibration process can generally be carried out by the installer using standards and procedures outlined by the system manufacturer. Care does need to be taken when carrying out these calibration activities as doing them incorrectly or poorly can lead to significant reductions in the system's effectiveness.

In relation to windscreen replacements, the interviewee reported that care should be taken to ensure replacement glass matches the original as closely as possible. While the camera systems can be calibrated for some variation such as minor changes in glass thickness, there is a limit to how far the original manufacturer's specification can deviate from the replacement before the calibration process can no longer accommodate for changes.

Potential maintenance activities were discussed that could be implemented as part of the warrant of fitness (WoF) process that would help to ensure ISA systems are working optimally. These include ensuring:

- there is no physical damage to the area of the windscreen the camera sees through (no cracks or inclusions in the glass)
- there is no foreign material between the camera lens and windscreen (dust or bonding material if the camera housing is fixed to the windscreen)
- the camera lens is clean.

It was mentioned that both Germany and Japan are investigating the possibility of testing vehicle radar/lidar systems as part of their WoF equivalents (the Hauptuntersuchung in Germany and Shaken in Japan), and this is a potential future activity for the New Zealand WoF process. This would take place using a special testing rig, and vehicle manufacturers would have to develop testing procedures for their vehicles that could be implemented using the rig. This concept could easily be extended to testing the functionality of camera-based systems, including ISA.

[8] https://www.here.com/platform/intelligent-speed-assistance

4 Benefits and costs of advisory ISA for New Zealand light vehicles

4.1 Introduction

To understand the extent to which ISA is likely to deliver cost-effective improvements in New Zealand road safety, this section looks at the benefits and costs of implementing an advisory ISA system into the New Zealand light vehicle fleet. The road safety-related benefits of ISA are a function of the:

- effectiveness of ISA at managing speed and crash risk
- crash scene – the light vehicle crashes that are occurring in New Zealand
- penetration – the level of ISA in the fleet over time.

The above benefits are then contrasted to the costs associated with installation and maintenance of ISA.

4.2 Benefit estimation

4.2.1 Effectiveness of ISA

4.2.1.1 The previous New Zealand trial

Waibl et al. (2013) investigated the impact on drivers' speed choices of a fixed speed limit advisory ISA and a variable speed limit ISA that also provided speed recommendations for advisory curves. Short-term trials (around 1 hour of driving with each experimental ISA condition) were undertaken on a fixed route that included a range of road types encountered in New Zealand.

Forty participants were recruited to represent the New Zealand driving public using a stratified sample of age and gender (based on the representative driving-exposure hours of these demographic groups). The study provided insights into the performance of an advisory ISA on urban local roads and arterials, rural roads, expressways and motorways. A range of speed limit zones (50 km/h, 80 km/h and 100 km/h) were included. The trials used the Dreevo2 device, which uses the Speed Alert software application and is a product of Smart Car Technologies Pty Ltd in New South Wales, Australia. The same device (see Figure 4.1) was used for the ISA trials in Lancashire and the New South Wales Roads & Traffic Authority trials (NSW Centre for Road Safety, 2010).

Figure 4.1 Speed alert device used in New Zealand ISA trials (reprinted from Waibl et al., 2013, p. 8)

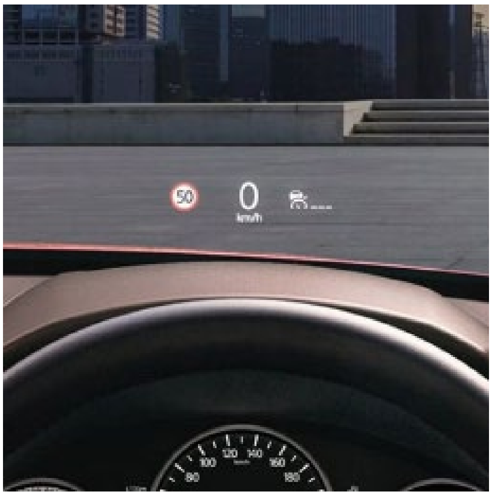
a) Driving below the speed limit in a 100km/h zone

b) Exceeding the speed limit in a 50km/h zone

While the device used is very similar to products such as EROAD, which have been retrofitted to a number of New Zealand fleets, it is more conspicuous than both the phone-based apps used by Waibl et al. (2013) in Figure 4.1 and by Starkey and Charlton (2018) in Figure 4.2. Both the interfaces for the Waibl et al. (2013) and Starkey and Charlton (2018) systems are considerably more conspicuous than the speed limit recognition systems in a number of newer vehicles that are EU compliant (for an example, see Figure 4.3). Waibl et al. (2013) make the important point that the effectiveness of ISA will in part be related to the form of the human-machine interface.

Figure 4.2 Mobile phone Interface (reprinted from Starkey & Charlton, 2018, p. 23)

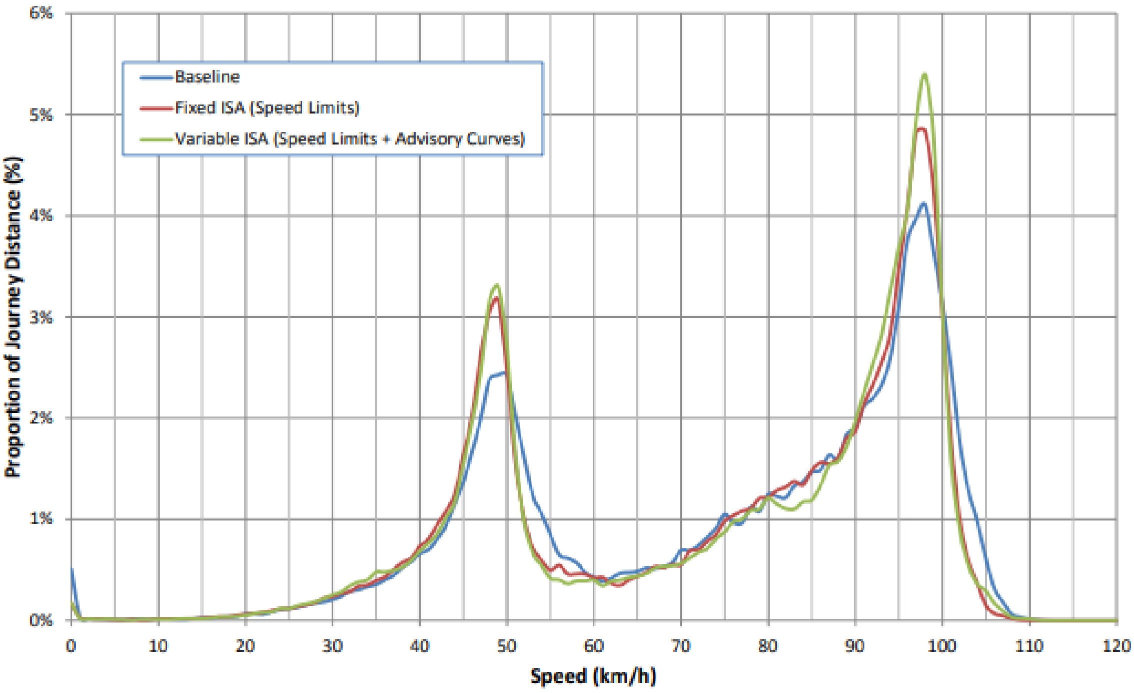
Figure 4.3 Mazda Drive Active (reprinted from Taylor Mazda, n.d.)



Results of trials

The impact of the two ISA variants on the overall speed distribution is shown in Figure 4.4. The result has been an obvious increase in travel at or immediately below the nominated speed limits and a reduction in the upper tail, resulting in a narrower speed distribution.

Figure 4.4 New Zealand ISA field trials (reprinted from Waibl et al., 2013, p. 124)



Waibl et al. (2013) tested several speed crash relationship models to establish the likely crash reduction benefits of ISA as outlined in Table 4.1. The range is large depending on the model type, and the researchers noted that the generally low speed travelled on much of the 100 km/h single carriageways had produced conflicting results. As a consequence, the research concluded that crash reductions for urban and rural environments should be used as outlined in Table 4.2. It should be noted that these are crash reductions where the crashes are classified based on the most serious injury.

Table 4.1 The impacts of fixed speed limit advisory ISA on crashes (reprinted from Waibl et al., 2013, p. 130)

Road type	Mean-speed crash risk models (Nilsson/Elvik power model)			Mean-speed & shape-of-speed-distribution models (Taylor et al models)	Individual crash risk models (Kloeden et al models)
	Fatal crashes (%)	Serious-injury crashes (%)	Minor-injury crashes (%)	All injury crashes (%)	Fatal and serious-injury crashes (%)
50km/h	5%	3%	2%	8% & 15%	22%
80km/h (single-lane carriageway)	6%	4%	2%	5%	9%
100km/h	1%	1%	0%	n/a	5%
• 100km/h single-lane carriageway	-2%	-1%	0%	0%	-3%
• 100km/h multilane carriageway	3%	2%	1%	n/a	6%
– 100km/h expressway	3%	2%	1%	n/a	5%
– 100km/h motorway	3%	2%	1%	n/a	6%

Table 4.2 Summary of the final predicted crash savings for the implementation of an advisory ISA system in New Zealand (reprinted from Waibl et al., 2013, p. 132)

Road type	Fixed speed limit ISA		
	Fatal (%)	Serious injury (%)	Minor injury (%)
Urban	22%	22%	7%
Rural	5%	5%	2%

4.2.2 Future crash outcomes without ISA

The benefit stream for ISA is related to the effectiveness of ISA in addressing the light vehicle crash scene both now and in the future. This section looks at the crash history of the New Zealand light vehicle stream to establish future crash outcomes without ISA.

Two approaches have been adopted. The first looks at the historical crash trend. It should be noted that, while the effectiveness of ISA is mainly associated with crash reductions, speed management impacts heavily on crash outcomes (ie, the deaths and serious injuries that result from crashes). Therefore, care should be taken when looking at crash occurrence and the frequency of outcomes-injuries.

In the alternative approach, data from the NZTA Integrated Intervention Logic Model for Road Safety (Graham, 2019) has been used. This data focuses on all predicted deaths and serious injuries in the absence of further interventions.

4.2.2.1 Historical crash data

Looking at crashes involving light vehicles (excluding single-party crashes where a light vehicle was not involved) and the outcome of those crashes since 1985 in Figure 4.5, there is a noticeable but short-lived plateauing of serious and fatal crashes from around 2010 followed by a perceptible upward trend from 2010 to 2018 before the impact of COVID-19 appears around 2019.

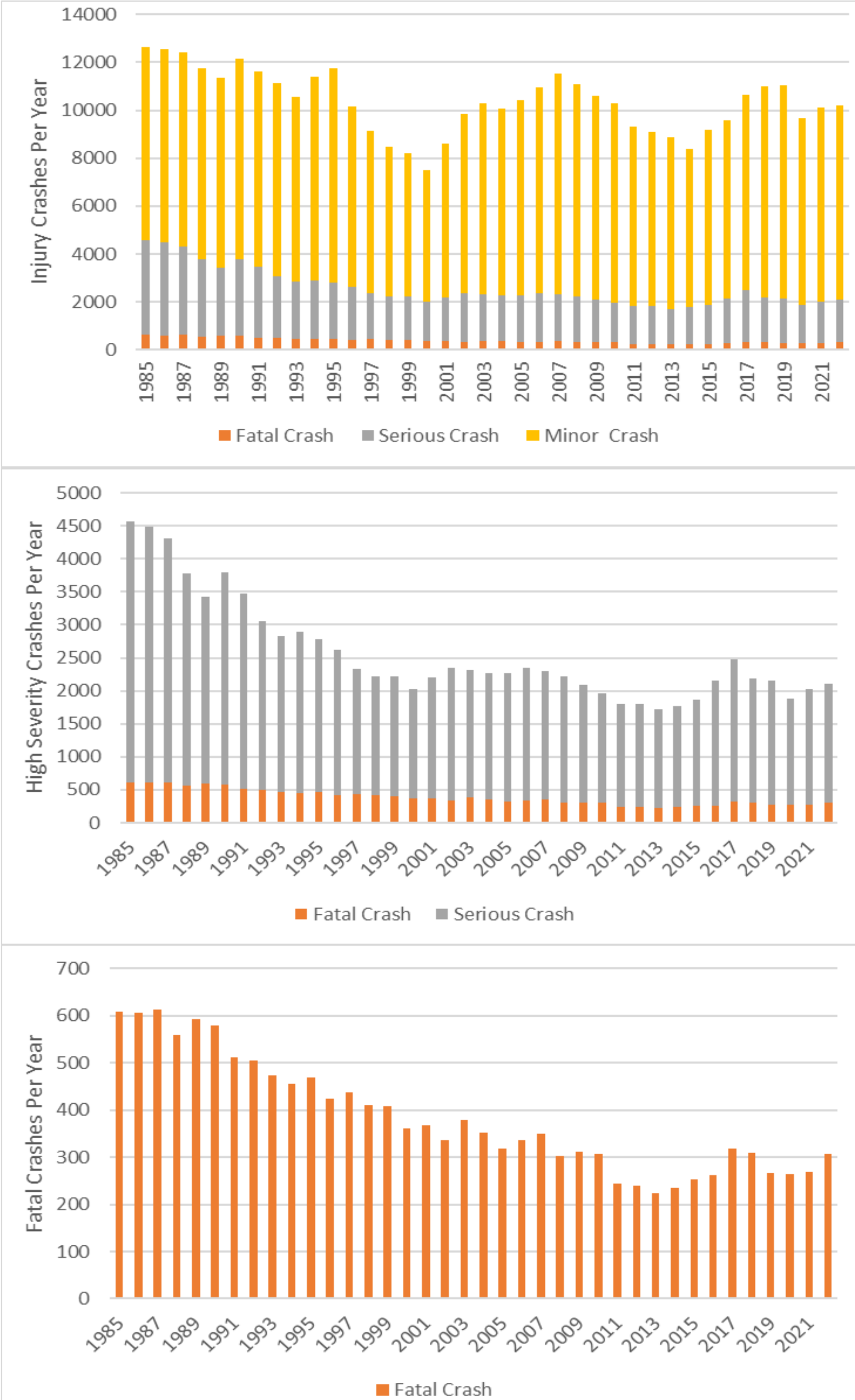
In terms of predicting future crash performance in the absence of other initiatives, extrapolating a simple mean of light vehicle crashes and outcomes for the last 10 years from 2013–2022 could be supported.

Going forward, this would result in 271 light vehicle fatal crashes per year and 1,763 serious injury crashes per year or 304 fatalities and 2,126 serious injuries resulting from crashes involving light vehicles.

However, the Monetised Benefits and Costs Manual (Waka Kotahi NZ Transport Agency, 2023a) proposes that future crash predictions be adjusted to reflect the general downward trend in crash occurrence and the impact of growth. Given the light vehicle kilometres of travel is increasing at approximately 1.3% per year (Te Manatū Waka Ministry of Transport 2023) and that approximately half of fatal and serious crashes (48%) and half of deaths and serious injuries (52%)[9] occur in open road speed limits, the associated growth in crash rate is assessed to be -1.5% (see Figure 4.8 historical trend line). While this figure should only apply to crashes, it has been applied here to the deaths and serious injuries that have resulted.

[9] It should be noted that approximately 70% of fatal crashes and fatalities occur on the open road while 45–50% of serious injury crashes and serious injuries occur on the open road. The open road is a speed limit area 80 km/h and above.

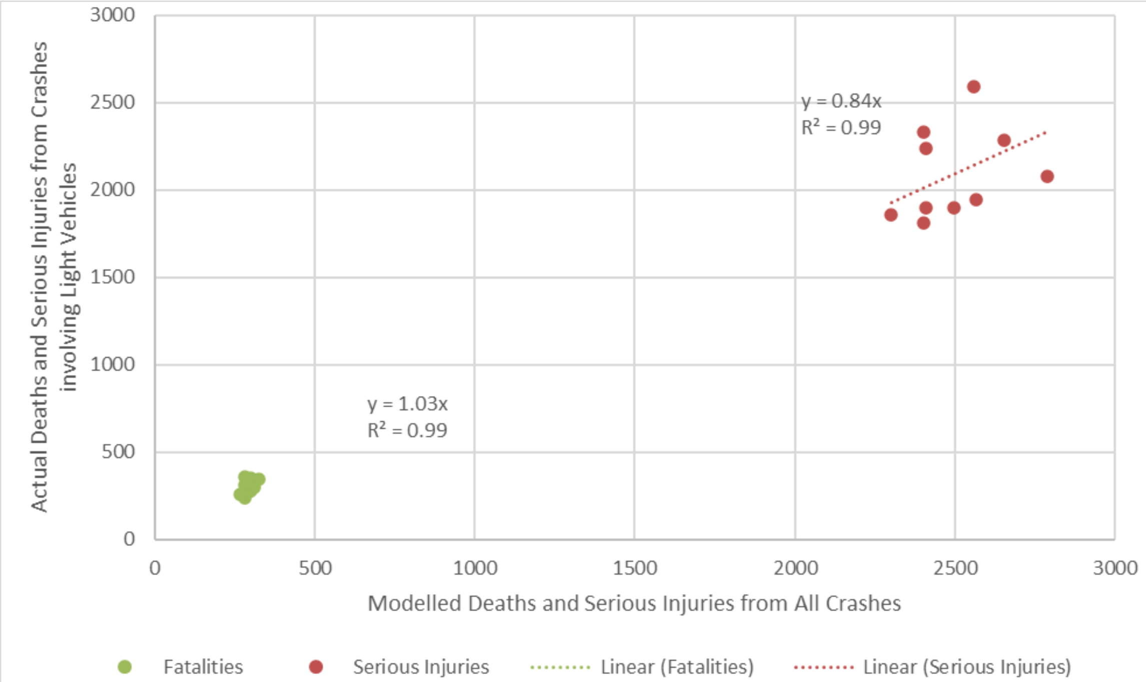
Figure 4.5 Light vehicle crashes since 1985



4.2.2.2 Integrated Intervention Logic Model for Road Safety

The alternative future projection methodology is based around the work completed by NZTA on the Integrated Intervention Logic Model (IILM) for Road Safety (Graham, 2019). This model seeks to assess the impact of various interventions against a baseline crash scenario – the status quo in terms of safety interventions. The model considers all deaths and serious injuries projected out to 2030 and therefore needs to be adjusted to focus only on those deaths and serious injuries associated with crashes involving the light vehicle fleet and extended through to the 40-year analysis period. Looking at Figure 4.6, the relationship between the modelled deaths and serious injuries for all reported crashes and the actual deaths and serious injuries from crashes only involving light vehicles is strong over the 10 years of data (2010–2019).

Figure 4.6 Relationship between actual light vehicle outcomes and the results of the IILM baseline model



Using the equations of Figure 4.6, the IILM has been adjusted to account only for deaths and serious injuries resulting from crashes involving only light vehicles (see Figure 4.7).

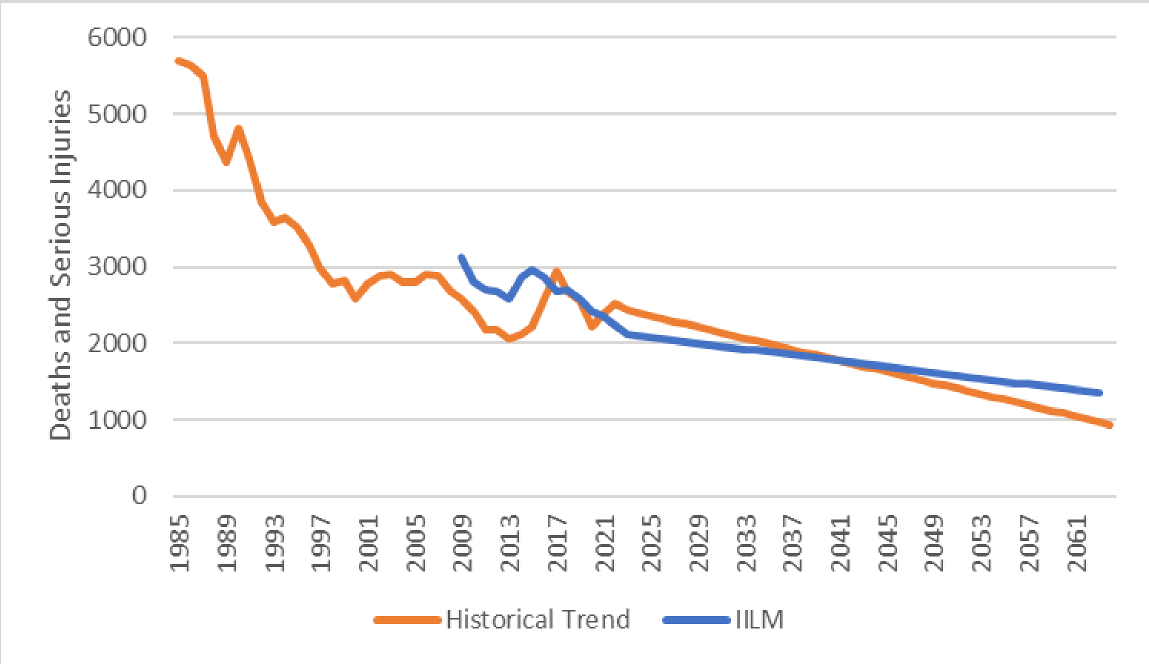
Figure 4.7 Modelled deaths and serious injuries resulting from crashes involving light vehicles

The IILM period from 2024 to 2030 involves essentially a reduction of 1% (0.00908) from 2024, which equates to 219 deaths and 1,877 serious injuries.

4.2.2.3 Summary of base predictions

The two alternative approaches shown in Figure 4.8 produce relatively similar results, which is encouraging. The two approaches can be expected to differ to some extent as they use very different approaches – the historical trend being an extrapolation of prior crash trends whereas the IILM is an extrapolation of an economic model inputting many variables as discussed in Graham (2019).

Figure 4.8 Comparison of death and serious injury projections



For consistency with other road safety initiatives pursued by Te Manatū Waka and NZTA, the baseline projections of death and serious injury from the IILM have been adopted going forward.

However, while road safety has a focus on deaths and serious injuries, the economic analysis required of this project is focused on crashes. Data from the last 5 years (2018–2022) indicates the following.

For every open road DSI, there are:

- 0.151 fatal crashes
- 0.622 serious crashes
- 2.396 minor injury crashes.

For every urban road DSI, there are:

- 0.075 fatal crashes
- 0.834 serious crashes
- 4.430 minor injury crashes.

In terms of the split between urban and rural, 52.38% of deaths and serious injuries occur on rural roads. Note that factors have not been developed for non-injury crashes as these are subject to considerable reporting variability and typically contribute little to the overall benefit stream. Most importantly, the previous research on the benefits associated with a New Zealand ISA trial (Waibl et al., 2013) did not develop crash reduction factors for non-injury crashes.

4.2.3 ISA penetration

The benefit stream for ISA depends on the size of the fleet being considered and the market penetration of ISA. The New Zealand light vehicle fleet is imported – a mix of both new imported vehicles and used imported vehicles.

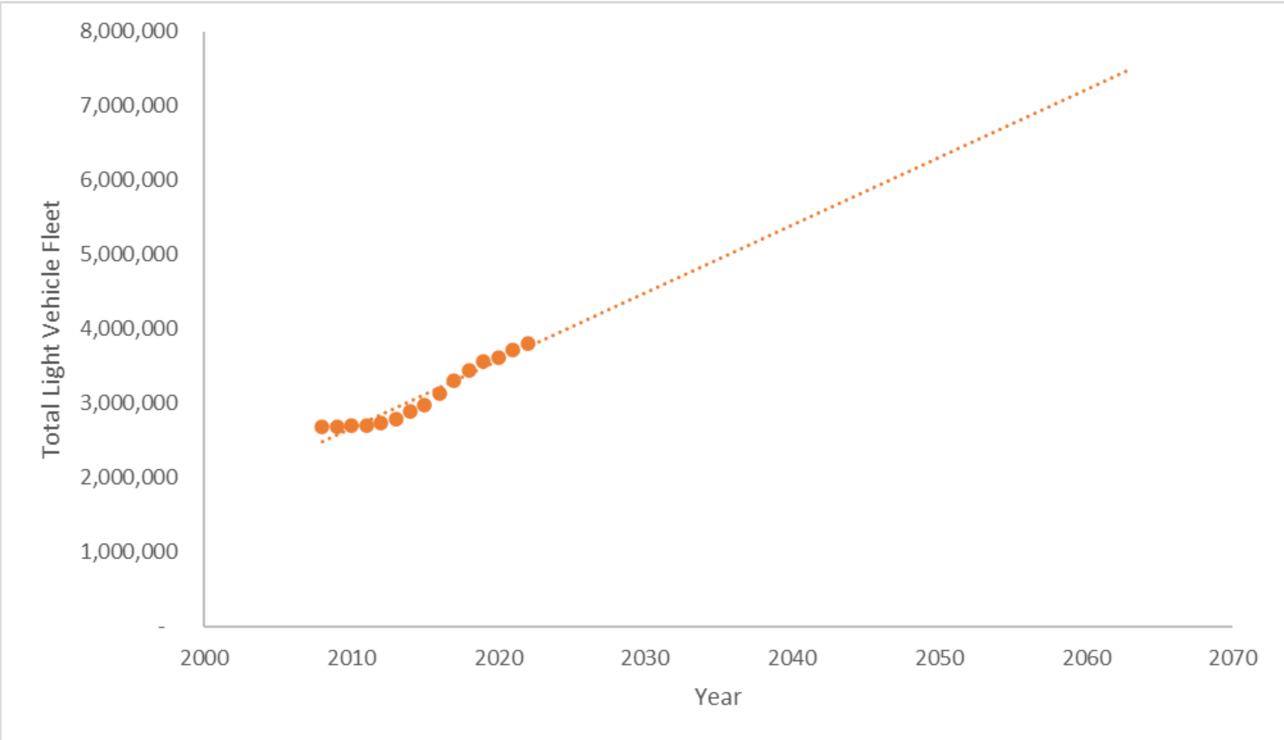
The implementation of ISA or indeed any new technology into new imported vehicles – and subsequently, over time, used imported vehicles – is dominated by the requirements of markets far larger than New Zealand. As a crude observation, while the functionality of many new technologies is generally built into the bulk of new imported vehicles, it may not necessarily be enabled.

This section of the study looks first at the penetration rates for new technologies in new imported vehicles and then looks at the penetration rates within the used import fleet. The two are then combined to produce a light vehicle fleet model. Two such models are considered – the first is based on the penetration patterns observed above while the second is a scenario where ISA functionality is mandated at a point in time as agreed with NZTA.

4.2.3.1 New Zealand fleet

For this research report, we have used the actual light vehicle fleet data for the last 15 years (2008–2022) and projected this out to 2063 using a linear trend line resulting in a total vehicle fleet of just over 7 million vehicles by 2063. Figure 4.9 shows two light vehicle fleet projections considered.

Figure 4.9 New Zealand light vehicle fleet projections considered out to 2063



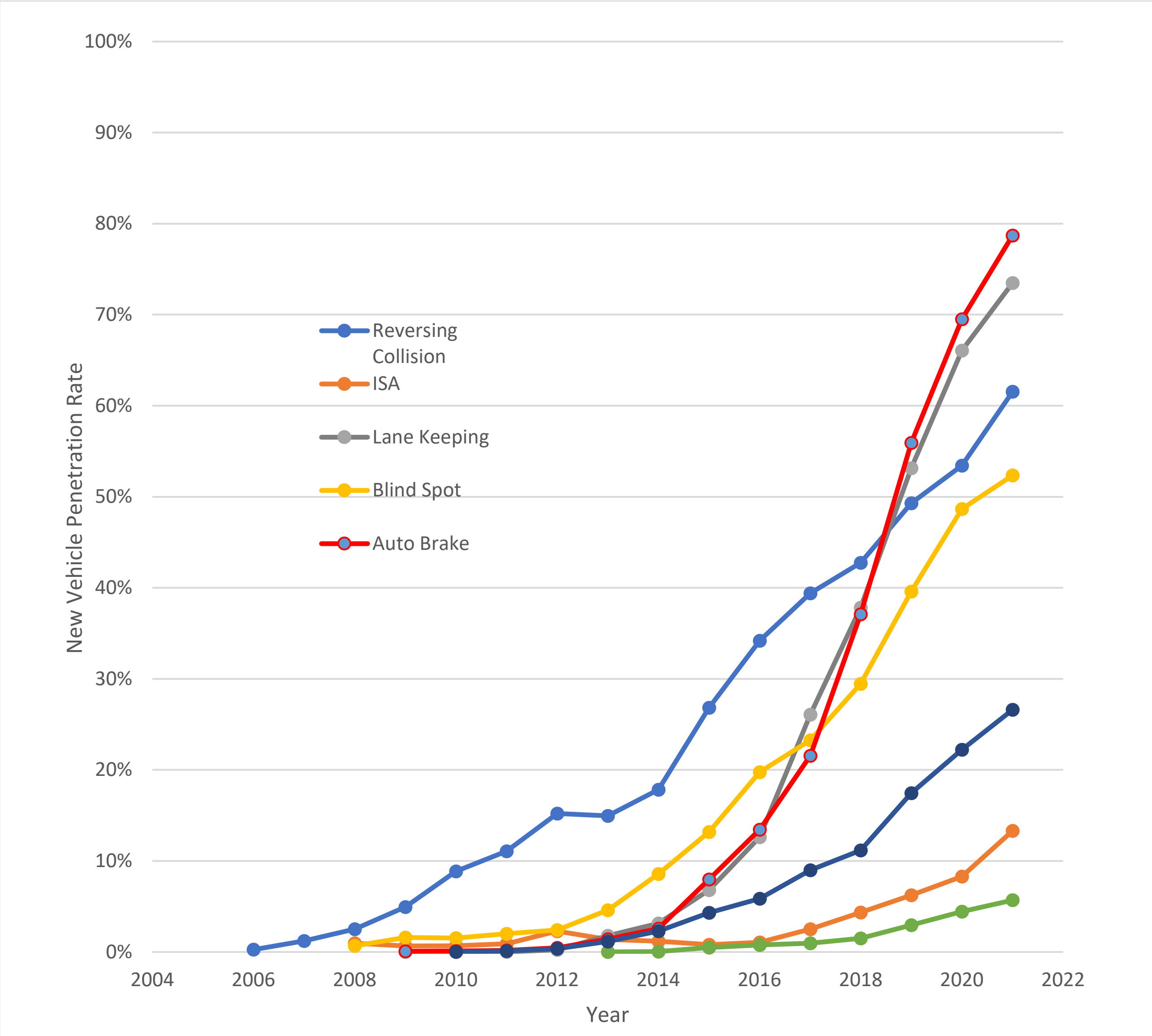
4.2.3.2 Penetration of ISA in new imported vehicles

The data supplied by NZTA looks at the penetration of a range of new technologies in imported new vehicles. These technologies are listed in Table 4.3. Plotting the new vehicle penetration rates for each, Figure 4.10 shows that, while automatic emergency braking and LKA have similar trajectories, the remaining technologies appear to have a wide range of penetration rates.

Table 4.3 New technologies considered

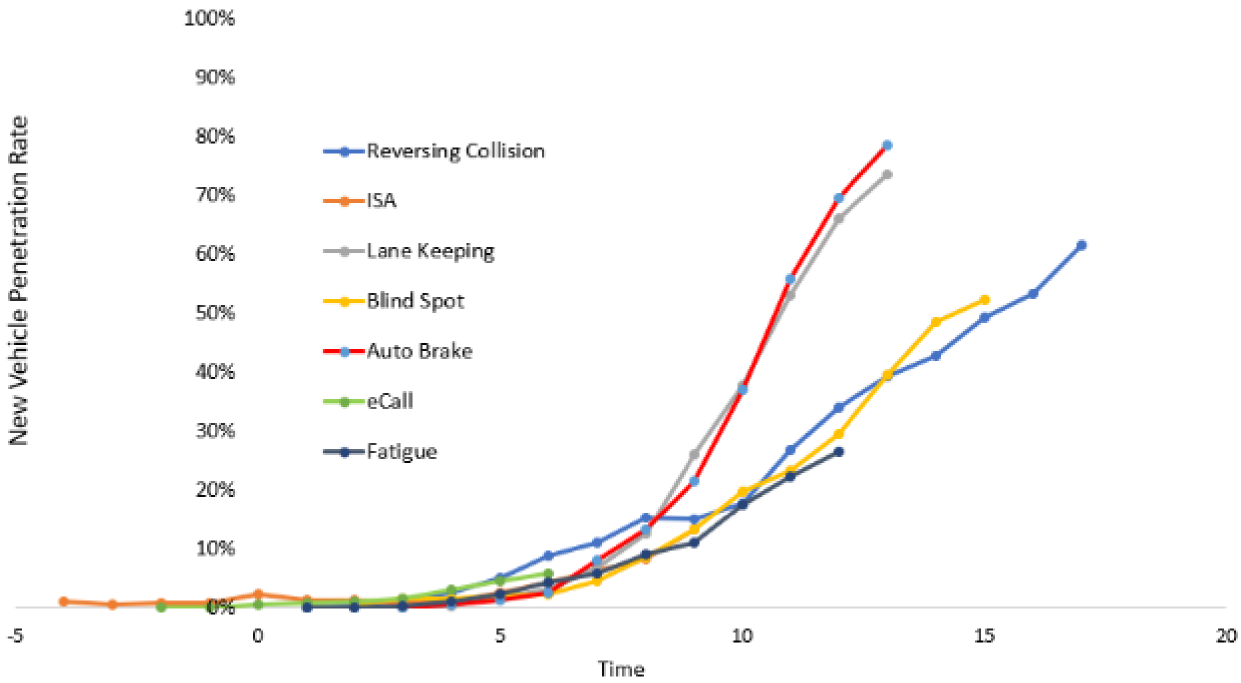
New technologies	
Fatigue (detection)	eCall (automatic emergency call)
Automatic emergency braking	Blind spot (monitoring)
Lane keeping (assist)	Reversing collision (avoidance system)
ISA	

Figure 4.10 New vehicle technology penetration



By adjusting the penetration dates to a common start rather than by year in Figure 4.10, it becomes clear that there are essentially two penetration pathways (see Figure 4.11) – one for LKA and automatic emergency braking and another slower path for the remaining technologies.

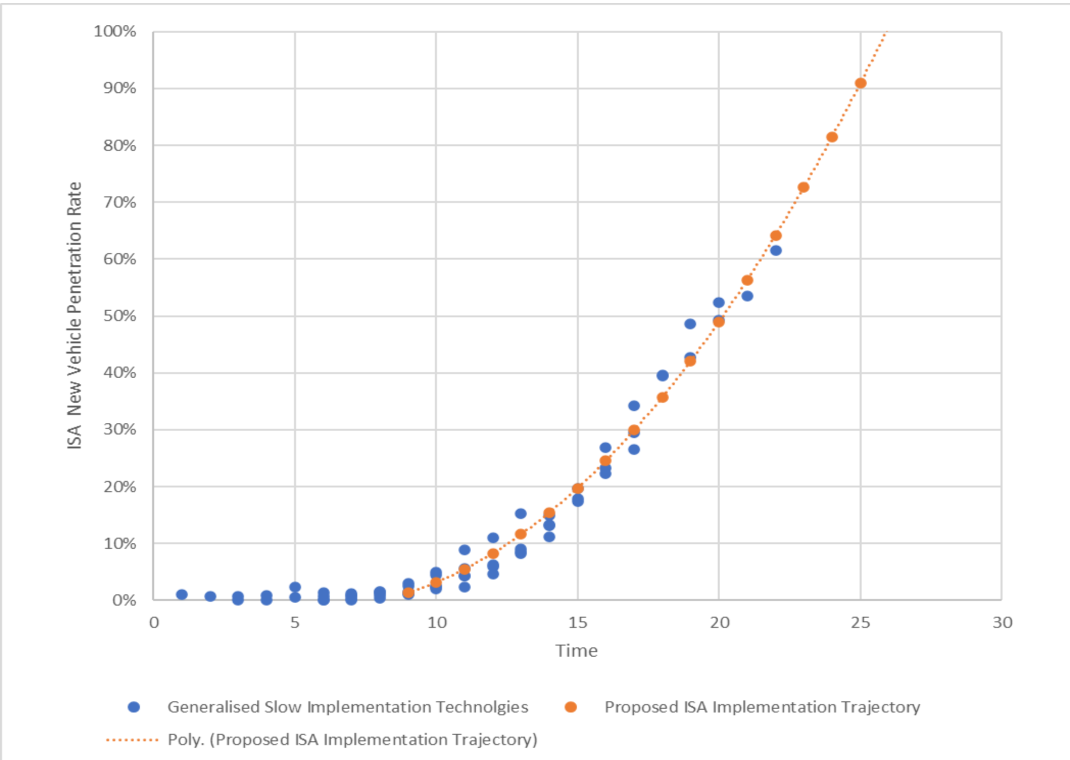
Figure 4.11 Standardised new vehicle penetration rates by technology



The two trajectories are most interesting. The higher trajectory relates to two technologies that have been mandated in the EU (see section 2.11) for implementation by 2024, while the slow penetration rates apply to systems that are not mandated in New Zealand or overseas at the time of writing.

Using the total implementation data for the slower systems, we can develop a model of the expected ISA penetration rate (see Figure 4.12) in the absence of any mandating in New Zealand or overseas.

Figure 4.12 Assumed ISA penetration rate for new vehicles

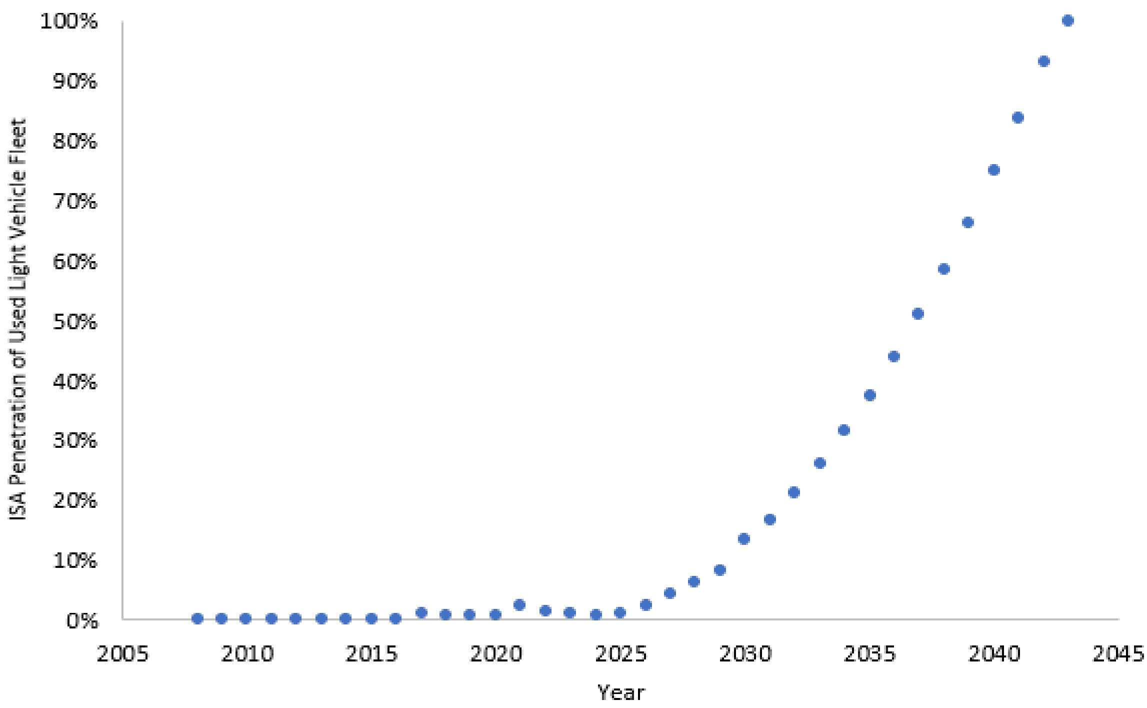


4.2.3.3 Penetration of ISA in used imported vehicles

NZTA has supplied data in the likely fitment of ISA systems within the used import fleet. However, because the data is still hovering at less than 0.4% penetration, we are not confident that the growth curve has started for used imports fitted with ISA. This data is therefore of limited value and has not been used in the development of this model.

As an alternative, the trajectory for ISA penetration into the used light vehicle fleet has been based on that derived for new vehicles but shifted by 9 years as supplied by NZTA and shown in Figure 4.13 (T. Wylie & I. Zikonda-Kraus, personal communication, 28 March 2023). This is based on the average age of used vehicles imported to New Zealand being 9 years and an assumption that the penetration of ISA in new vehicles here is similar to that of countries exporting used vehicles to New Zealand.

Figure 4.13 ISA penetration of used light vehicle fleet

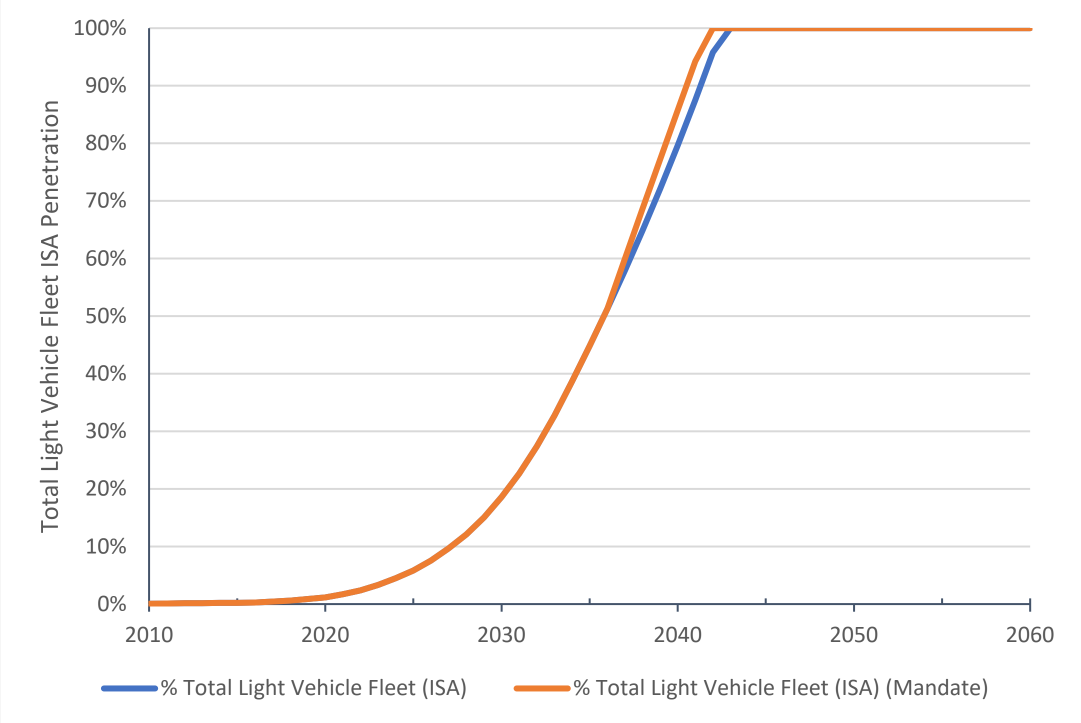


4.2.3.4 Mandated implementation scenario

A second scenario is also assessed where ISA is mandated for all new vehicles entering the New Zealand light vehicle fleet. NZTA (T. Wylie & I. Zikonda-Kraus, personal communication, 28 March 2023) has advised that such a mandate, if required, would occur once ISA is fitted to 75% of new vehicles entering the fleet. This first occurs is 2036 (total imports fitted with ISA = 75.22%) so it is assumed that, from 2037, all vehicles imported to New Zealand will be fitted with ISA. It should be noted that the mandate doesn't affect new import ISA uptake as this has already reached 100% in 2034 (3 years earlier), but it has a significant impact on used import ISA uptake, which rises sharply from 43.98% in 2036 to 100% in 2037. It is important to note that the mandate does not include retrofitting non-ISA vehicles in the fleet.

The result is shown in Figure 4.14 and the differences are to some extent trivial. However, the mandated approach agreed here differs from that which appears to have been applied to LKA and autonomous emergency braking. In these situations, it appears a future date has been set and advised and the industry has moved towards meeting that date. This has resulted in a more accelerated implementation as shown in Figure 4.11. The agreed mandatory scenario is somewhat reactive and retains the slower implementation of Figure 4.11.

Figure 4.14 ISA penetration of total light vehicle fleet



Although beyond the scope of this project, it is recommended that a range of alternative mandate scenarios should be investigated.

4.3 Costs

4.3.1 Introduction

Identifying the costs associated with an advisory ISA in the New Zealand light vehicle fleet has been possibly the most difficult task within this research not only because there is a wide range of systems that provide the desired functionality but also because many are commercially sensitive.

At one end of the scale are map-based systems that can be operated on mobile phones or similar in-vehicle devices that are essentially independent. At the other end are systems that combine cameras with traffic sign recognition with speed limit databases.

Either way, the costs for advisory ISA systems in the New Zealand light vehicle fleet are a combination of:

- the establishment of and maintenance of a spatially referenced speed limit database
- device purchase/fitment, including any camera system for sign recognition
- transmission of database material to the vehicle.

It is also important to note that retrofitting of in-service vehicles has not been considered as part of the market-driven or mandated implementation scenarios.

4.3.2 Costs associated with a speed limit database

Waibl et al. (2013) discussed the issues associated with building and maintaining a speed limit database to support the implementation of ISA, among other things.

In the 10 years since this possibility was first developed, NZTA has developed a National Speed Limit Register (Waka Kotahi NZ Transport Agency, 2023b) to support road controlling authorities to set and maintain speed limits. The Register is referenced in the setting of speed limits legislation and is now considered to be the sole source of truth when it comes to speed limits.

While the Register will form a key component for the provision of speed limit data to some ISA systems, there will effectively be no costs associated with this as it already exists and is maintained for other purposes.

4.3.3 Vehicle systems

Some ISA systems on the market also use traffic sign recognition cameras to provide speed limit data. Again, these units support a range of applications such as LKA or emergency braking. The use of GPS is also required for navigation systems and eCall emergency response.

As a number of technologies such as eCall, LKA and ISA have been mandated in Europe and potentially Australia, this functionality is typically built into new vehicles even if it is not always enabled depending on the vehicle profile package. It has not therefore been possible to obtain from suppliers a cost for the provision of the ISA component alone. However, it is considered trivial.

4.3.4 Transmission of data

Where a vehicle relies in part on a database to support the ISA system, there are essentially two ways of supplying data:

- Physically – where onboard hard storage is manually updated. This could be for example an SD data card or similar that contains navigational maps, which typically have speed limit data attached. These are supplied with the vehicle and can be updated with new cards as desired. These systems are being replaced by mobile phone-based systems.
- Over the air – where ISA data for the local area of interest, often referred to as tiles, is downloaded over the cellular network and stored within the vehicle. Such systems are common in fleet management. While the cost associated with these systems is confidential to the suppliers and users of such systems, it is believed this could be in the region of $100 per year for over-the-air data.

An alternative that is gaining popularity is the use of mobile phones where Google Maps or Apple Maps are fed into the vehicle via a mobile phone connection (Apple CarPlay or Android Auto). Again, the supply of the data would be less than $100 per year as part of the user's mobile phone data package.

In essence, the infrastructure required to deliver ISA is in place and should not result in any additional costs. That said, an allowance of $50 per year will be used in the analysis.

4.4 Evaluation of ISA

4.4.1 Introduction

This section reports on the desktop evaluation of ISA. The resulting analysis focuses on the economic assessment and the specific impact on deaths and serious injuries of ISA under market-driven and mandatory implementation scenarios.

4.4.2 Approach and assumptions

4.4.2.1 Economics

The economic analysis has been performed over a 40-year period with a base year of 2022 and time zero being 1 July 2023. A base discount rate of 4% has been applied together with crash costs as set out in Table 4.4. This is in accordance with the Monetised Benefits and Costs Manual (Waka Kotahi NZ Transport Agency, 2023a), and NZTA update factor of 1.06[10] has been used to take the crash costs to the base year of 2022.

Table 4.4 Crash costs $M July 2021

Situation	Urban			Rural		
Crash severity	Fatal	Serious	Minor	Fatal	Serious	Minor
Crash cost ($M July 2021)	14.2	0.755	0.08	14.9	0.842	0.086

4.4.2.2 Implementation

The benefits are based on the product of the ISA market penetration, and the expected crash reductions from Figure 4.15 are applied to the expected number of fatal, serious and minor injury crashes, which have been derived for the predicted number of deaths and serious injuries extrapolated from the Integrated Intervention Logic Model baseline as discussed in section 4.2.2.2.

Two ISA fleet penetration scenarios have been considered – the market-driven penetration, which is in effect the natural growth, and a mandated scenario where ISA will be mandated for all vehicles joining the New Zealand fleet once ISA is fitted to 75% of new vehicles entering the fleet.

4.4.3 Benefit profile

4.4.3.1 Crash reductions

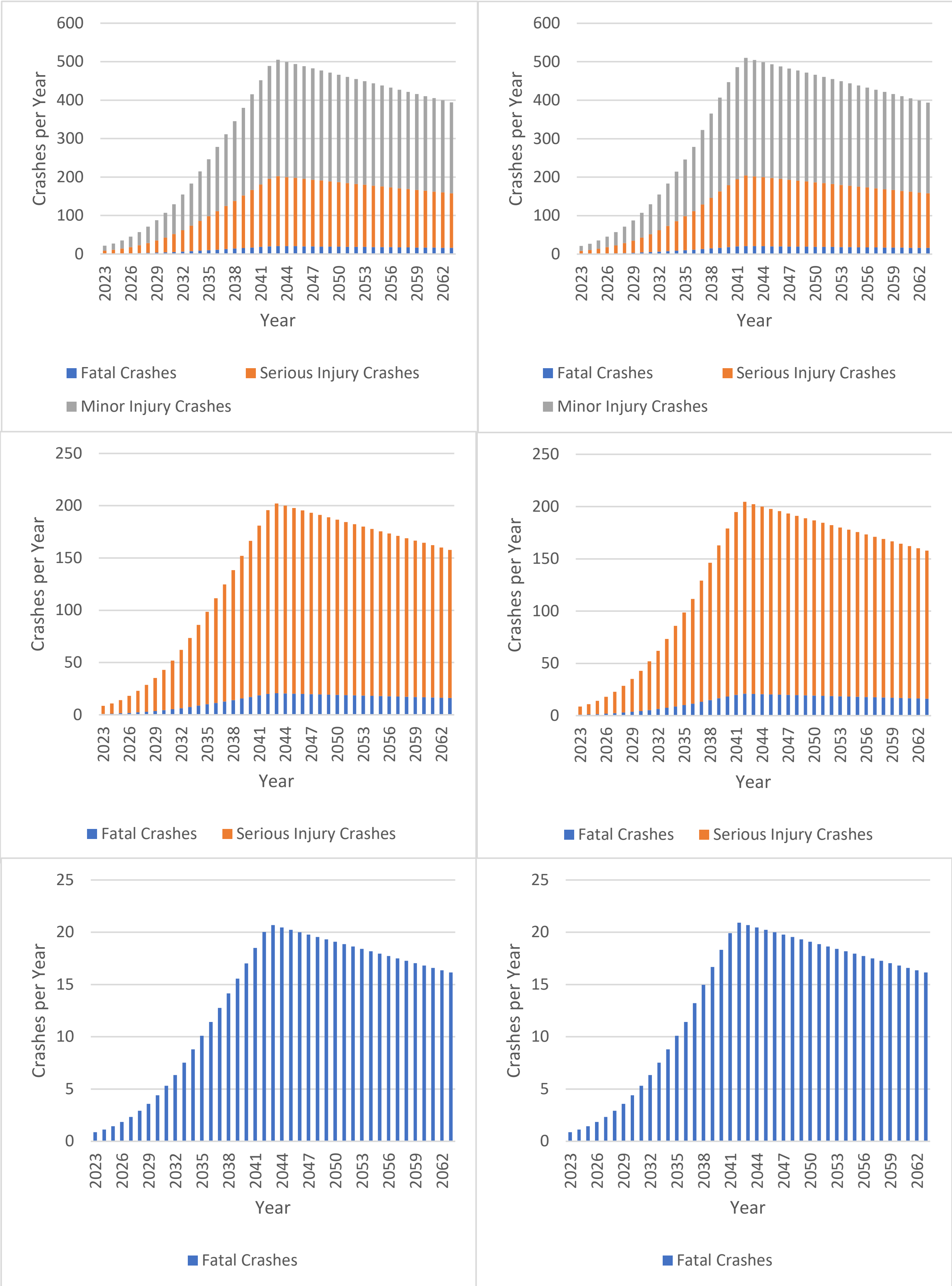
The impact on injury crash occurrence of the two ISA implementation strategies is shown in Figure 4.15.

The overall picture is one of increasing crash reductions with increasing penetration until such time as the fleet is essentially fully equipped with ISA, after which time there is a general decrease as ISA along with the other baseline interventions improve road safety.

The difference between the two implementation scenarios – market-driven on the left and mandated on the right – is minimal and reflects the minor changes in penetration identified in Figure 4.14.

[10] https://www.nzta.govt.nz/assets/resources/monetised-benefits-and-costs-manual/update-factors.pdf

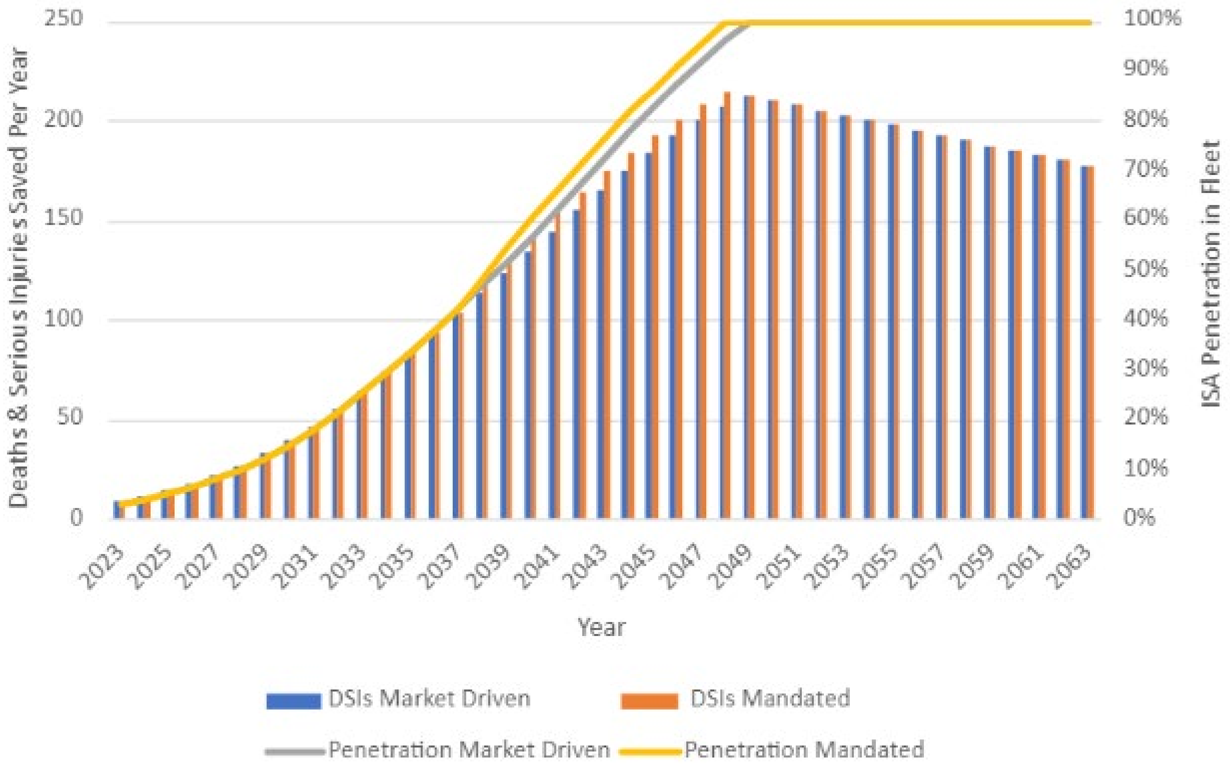
Figure 4.15 Impact of ISA on avoidance of crashes – market-driven scenario (left) and mandated scenario (right)



4.4.3.2 Reductions in death and serious injury

While crash reductions may be interesting, the focus of this project is on the potential contribution ISA might make to road safety, including the reduction of deaths and serious injuries. Working back from crashes to deaths and serious injuries, Figure 4.16 shows the contribution ISA can make to reductions in deaths and serious injuries. Again, what is obvious is that there is little additional benefit to be gained from mandating ISA once it is fitted to 75% of new vehicles entering the fleet.

Figure 4.16 Impact of ISA penetration on death and serious injury savings



4.4.4 Cost profile

The cost profile is based on the number of light vehicles fitted with ISA multiplied by an assumed annual cost of $50 (in 2022).

While the annual cost of $50 assumed is small, the fleet is large, estimated at some 7 million vehicles in 2063 in the absence of any other interventions (see Figure 4.9).

As a result, the costs become significant even with such a small nominal allocation.

4.5 Summary of the benefits and costs of ISA

The net present value (NPV) of the benefits and costs of ISA implementation are given in Table 4.5 together with the results of a series of sensitivity analyses. Note here the costs have been based on a nominal cost of $50 per year per fitted vehicle, which is considered conservative.

Table 4.5 Net present value of benefits and costs of crash reductions

ISA penetration scenario	Crash reductions	Discount rate	NPV benefits	NPV costs	Benefit-cost ratio
Market-driven	Base	4%	5,298,140,189	3,110,145,418	1.70
Mandated	Base	4%	5,371,672,149	3,147,388,686	1.71
Market-driven	Base	6%	3,581,881,258	2,012,347,138	1.78
Mandated	Base	6%	3,635,342,786	2,039,393,919	1.78
Market-driven	Base	3%	6,540,435,244	3,925,297,801	1.67
Mandated	Base	3%	6,626,898,295	3,969,115,876	1.67

Under both the market-driven and mandated implementation strategies for the provision of an advisory ISA system in the New Zealand light vehicle fleet, penetration is likely to reach 100% of the fleet around 2043.

At that time, it is expected that ISA should save around 13% of annual deaths and serious injuries based on the predicted crash reductions for New Zealand (Waibl et al., 2013). However, this figure of 13% does seem low compared to the international literature. This is particularly so for rural road crashes where a maximum saving of 5% for high-severity crashes is predicted in Table 4.6. Therefore, the rural crash reduction expectations from Waibl et al. (2013) have been doubled to account for this possible discrepancy (fatal 10%; serious 10%; minor 4%).

Table 4.6 Net present value of benefits and costs of crash reductions with double the rural crash reductions

ISA penetration scenario	Crash reductions	Discount rate	NPV benefits	NPV costs	Benefit-cost ratio
Market-driven	Double rural	4%	6,798,402,801	3,110,145,418	2.19
Mandated	Double rural	4%	6,892,756,643	3,147,388,686	2.19
Market-driven	Double rural	6%	4,596,154,633	2,012,347,138	2.28
Mandated	Double rural	6%	4,664,754,743	2,039,393,919	2.29
Market-driven	Double rural	3%	8,392,475,793	3,925,297,801	2.14
Mandated	Double rural	3%	8,503,422,395	3,969,115,876	2.14

What is abundantly clear is that the proposed mandating has a negligible impact on the results, and allowing the market to drive ISA implementation is probably the best overall scenario given the present state of knowledge.

5 Discussion

5.1 Literature review

5.1.1 Advisory ISA

The results of recent studies are generally in line with the conclusions of Waibl et al. (2013) in that users were generally positive about advisory ISA and there was enough compliance to make a useful difference. However, three studies were from countries that could have different compliance characteristics from New Zealand.

Studies indicated that incentives could work well but that they need to be very carefully designed to do so. In an advisory ISA fleet, setting incentives works better for those who are already more compliant (rather than those who are non-compliant in other driving areas).

5.1.2 ISA apps

Properly configured ISA apps have a demonstrable safety benefit and do not produce adverse distractive effects. The greatest challenge may be encouraging drivers to use them appropriately and consistently.

5.1.3 Preference for ISA

Most users are accepting of using speed limiting devices in cars, with studies reporting 80–97% of drivers perceiving it as beneficial for all drivers. Not unexpectedly, drivers prefer less-mandatory forms of ISA, but conversely, the more mandatory types were more effective in reducing speeds. However, mandatory ISA can be effective in a working environment where the driver has no choice but to use it.

Free ISA provision was preferred but a minority were willing to buy informative or warning ISA at a fair price with respect to a navigation system.

5.1.4 ISA for specific groups of drivers

ISA was seen as preferable for problematic or frequent speeders, professional drivers and young drivers. ISA has been demonstrated to improve the behaviour of recidivist offenders when used in conjunction with rewards and as a control mechanism.

ISA systems assist older drivers with speed moderation and lane keeping, but the results gained vary with the system used. Acceptance of both advisory and mandatory forms of ISA was generally high for older drivers. As well as reducing speeds, ISA may also improve older driver safety by reducing their mental load.

5.1.5 Suitability of speed crash models in the case of advisory ISA

Individualised speed crash models fit best with the plethora of individual driver decisions that occur with advisory ISA and the subsequent changes in the shape of the speed distribution. Therefore, as in Waibl et al. (2013), the individualised Kloeden model was used in the analyses of advisory ISA.

5.2 User interviews

Individual interviewees believed the ISA system was useful in helping reduce the risk of speeding tickets and to a lesser extent mentioned road safety. However, they reported that the systems can be unreliable. This impacts trust in the system and use of the system, with some turning off the system or not using the system during parts of their drive when the system was incorrectly giving speeding alerts. This was supported by the fleet drivers who understood the need for the systems being installed and had no issue with the concept as long as the system was working as intended.

Both individual and fleet users stated that updating, giving feedback and making corrections on systems is difficult. Other car features such as ACC were highly regarded and used to help manage speed.

For fleet management systems, data being sent to workplaces impacts driver behaviour more so than in their personal vehicle. There was concern that the fleet monitoring system may increase attention to the vehicle's speed thus reducing the driver's attention to other aspects of the road environment.

5.3 Benefits and costs of advisory ISA for New Zealand light vehicles

The study into the benefits and costs of ISA was based on existing data. Using this data, an economic assessment of ISA was undertaken for two scenarios. The first was a natural market-driven implementation of ISA and the second a strategy whereby, once ISA is fitted to 75% of new vehicles entering the fleet, it would be mandated for all vehicles entering the fleet, new or used.

The resulting analysis found that, when assessed according to the Monetised Benefits and Costs Manual (Waka Kotahi NZ Transport Agency, 2023a), the benefit-cost ratio for both scenarios was positive (ie, above 1.0, being in the order of 1.7). The big driver and to a certain extent the big unknowns are the costs that are associated with ISA. Even a nominal cost has a major impact on the resulting analysis. Furthermore, there seemed to be essentially no benefit from mandating ISA at such a late stage. Further analysis is recommended to investigate benefits from mandating ISA at lower levels of fleet penetration.

On the benefits side, effectiveness of ISA depends to an extent on the form of the ISA interface/warnings and probably the regime in which the ISA is operating. There is a likely to be a significant difference in responses between:

- a simple, in-vehicle, on-the-dash/heads-up speed sign in a private vehicle or the above with audible warnings
- an EROAD-style device with audio warning in a fleet vehicle where there are strict protocols and penalties associated with violation.

The crash reductions given by Waibl et al. (2013), while based on on-road New Zealand studies, appear low compared to those reported in the literature. Furthermore, these were conducted prior to the recent moves towards designating safe and appropriate speeds.[11] As a result, in rural areas where 100 km/h was the speed limit, participants may not have been able to exceed the speed limit frequently and therefore the value of ISA would be diminished. The assessment of ISA from a wider dataset using the more recent safe and appropriate speed data from suppliers such as EROAD could greatly improve the validity of the crash reductions and the subsequent benefits of ISA.

[11] This is resulting in 80 km/h speed limits in many areas where the limit was previously 100 km/h.

6 Overall conclusions

The provision of ISA in the New Zealand light vehicle fleet is increasingly driven by overseas mandates.

While the costs associated with ISA are assumed to be small, if not non-existent, when distributed over the fleet, these mount up. Nevertheless, in a New Zealand context, the provision of ISA has a probable positive benefit-cost ratio (around 1.7) and the potential to save a total of 5,298 deaths and serious injuries over the next 40 years from 2023 to 2063.

There seems to be no compelling argument to mandate ISA once it is fitted to 75% of new vehicles entering the fleet. There are several caveats to the above mentioned throughout this report, and further work on the benefits realisation is warranted.

7 Recommendations

The following recommendations are made for consideration.

To encourage uptake of advisory ISA:

1. Develop a standard or system to ensure that speed limit information displayed to drivers is accurate.
2. Identify implications for over-the-air updates in the used import second-hand market and the impact of these on ISA adoption.

For fleet managers and providers of ISA systems used in fleet management:

3. Evaluate the impact of additional in-vehicle displays and the role of fleet monitoring and associated protocols on ISA compliance.
4. Provide users with information regarding how their driving data is used and a means to access their personal driving data.
5. Investigate use of fleet systems to increase exposure to ISA (for example, retrofitting of ISA in fleet vehicles for organisations with more than a specified number of employees).

For future ISA research:

6. Further field trials or analysis of data for a wider range of safe and appropriate speeds.
7. Assess the impact of human-machine interface design on compliance.
8. As more post-COVID-19 data becomes available on the proportion of used imported vehicles with ISA, the penetration rate assumptions for the used imports should be revisited.
9. A range of alternative mandated scenarios should be investigated.
10. Investigate the potential broader use of the National Speed Limit Register data and the development of data sets that reduce repeated processing of the entire data set.

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Appendix A: Interview with individuals with ISA in their private vehicles

Interview title: Interview on vehicle safety features

Thanks for taking the time to talk to me, this will take from 30–60 minutes depending on how much you want to say. We are conducting research for Waka Kotahi/NZTA, and information from this will be used in a Waka Kotahi/NZTA research report. This research supports work to reduce deaths and serious injuries on our roads by understanding the potential for intelligent speed adaptation to help achieve this. All info is anonymous, no identifying features will go into the report. Are you OK with recording for notes purposes only?

1. **About you**

What age are you or what age group do you fall into? < 25; 25–65; 65–75; > 75.

How long have you been driving?

How regularly do you drive in a week?

What types of trips are you making? *Prompts: work, city, rural, town, long distance*

Any locations you avoid?

2. **About your main personal vehicle**

How long have you had your current vehicle?

Year, make, model?

Did you buy added features or packages?

3. **Do you know what intelligent speed adaptation/assistance technology is?**

Define ISA here based on accurate, simple definition. In-vehicle feedback around your speed in relation to the current speed limit (information/prompt only) and, at a more advanced level, adjusting your vehicle speed in relation to speed limits (adaptation).

4. **What form of intelligent speed adaptation technology do you have in your vehicle?**

(May need to prompt – want to understand if they know)

- Advisory
- Top speed max setting (speed limiter)
- Volvo/Landrover (adaptive speed limiter)
- App-based – linked to vehicle/mounted (eg, built into Waze/Apple CarPlay – Waze has a setting where it shows your current speed, the limit and will sound a chime if you're over a fixed limit)

5. **Was ISA a feature you considered when purchasing the vehicle? Where did it rate in relation to other features?**
6. **Your use of ISA**

How would you describe your current use of ISA? Do you use it? (Don't know; have it – it is set to on; have it – don't use it; have it – use it sometimes)

Was it set up automatically? How was ISA set up in your initial set-up: Did you have to opt in to ISA? Was it already on? **Did you opt out?** (ie, turn it off or certain settings off)? **What settings can you alter in your set-up? (Note: knowledge test)**

7. **How much were you told about the system through the sales process?**

8. **How knowledgeable would you say you are about your system?**
9. **When would you see ISA as useful:**

Open question prompt if necessary (use it for all conditions now; use if for no conditions; would like to use it for only specific conditions (see list below)

- High speed only
- Low speed
- Advisory curves
- School zones (where limits change depending on time of day)
- Urban zones
- Work zones
- Unfamiliar roads
- Fixed speed limits
- Variable speed limits (eg, overhead gantry Wellington; Auckland Harbour Bridge)

Any other conditions?

10. **When is it not useful?**
11. **How well does it perform?**

Any locations where it has issues?

(Prompts: speed transitions – eg, 70 to 50 to 100 etc., temporary speed zones)

12. **Motivations and barriers**

For those that use it – Why? How does it help you drive? What do you do differently?

For those that don't use it – Why not? What is the largest barrier for you? Why is this a barrier? Do you think this would be a barrier for others?

Prompts:

- Trust in the system/accuracy
- Different method of feedback (audio/visual/tactile/ignore function/customisability)

13. **Anything else to add?**

Appendix B: Commercial fleet interviews

Interviews were run with drivers who varied in their responsiveness to the fleet monitoring in-vehicle speed feedback system to understand what was working well or motivating for compliant fleet drivers and what was challenging for less-compliant fleet drivers.

1. **Your driving**
   - How long have you been driving?
   - Would you describe your driving style? (cautious, moderate or energetic)
   - Can you tell me a little about the decision-making process you go through when selecting your driving speed? (eg, are you influenced by time pressures from work, consider the road conditions?)
2. **Your fleet vehicle**
   - How regularly do you drive for work (eg, how many hours in a typical week?)
   - What types of trips are you making for work? (short or longer trips, between sites/cities, highways, rural etc.)
   - What about speeding fines? (in the last 2 years while using a work vehicle)
3. **Your perception of [the fleet monitoring system] (pros and cons)**
   - Where do you think [the fleet monitoring system] performs well? (ie, what are the positive aspects of this device?)
   - Is there anything you would do to improve [the fleet monitoring system]?
   - Any changes to your driving behaviours since [the fleet monitoring system] has been in use?
   - Overall, how do you think speed feedback systems like [the fleet monitoring system] should be used in commercial fleets in New Zealand? Why? (all people, target certain people)
   - Are there any differences when you are driving your private vehicle vs a company vehicle?
4. **Organisational feedback**
   - Do you know what happens with the information collected from [the fleet monitoring system]?
   - How would you describe the existing process around drivers that have overspeed events from [the fleet monitoring system]?
   - How would you describe the existing process around drivers that are high performers in [the fleet monitoring system] rankings?
   - Is there anything you think could be improved on in relation to how the organisation approaches [the fleet monitoring system]/driving behaviour?