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CLIENT PROJECT REPORT CPR2332

Intelligent Speed Assistance on London Buses

A trial on two London bus routes

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Report details

Report prepared for:	Transport for London, Kerri Cheek
Project/customer reference:	tfl_scp_001142
Copyright:	© Transport Research Laboratory
Report date:	November 2016
Report status/version:	Client report

Quality approval:

Stuart Greenshields (Project Manager)	**Stuart Greenshields**	Simon Tong (Technical Reviewer)	**Simon Tong**

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Contents amendment record

This report has been amended and issued as follows:

Version	Date	Description	Editor	Technical Reviewer
V1	17/11/2016		SG	ST

Document last saved on:	17/11/2016 17:12
Document last saved by:	Greenshields, Stuart

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Executive Summary

TfL committed to 'a trial of Intelligent Speed Assistance (ISA) technology on a small number of vehicles in the bus fleet to understand the potential role of this technology in promoting adherence to speed limits across the road network and its impact on reducing killed and seriously injured (KSI) casualties'. This commitment in the Pedestrian Safety Action Plan was part of a strategy to deliver a 50 per cent reduction in KSI casualties by 2020, compared to the 2005-2009 baseline.

What is ISA?

Intelligent Speed Assistance technologies bring speed limit information into the vehicle. These can understand a prevailing speed limit via various means, including positional (using GPS), optical (using on-board cameras that can 'read' speed limit signs), radio beacon (which send data about the area, such as the speed limit, to the vehicle), and dead reckoning (which uses gyroscopes and the like to estimate the location from a known start point). What is then done with this information varies from informing the driver of the limit (advisory ISA), warning them when they are driving faster than the limit (supportive ISA) or actively aiding the driver to abide by the limit (intervening ISA).

The ISA system used in this trial by TfL was supplied by Zeta Automotive Ltd. It was an intervening type which utilised GPS data matched against an on-board map and speed-limit database to electronically prevent any equipped vehicle from exceeding the prevailing speed limit by controlling the amount of acceleration that was possible. The system was not able to apply the brakes and nor did it prevent the bus driver from doing so at any time. The driver retained regular control of the accelerator up to the posted speed limit of the road on which they were travelling, after which point any demand for further acceleration was restricted.

This report provides an analysis of the impact of ISA devices fitted to vehicles serving two bus routes within London. Comparable measurements were taken both before and after the ISA equipment was fitted to address eight research questions:

1. Is ISA an effective method of speed limit compliance?
2. Is ISA an efficient method of speed limit compliance?
3. What is the impact of ISA vehicles on the behaviour of surrounding traffic speeds?
4. What is the impact of ISA vehicles on the behaviour of surrounding traffic actions?
5. What are the benefits and disbenefits of ISA for TfL?
6. What are the benefits and disbenefits of ISA for the bus operator?
7. What are the benefits and disbenefits of ISA for the bus driver?
8. What are the benefits and disbenefits of ISA for the bus passenger?

Overview

The system was tested on two bus routes in London: Route 19 between Battersea and Finsbury Park, and Route 486 between the Greenwich Peninsula and Bexleyheath. Data was gathered from a range of sources including iBus data, on-board cameras, roadside

equipment, fuel records, and interviews with bus drivers, before and after the system was introduced. The results measured various metrics around in-service buses to isolate the impacts of ISA.

Data collected before the ISA device was switched on, indicated that higher speeds[1] were mainly recorded on off-route sections (e.g. between the bus garage and start/end of the route) and in 20mph speed limits. Speed compliance issues were most commonly found in the late evening, followed by the morning, and then daytime.

Key Findings

1. Is ISA an effective method of speed limit compliance?

The ISA system was generally found to limit speeds as anticipated, with occasional failures on downhill sections of road where the bus would temporarily exceed the speed limit under the influence of gravity. Compliance with the speed limit improved after buses were equipped with ISA; the percentage of time buses spent travelling above the speed limit reduced from a range of 14.9-17.8% to 1-3.3% in 20mph zones, and 0.5-3.3% to 0-1.1% in 30mph zones.

2. Is ISA an efficient method of speed limit compliance?

The clear advantage of ISA over other methods of speed reduction is that it can limit speed quite effectively for equipped vehicles over as wide an area as desired and this effect does not reduce over time. Its limitations are that it only applies to equipped vehicles and only reduces speed to the limit, not to the most appropriate speed for the conditions.

3. What is the impact of ISA vehicles on the behaviour of surrounding traffic speeds?

Buses generally represent a small proportion of all vehicles on the road and ISA only has the potential to impact speeds that are above the speed limit; therefore, there will always be limitations to the impact upon speeds of surrounding traffic. However, where a platoon exists behind an ISA-equipped bus in a 20mph zone, the average speeds of those platoon vehicles did have a statistically significant reduction in average speed from 17.88mph to 16.79mph. The platoon length behind the bus in 20mph zones also marginally increased, from 1.2 to 1.6 vehicles following on average. For the 30mph zones such an effect was not detected, although ambient speeds were often well below the 30mph speed so ISA was probably activated only rarely. As such, based on the sample collected, it is not possible to draw robust conclusions on the impact that ISA may have more generally on other 30mph sites with higher ambient speeds.

4. What is the impact of ISA vehicles on the behaviour of surrounding traffic actions?

Overall, the frequency of other road users overtaking buses appeared to be similar before and after ISA, albeit with a slightly greater proportion of overtaking occurring in the opposing lane after-ISA. This suggests that ISA did not induce additional drivers to overtake

[1] Higher speeds are those higher than the prevailing speed limit.

but might have had a slight impact upon their propensity to take risk. An expected increase in dangerous outcomes from riskier overtaking was not observed.

5. What are the benefits and disbenefits of ISA for TfL?

The study examined ISA's impact on three key areas; (i) number of operational buses required; (ii) emissions; (iii) safety.

(i) The study found a marginal (1.4%) increase in route journey times for route 19, which could potentially require more buses on this route. ISA will highlight any existing issues with route timings. If TfL was to implement ISA London-wide for all bus routes there would be a requirement to calculate the impact of ISA separately for all routes.

(ii) Overall, there was little impact upon emissions, which was modelled from the iBus speed traces, but with some evidence of improved emissions in some 20mph zones after ISA.

(iii) Road safety was modelled using calculations of reduced mean speed, as the project duration was too short to provide reliable STATS19 results. A marginal safety improvement related to bus collisions was modelled and valued at around £0.5M to £0.6M per annum for all buses in London. Improvements to the safety of following vehicles were negligible.

6. What are the benefits and disbenefits of ISA for the bus operator?

Two parameters were observed:

(i) Fleet journey times: As for Research Question 5, the study found a slight increase in average journey times that may in some cases require additional buses.

(ii) Bus fuelling data: The study found no significant detectable difference in fuel usage before and after ISA.

7. What are the benefits and disbenefits of ISA for the bus driver?

Findings from the interviews conducted with drivers initially indicated a predominantly negative experience towards the technology, due to set up and calibration issues between the ISA unit and the buses. Following further work by Zeta Automotive Ltd to address these issues, another set of driver interviews were undertaken. The results were more positive with far fewer issues raised by drivers. Residual concerns remain relating to off-peak conditions when traffic is lighter and drivers' perception remain that other vehicles become frustrated at being held up by buses complying with the speed limit.

8. What are the benefits and disbenefits of ISA for the bus passenger?

Interviews with passengers showed no real awareness of the ISA technology. When it was explained, most were positive towards its application as a safety measure.

Conclusions

The ISA system does appear to ensure effective speed limit compliance except temporarily on some downhill sections and at the initial transition boundaries to lower speed limits. This has comparably greater impact in (increasingly common) 20mph speed limits as bus performance and street geography generally enable buses to reach and exceed 20mph with relative ease (far more easily than a 30mph limit or greater). A similar effect occurred in the 10mph zones occasionally found at bus terminals (such as Finsbury Park and North Greenwich). On the routes tested, the issues that ISA is designed to prevent (travel above the speed limit) were frequent but generally fleeting in nature, therefore the cumulative impact of ISA on buses and other vehicles was relatively small overall when assessed along the routes of operation. However, in areas where speed limit compliance is more of an issue (e.g. links between routes and bus depots, or in 20mph speed limits) ISA has the potential to be more effective.

Introduction

Improving the safety of London's streets is vital to making life in London better. Death and injury on our roads ruins lives. Collisions also increase congestion, reduce the resilience of the road network and create an additional cost to the economy. The number of people killed and seriously injured (KSI) on London's roads each year has more than halved since 2000[2] – but each death is one too many. TfL will continue to work towards reducing the number of KSIs on London's roads by 50 per cent by 2020[3]. Good progress has been made, but further reduction needs to be achieved against a backdrop of increasing levels of walking and cycling. Around 80 per cent of the people killed or seriously injured on London's roads are walking, cycling or riding a motorcycle[4]. Therefore TfL must prioritise the safety of the most vulnerable groups so they can reduce casualties.

Modern technology offers substantial potential improvements to the management of speed and the compliance with speed limits. Intelligent Speed Assistance (ISA) is the term[5] given to a range of devices that assist drivers in choosing appropriate speeds and complying with speed limits.

What is ISA?

Intelligent Speed Assistance technologies bring speed limit information into the vehicle. Navigation devices in the vehicle (typically GPS or GPS enhanced with additional information) give a precise location and heading, whilst an on-board map database compares the vehicle speed with the location's known speed limit. What is then done with this information varies from informing the driver of the limit (advisory ISA), warning them when they are driving faster than the limit (supportive ISA) or actively aiding the driver to abide by the limit (intervening ISA)[6].

In the Pedestrian Safety Action Plan[7], TfL made a commitment to 'run a trial of ISA technology on a small number of vehicles in the bus fleet to understand the potential role of this technology in promoting adherence to speed limits across the road network and its impact on reducing KSI casualties. Subsequently, in 2015 TfL carried out a trial of ISA on London buses using an intervening ISA system by Zeta Automotive Ltd. Such a system is the

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[2] *Safe Streets for London, The Road Safety Action Plan for London 2020*, June 2013 (p.16 Table 1), TfL

http://content.tfl.gov.uk/safe-streets-for-london.pdf

[3] *Safe London streets: Our approach*, October 2015 (p.11), TfL http://content.tfl.gov.uk/safe-london-streets-our-approach.pdf

[4] *Road Safety Annual Report (Collisions and casualties on London's roads: Annual Report 2014)* – Table 1 2014 figures http://content.tfl.gov.uk/collisions-and-casualties-on-londons-roads-annual-report-2014.pdf

[5] http://etsc.eu/intelligent-speed-assistance/

[6] http://archive.etsc.eu/documents/ISA%20Myths.pdf

[7] *Pedestrian Safety Action Plan, Working together, towards roads free from death and serious injury*, TfL http://content.tfl.gov.uk/pedestrian-safety-action-plan.pdf

focus of this study. Zeta Automotive Ltd.'s description of its equipment is given in Appendix D.

Aims and objectives

The objective of the project was to observe a TfL trial of an ISA system on live bus routes within London, with the aims of understanding both its efficacy and its impact on bus operations and the wider road network. This was to provide TfL with an evidence base on which to make any future decision regarding further implementation of ISA in London buses. This was achieved by setting and answering eight research questions. These are indicated in Figure 1 alongside the data required and metrics processed.

Structurally, the research questions (RQ) are answered in turn within this document:

1. Is ISA an effective method of speed limit compliance?
2. Is ISA an efficient method of speed limit compliance?
3. What is the impact of ISA vehicles on the behaviour of surrounding traffic speeds?
4. What is the impact of ISA vehicles on the behaviour of surrounding traffic actions?
5. What are the benefits and disbenefits of ISA for TfL?
6. What are the benefits and disbenefits of ISA for the bus operator?
7. What are the benefits and disbenefits of ISA for the bus driver?
8. What are the benefits and disbenefits of ISA for the bus passenger?

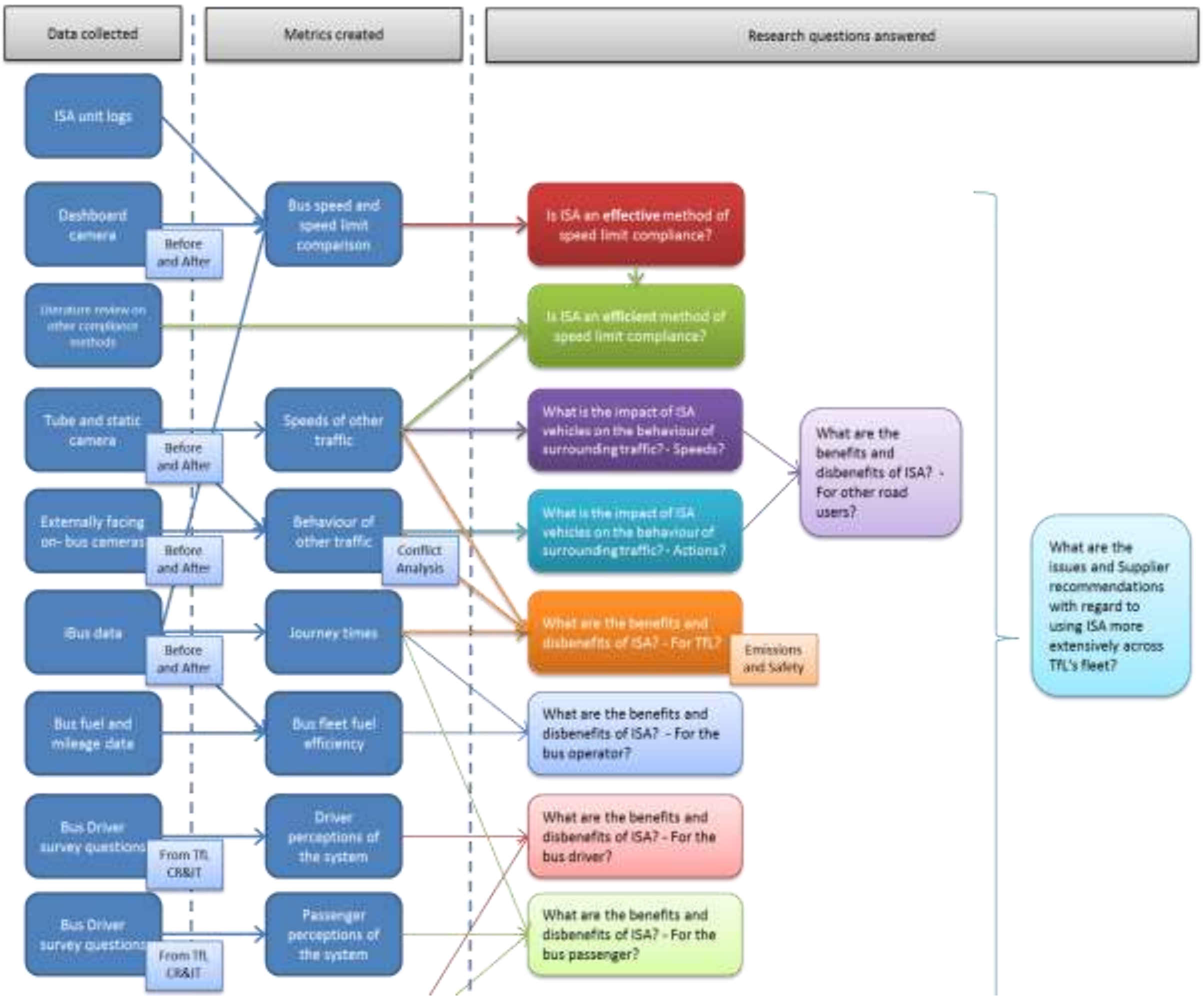


Figure 1 Data sources and the relationship with the defined research questions

Approach

The ISA devices supplied by Zeta Automotive Ltd were electronic devices which limited the speed of the vehicles to which they are fitted to the prevailing speed limit of the road on which they were travelling, but had no impact below that speed. The system matched the GPS location of the bus against an internal map to determine the prevailing speed limit, and then worked to prevent further accelerator input when that limit was reached.

The ISA system was tested on two bus routes in London, Route 19 between Battersea and Finsbury Park, and Route 486 between the Greenwich Peninsula and Bexleyheath. A before and after observational approach was used, where measurements were taken before the system was fitted, and measurements were taken afterwards. The results were then compared to measure the differences and provide insight into the impact of ISA.

The observational approach did not aim to manipulate the operation of the ISA equipment or influence bus activity in any way. Instead it measured various metrics around in-service buses in a ‘before’ and ‘after’ study design so that the impacts of ISA could be isolated and examined within this report. This used both existing data sources (such as TfL’s iBus data and the bus operators’ fuel data) and primary data collected by TRL via cameras and traffic detection technologies.

Compatibility issues with different bus models

Various issues occurred during the project relating to the compatibility of the ISA equipment with different models of bus. Whilst outside the direct remit of this report, the difficulties of the ISA system compatibility with different models of bus in operation currently and in the future should be considered if planning any wider implementation of ISA.

Bus routes and prevailing speed limits

Bus route general distance information

The bus routes are primarily comprised of 20mph and 30mph zones, with some 10mph zones within the bus terminal areas[8]. The table below excludes the 10mph zones.

Table 1 Route distances

Route	Speed zone	Distance (m)	Total	Proportion
19	20mph zones	5,342	13,306	40.1%
	30mph zones	7,964		59.9%
486	20mph zones	1,181	14,426	8.2%
	30mph zones	13,245		91.8%

Route 19

Bus route 19 travels between Battersea and Finsbury Park. It uses public roads of 20mph and 30mph, and has a short 10mph zone within the bus terminal at the Finsbury Park end. These are shown in Figure 2. This bus route uses two different versions of the same double-decker bus, the Wrightbus Volvo B9TL (diesel), and the Wrightbus B5H (hybrid diesel electric).

Timescales

Initial monitoring of the 'before' ISA scenario for routes 19 and 486 was undertaken in June and July 2015, see Table 2. Due to issues with the ISA system on both routes, the 'after' scenario for route 19 occurred in September, and in January 2016 for route 486.

Table 2 Monitoring timescale

	Mar	Apr	Mau	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Route 19				Before			After					
Route 486				Before							After	

[8] Note that in the after scenario for route 486, there was a conversion of some 30mph zones to 20mph zones. However, due to delays in the route 486 elements of the trial, the after measurements which this would have affected were abandoned.

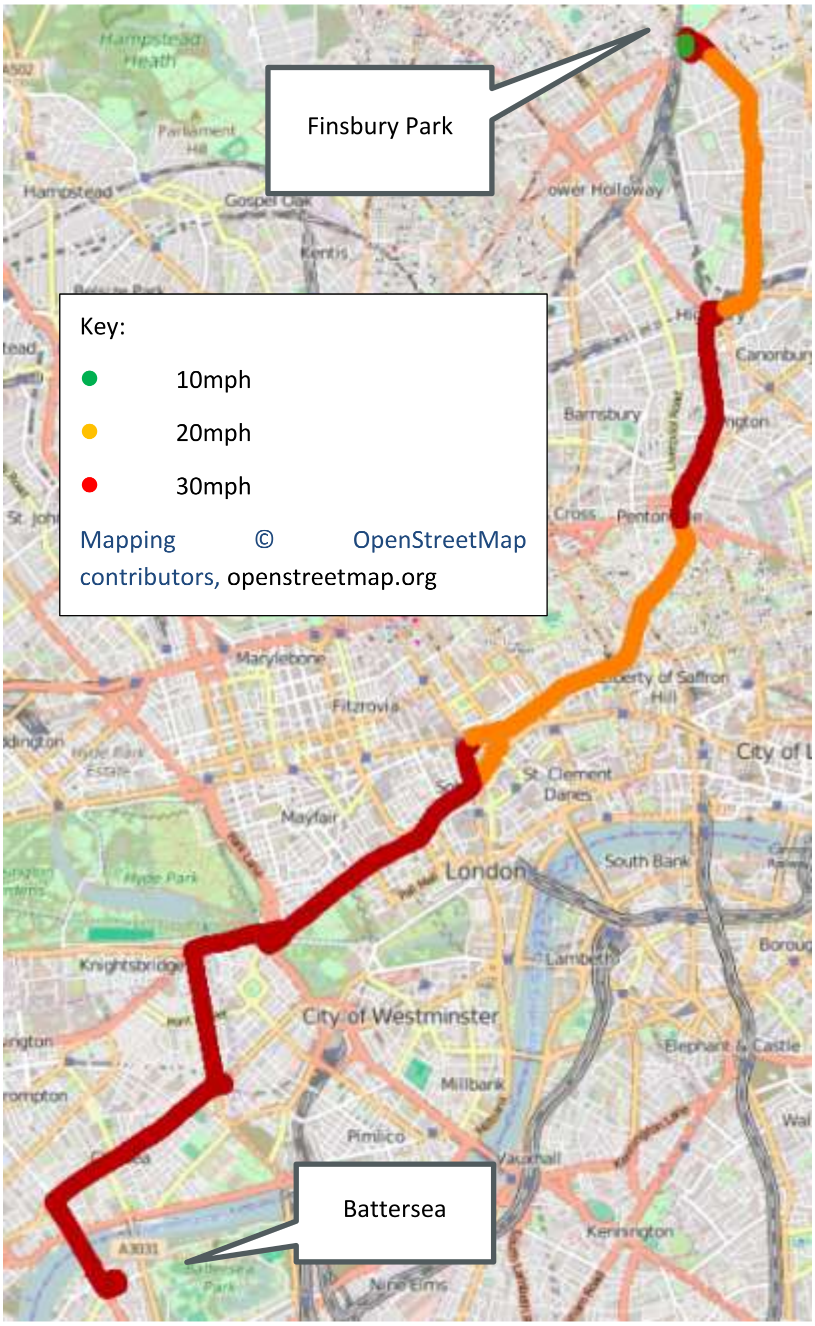


Figure 2 Route 19 speed limits

Route 486

Bus route 486 travels between the Greenwich Peninsula and Bexleyheath. It uses public roads of 20mph and 30mph, and has a short 10mph zone within the bus terminal at both ends. Between the before- and after-ISA measurements, some 30mph speed limits were changed to 20mph as indicated by the larger map markers. These are shown in Figure 3. This bus route uses a different model of bus from route 19, and is an ADL E400 diesel double decker bus.

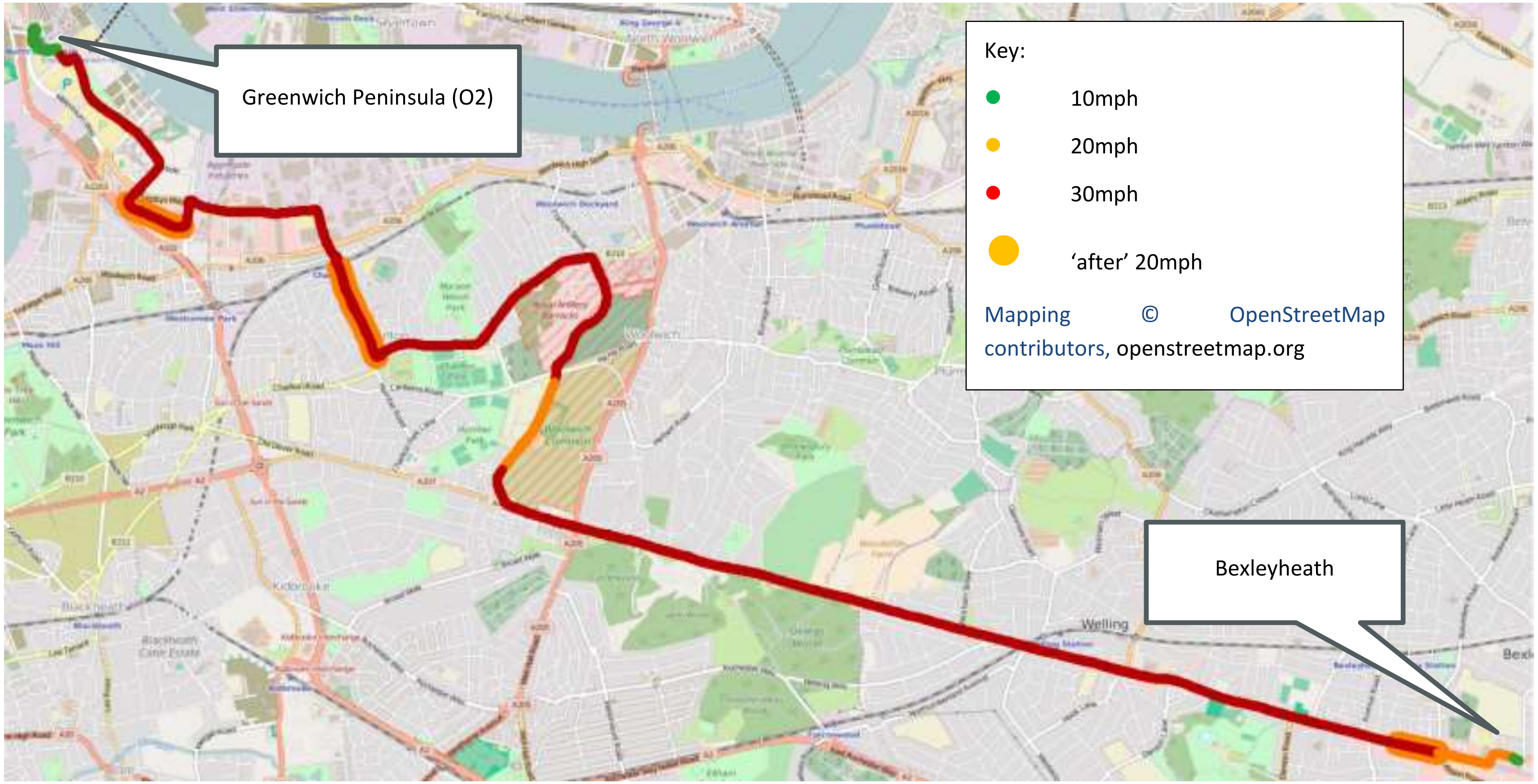


Figure 3 Route 486 speed limits

1 Research Question 1 - Is ISA an effective method of speed limit compliance?

1.1 Introduction

Intervening Intelligent Speed Assistance offers the potential for perfect speed limit compliance. Whilst the speed limit may not always be the most appropriate speed, given the impact of speed as a contributory factor in injury collisions, limiting vehicle speed to the speed limit offers a potentially positive impact towards road safety. The key question for ISA is therefore, *does it work?* Or perhaps more importantly, *does it work in all conditions?*

All systems have failures and ISA is unlikely to be free of failure. It is important to note that ISA is a system to limit speed to the posted speed limit, and actual speed up to the posted limit (or above this in the event of failure) remains within the control of the driver who operates the accelerator pedal and brakes. The purpose of this section is to report on work undertaken to observe the behaviour of the ISA system during the trial in an attempt to discover failures and provide potential reasons for them.

If no speed limit compliance issues were detected with the ISA fitted, it would not be clear if this merely reflected normal driving behaviour or if the speed limit compliance was due to the ISA technology. For this reason the before-ISA-fitment speeds were measured to gain a better understanding of the propensity for speed limit non-compliance and give any greater confidence with the findings. It will also reveal the characteristics of higher speeds by buses.

1.1.1 Potential failure mechanisms

The key failure of ISA is to allow a vehicle fitted with it to exceed the speed limit. ISA is expected to be liable to the following failure mechanisms:

- Electrical failure of the system
- A system algorithm/integration failure, so that the system may fail to respond to higher speed under certain conditions
- GPS system failure
- Errors within map-matching
- Errors within the road speed limit database

It can also be said that ISA technology may also be expected to have some limitations:

- The effect of gravity downhill allows buses to temporarily accelerate above the speed limit (this particular ISA system could not actively retard speed and it is thought that ISA systems which retard the brakes were neither available or near to market at the time of trialling). The selected ISA system does not prevent the driver applying the brakes at any time to retard the speed as desired
- The system not anticipating the approach to a lower speed limit zone thus allowing the bus to carry higher speed when entering a lower limit and continue to do so until it has slowed to the new limit

1.2 Methodology

Various sources of information can be used to discover if in-service buses are exceeding the speed limit both before and after ISA implementation. Instances of speed limit non-compliance before ISA fitment would indicate ISA was required, with the scale of any higher speed providing some indication of the potential impact of ISA in the before scenario and a measure of the effectiveness of the ISA system in the after scenario.

TRL collected data from four sources to explore ISA effectiveness:

- TfL iBus data
- Cameras placed on vehicles by TRL
- Average between-bus-stop speed data provided by TfL
- Speed tube data

The original plan was to use ISA equipment data logs; however, these only collected data every one minute and might fail to record the often fleeting moments in which speed is above the speed limit. TfL provided iBus data as a supplementary data source of speed profiles for each bus and, given that it is generally recorded at 1Hz, it was considered more likely to capture moments when a bus was travelling above the speed limit.

Note that for reasons of research ethics, we have removed exact dates to reduce the possibility that any incident of higher speed can be attributed to an individual driver. Given much data is related to traffic flow which is often dependent upon date, we have retained month and day data.

1.3 Key findings

1.3.1 Findings of TfL iBus data

A mid-week day for each of the three different bus types was reviewed for the before data. This found instances of speed limit non-compliance on each bus, and the location and scale of the instances matches that of the speedometer (dashcam) cameras. This found between 9 and 26 seconds of time difference per end to end journey as a result of speed above the speed limit on the sample examined.

With ISA fitted to route 19, the system was found to generally work as expected (i.e. with a 10% upper tolerance on speed, the tolerance effected for the trial) although occasional failures were found with speeds far higher than the speed limit.

1.3.2 Findings of TRL speedometer (Dashcam) cameras

Fleeting instances of speed limit non-compliance were found regularly on buses without ISA fitted. This gave confidence that the effect of ISA should be detectable once fitted as the theoretical impact would be the complete removal of speed limit non-compliance.

Following the switching on of the ISA system on route 19, bus speeds were compliant to within around 10% of the speed limit with a few minor exceptions usually associated with downhill sections. Route 486 was also found to be largely compliant after switching on ISA.

1.3.3 Findings of average between-bus-stop speed data provided by TfL

This analysis found some reduction in instances of averages exceeding the speed limit; however, higher speeds were not completely eliminated.

1.3.4 Findings of bus spot speeds measured by tube data

The before spot speed data found evidence of buses above the speed limit. Caution should be taken that whilst the proportion of buses above the speed limit was relatively high, these locations were deliberately chosen because they had characteristics which lent themselves to higher speed (further detail of this rationale can be found in Research Question 3). The after data (collected for route 19 only) found fewer instances of speed limit non-compliance.

The remainder of the chapter discusses the detailed methodology and data evidence for answering Research Question 1.

1.4 TfL iBus data

iBus is a system which sends data from each bus remotely to a central processing and storage facility run by TfL. This system was fitted a number of years ago to all London buses and works in the background; therefore, it is likely that this will have minimal 'observer effect' of drivers altering their speed in response to a feeling of being monitored. TfL supplied iBus data for each bus type on route 19 (two types of one model) and route 486 (one type). This data was supplied at around 1Hz (the frequency is not set exactly), and contains a variety of types including geographical coordinates (WGS84 standard), time to 1 millisecond, and speed data. From this it is possible to determine the speed limit which would apply at a given location, and compare this limit with the speed of the bus so that instances of higher speed can be detected.

The time difference from speed above the limit was also calculated, however this should be strongly caveated, as vehicles may actually simply be travelling to the rear of congestion a little more quickly, therefore the overall time difference is zero.

1.4.1 Method of calculating speed from iBus data

The data for speed above the speed limit was calculated from iBus data in the following manner:

- Data were transferred to Excel and columns defined
- Locational data were assigned a speed limit based upon a geofenced area
- Areas outside of the main route were excluded as these covered positioning mileage
- Any 10mph areas were also excluded as these were generally very short
- Speed was taken as the kph speed directly from iBus data, this is rounded by iBus to the nearest integer, therefore contains an element of inaccuracy
- Data records are approximately 1hz, however for increased accuracy milliseconds were used for analysis as the interval between records was not consistent

- The distance each bus had travelled was calculated against the distance it should have travelled at the speed limit. Where actual speed was above the speed limit, the additional time it would have taken to travel that distance at the speed limit was calculated. The summation of this is the total time difference generated by speed above the speed limit. This ignores speed limits set at zero (as these are areas out of range)

To take into account speedometer inaccuracies, we have also indicated separately results where a 10% error margin was allowed.

1.4.2 Bus speed profiles before ISA

Sections 1.4.2.1 to 1.4.2.3 provide examples of speed profiles for buses on each route prior to fitment of ISA. These speed profiles show instances of speed above the speed limit. These were a randomly chosen sample of mid-week records to determine if speed above the speed limit could be observed. The length of recordings versus the duty length of drivers determines that multiple drivers will have driven each bus. More representative speed data is examined in section 0.

1.4.2.1 Route 486 iBus before ISA data (bus code E51)

This was measured on a Wednesday in June 2015, and the bus speeds vs. the speed limit data were used to create speed compliance graphs, in which higher speed is identified where the blue line is above the 20mph or 30 mph red line (Figure 4).

The time difference generated by higher speed over the period shown was around 90 seconds faster, or around 9 seconds per end-to-end journey on average. Around half (44 seconds) of this occurred at the 20mph zone by the Queen Elizabeth hospital. The highest speed (around 38mph) was recorded east of Eaglesfield Road whilst travelling eastbound along Shooters Hill. Greater speeds occurred in the middle of the day (on route 19, the opposite occurred).

Note that if the speed limit was given a tolerance of 10%, the time saving would be around 26.5 seconds, therefore around 2.5 seconds per end-to-end journey on average. Of this total, 19 seconds were in the 20mph zones.

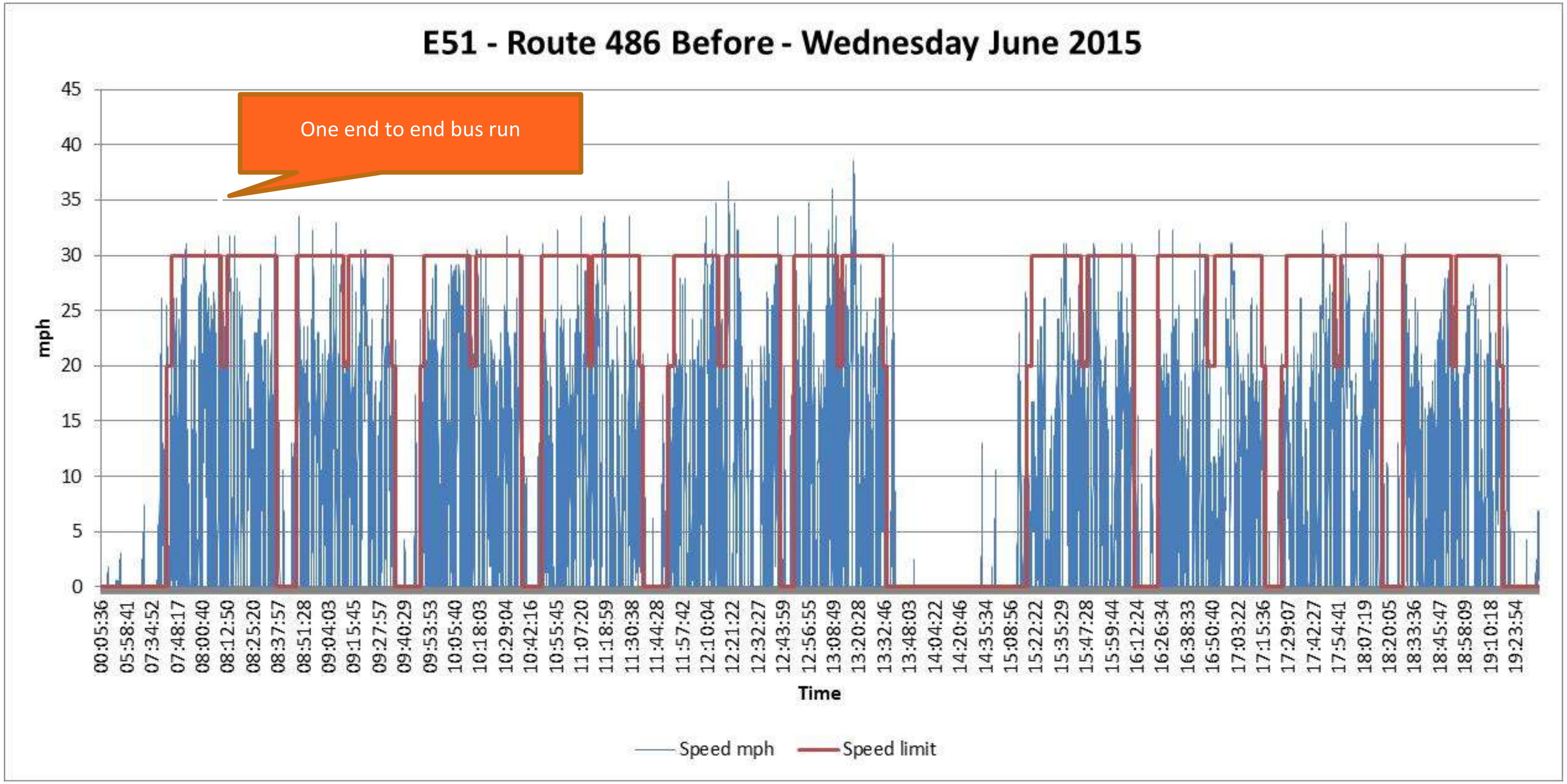


Figure 4 Route 486 Bus E51 iBus 'before' ISA speed compliance data

1.4.2.2 Route 19 iBus before ISA data (bus code WVL491)

This was measured on a Wednesday in June 2015, and the bus speed vs. the speed limit data is shown in Figure 5. Bus WVL491 on Route 19 demonstrated low levels of higher speed, with around 92 seconds of time difference in the day generated from higher speed, equating to an average of around 11.5 seconds faster for each end-to-end journey. Most higher speed (saving 80 seconds) occurred in the 20mph zones, with the remaining 12 seconds being saved in the 30mph zones.

Note that if the speed limit was given a tolerance of 10%, the time difference would be around 30.5 seconds, therefore around 4 seconds per end-to-end journey on average. Of this around 27 seconds were in the 20mph zones, with around 4 seconds time difference in the 30mph zones throughout the day.

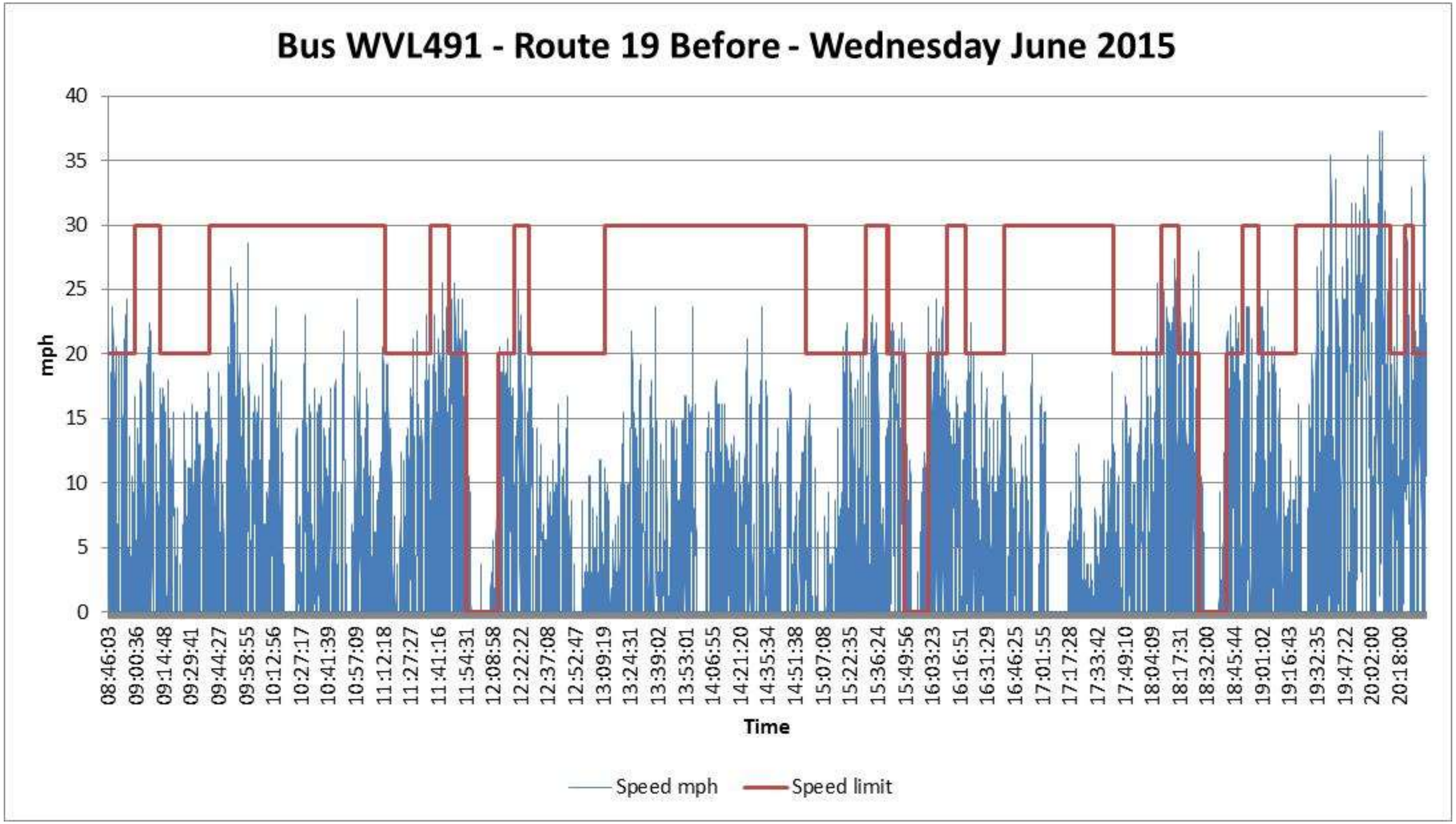


Figure 5 Route 19 Bus WVL491 iBus 'before' ISA speed compliance data

1.4.2.3 Route 19 iBus before ISA data (bus code WHV17)

This was measured on a Tuesday in June 2015, and the bus speed vs. the speed limit data is shown in Figure 6. The time difference generated by higher speed is 302 seconds (approx. 5 minutes), this is around 26 seconds per end-to-end journey although this varies greatly through the day. As found in other data, higher speed is most commonly found in the late evening, followed by the morning, and then daytime.

Note that if the speed limit was given a tolerance of 10%, the time difference would be around 148 seconds, therefore around 13 seconds per end-to-end journey on average. Of this around 147 seconds were in the 20mph zones, with less than 1 second time difference in the 30mph zones.

Over the day in the 20mph and 30mph zones, the bus travelled 91.23 miles taking 8 hours 16 minutes and 10 seconds. Assuming a theoretical time difference generated by higher speed of 302 seconds, the mean speed changes from 11.026mph to 10.915mph, a change of 0.11mph. A similar calculation was undertaken for a Wednesday in June 2015, which found 203 seconds of time difference generated by speed above the speed limit.

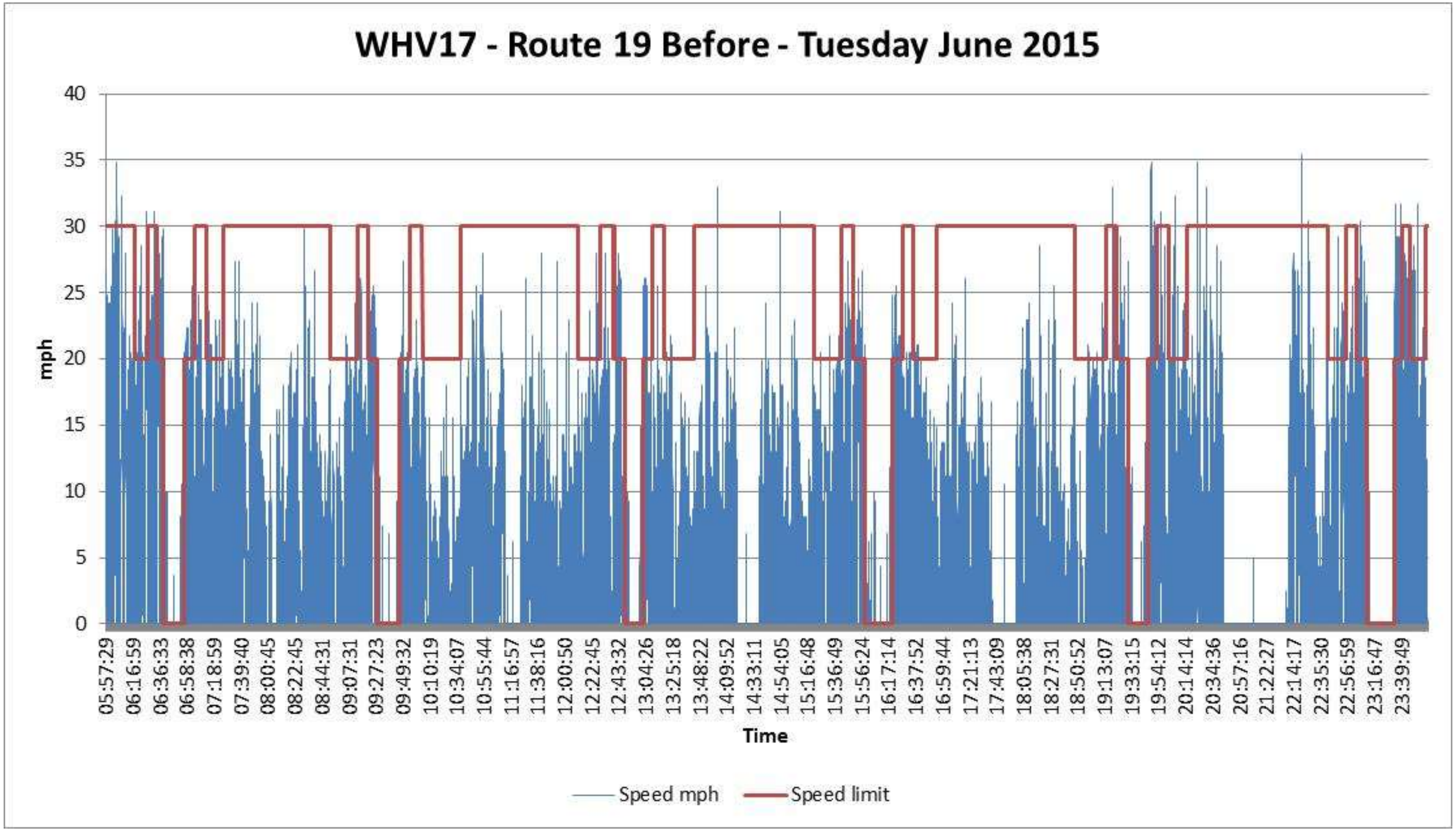


Figure 6 Route 19 Bus WHV17 iBus 'before' ISA speed compliance data

1.4.3 Instances of higher speed with ISA fitted (Route 19)

The ISA equipment on route 19 is known to allow a tolerance of 10% above the speed limit, and can temporarily exceed the speed limit downhill under the influence of gravity if the driver does not manually apply the brakes. There were also instances of higher speed outside of these known parameters.

Figure 7 below indicates speeds across a whole day on a Thursday in September 2015 on bus route 19 with ISA switched on. What can be seen is that when the bus is off-route (where the ISA route map does not have an effect) there are higher speeds. The on-route sections have been outlined.

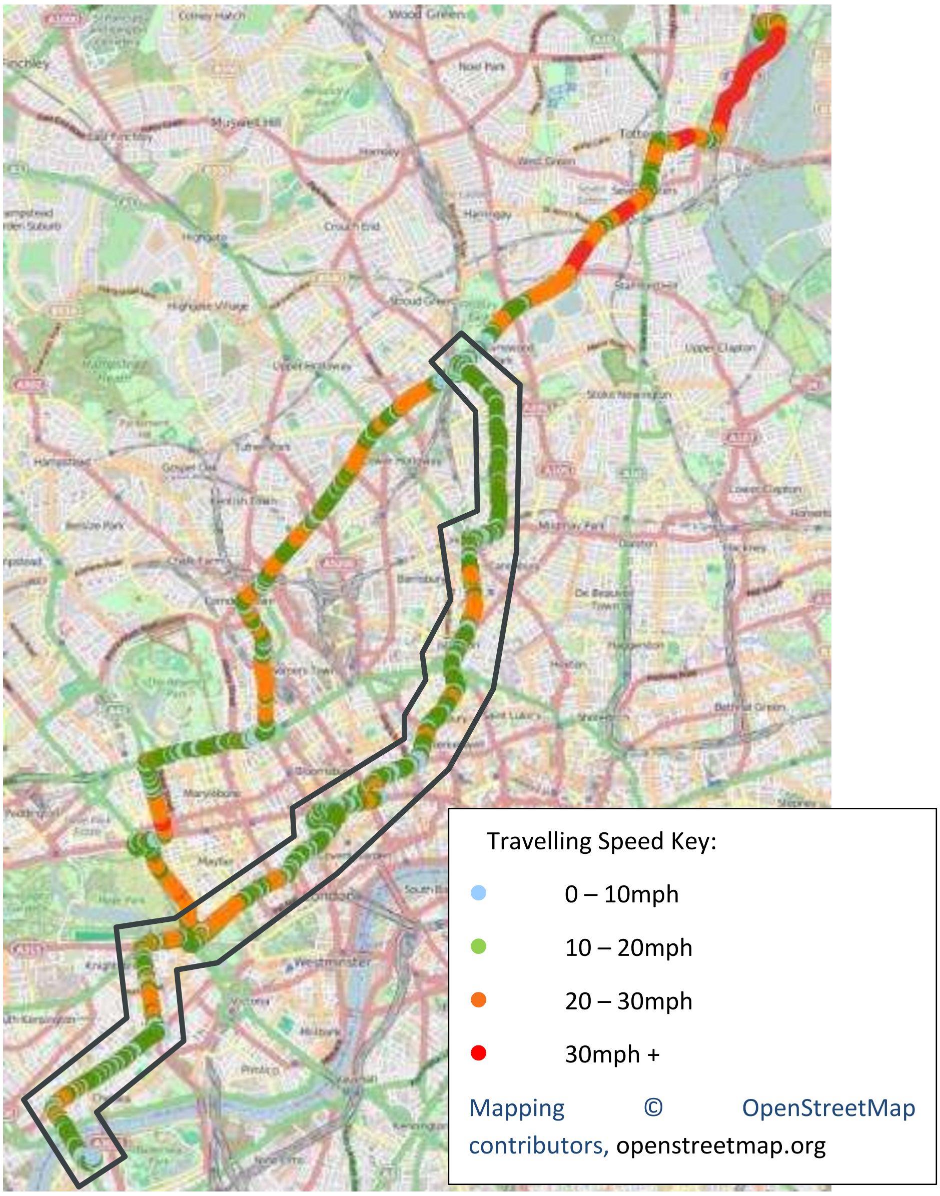


Figure 7 Speeds on route 19 with ISA fitted

Figure 8 indicates the same data, but shows the number of mph over the limit, with red being 3-4mph over the limit, and black being greater than 4mph. Those instances circled in red are where the bus speed exceeded the speed limit by 3mph or more on the bus route (both were in 20mph zones), note that all other records in the figure are away from the bus route and include positioning mileage (any distance the bus travels away from the route, typically this is from the depot to the route start/finish). Similar results were found in other records, suggesting that whilst ISA generally appears to work, it occasionally allows the bus to exceed the speed limit on the bus route. It must also be noted that these records are purely observational based upon iBus data, and instances of not exceeding the speed limit may have been due to the bus driver observing the speed limit rather than the ISA system effectively restricting speed at all times. The on-route sections have been outlined.

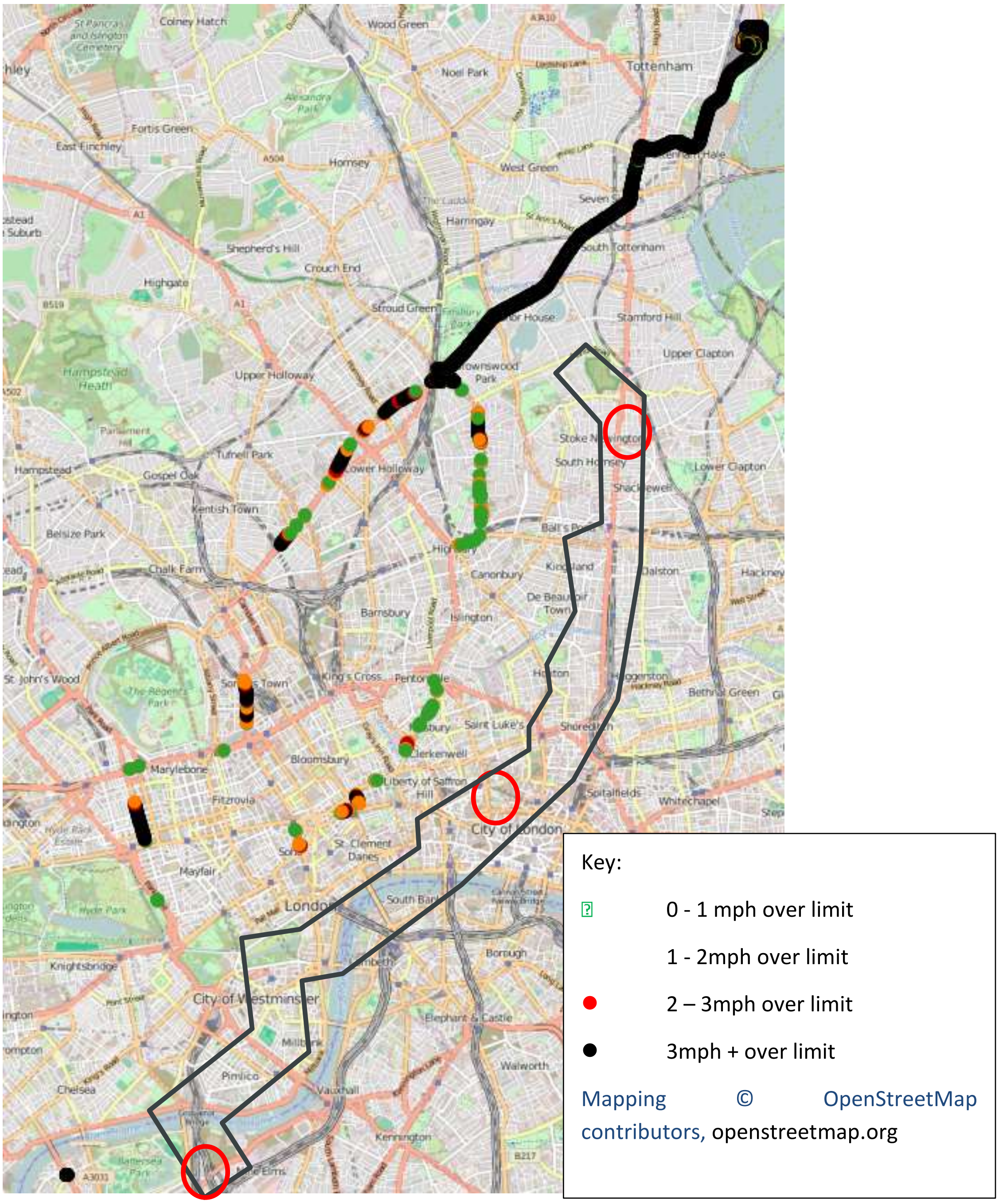


Figure 8 Higher speeds on route 19 with ISA fitted

It should also be noted that whilst not included in the graphs and not part of the calculations, the positioning mileage at the start and end of the day was often associated with high speeds (see circled areas of Figure 9). A provisional check of the locations suggests that the buses were above the speed limit. On this basis it might be concluded that the route to and from any bus route should also be covered by ISA.

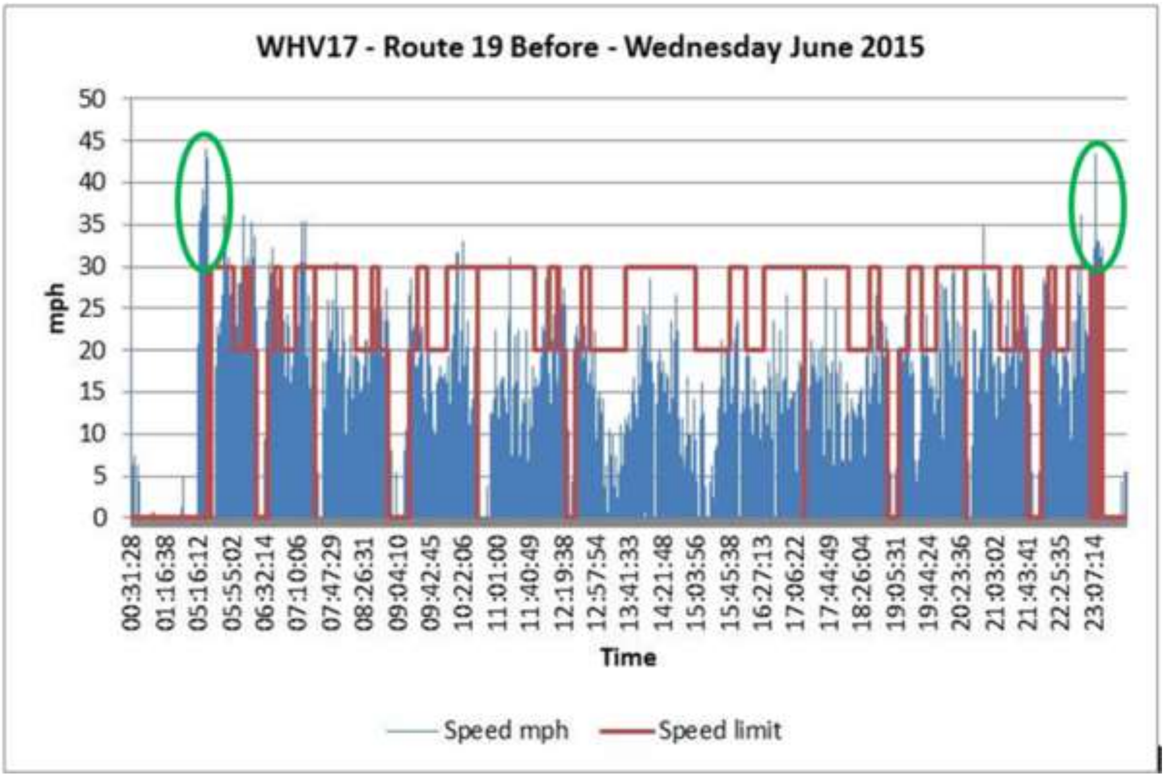


Figure 9 Speed profile highlighting higher speeds during positioning mileage

1.4.4 Instances of higher speeds with ISA fitted (Route 486)

Speeds on route 486 on a Friday in January 2016 (with ISA fitted) are shown in Figure 10 below.

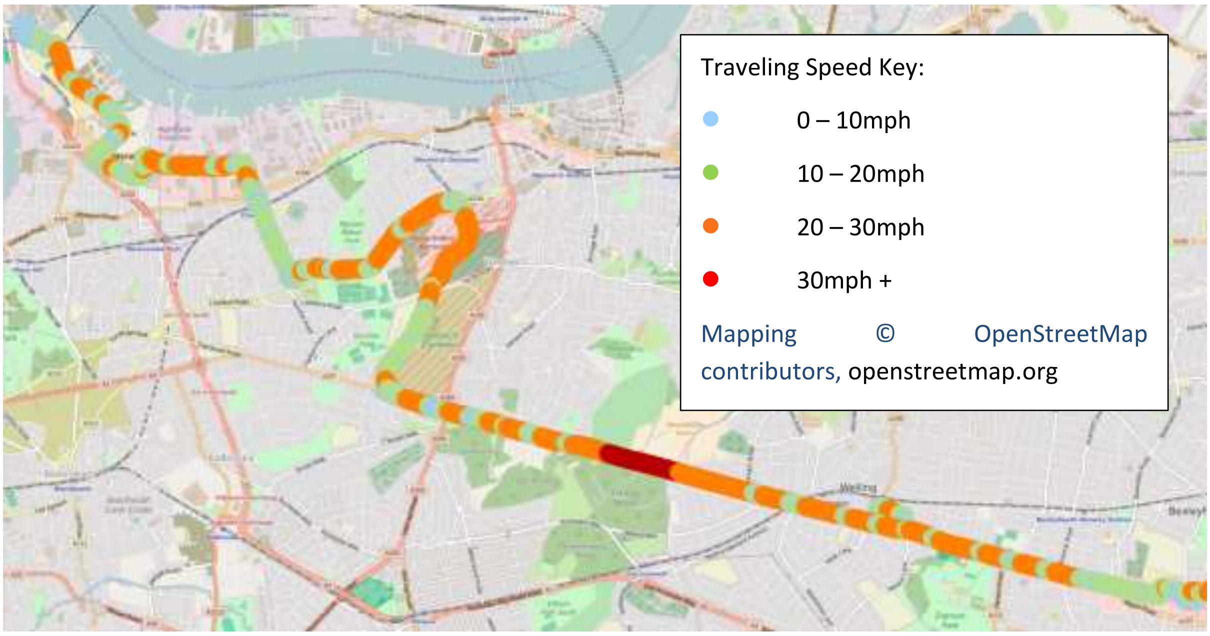


Figure 10 Speeds on route 486 with ISA fitted

Instances of speed above the speed limit still occurred on route 486. Data in Figure 11 below indicates the location and scale of this higher speed on a Friday in January 2016. There are three key areas, one is at the North Greenwich station (the O_2) in the 10mph zone, and much of this seems to relate to the time taken to slow down from the 30mph zone. The second occurs at a retail park. The third is Shooters Hill, where the bus exceeds the speed limit greatly and it is envisaged that this occurred under the influence of gravity. Note that the driver always has the option of using the vehicle brakes.

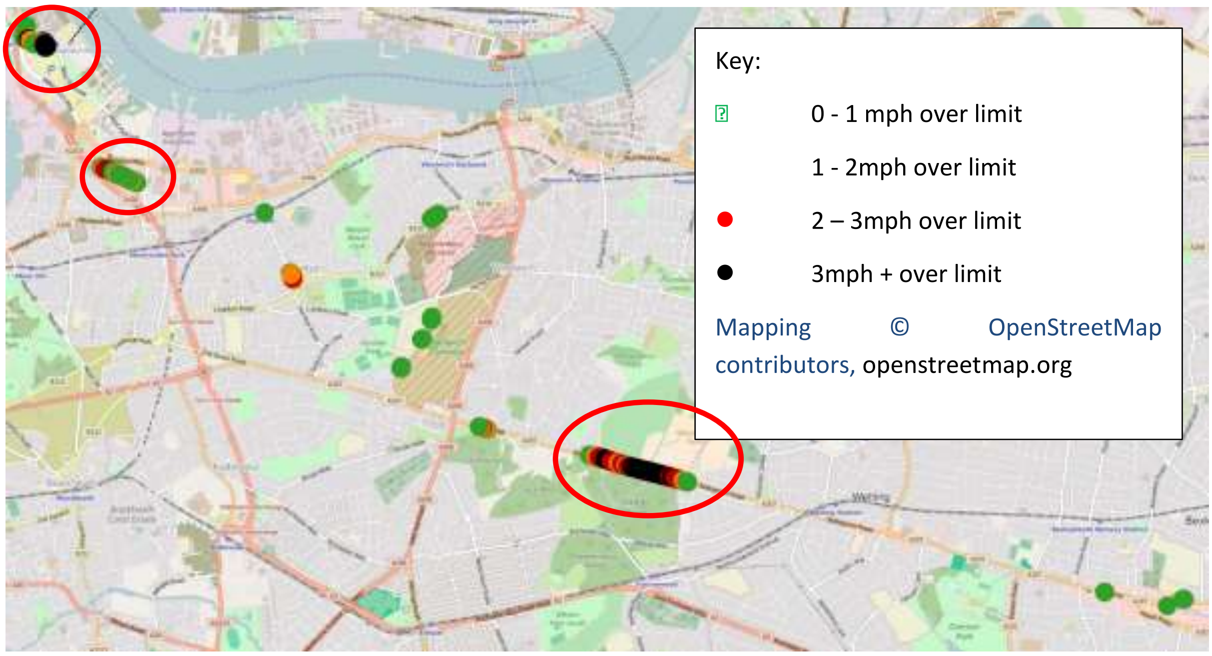


Figure 11 Instances of higher speed on route 486 with ISA fitted

1.4.5 Changes in speed

Whilst average speeds may indicate a change, they mask changes within the profile of that speed. A measure was made of the time before- and after-ISA spent at each speed 'bin' (integer), using a day of data for each bus and represented as a percentage of time on route (note that the ISA during the trial was able to restrict speed only on the bus route). This utilised iBus data which is received in rounded 1kph units, and has been converted in the figures below to mph.

For route 19, this indicated that on 20mph roads there was a large change in the speed profile, with the after-ISA profile heavily skewed towards the upper speed range. This suggests that, whist average speeds may be lower and speed above the speed limit is largely removed, demand for speed above 20mph is now bunched at around 20mph. There appears to be a transfer of speed from above 20mph to just below it, and this also occurs in the route 486 20mph and 30mph speed limit zones.

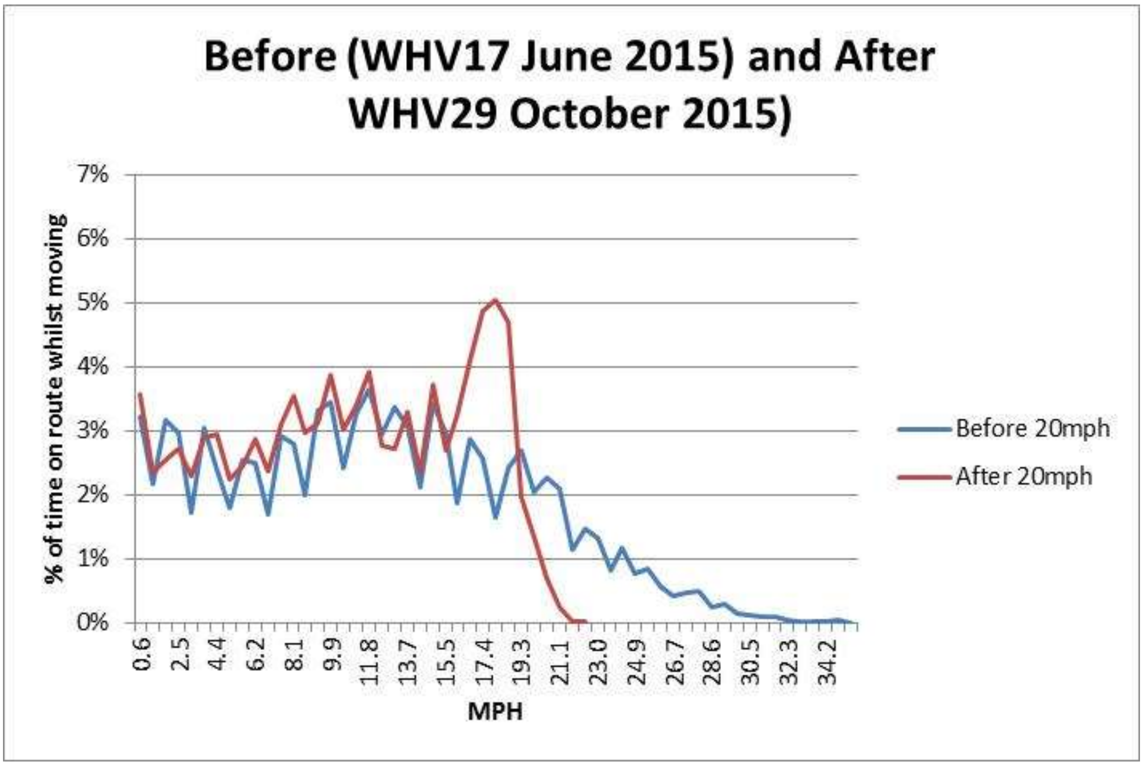


Figure 12 Changes in speed profile before- and after-ISA for 20mph sections of route 19

The profile for the equivalent 30mph zones did not indicate the same skew (Figure 13).

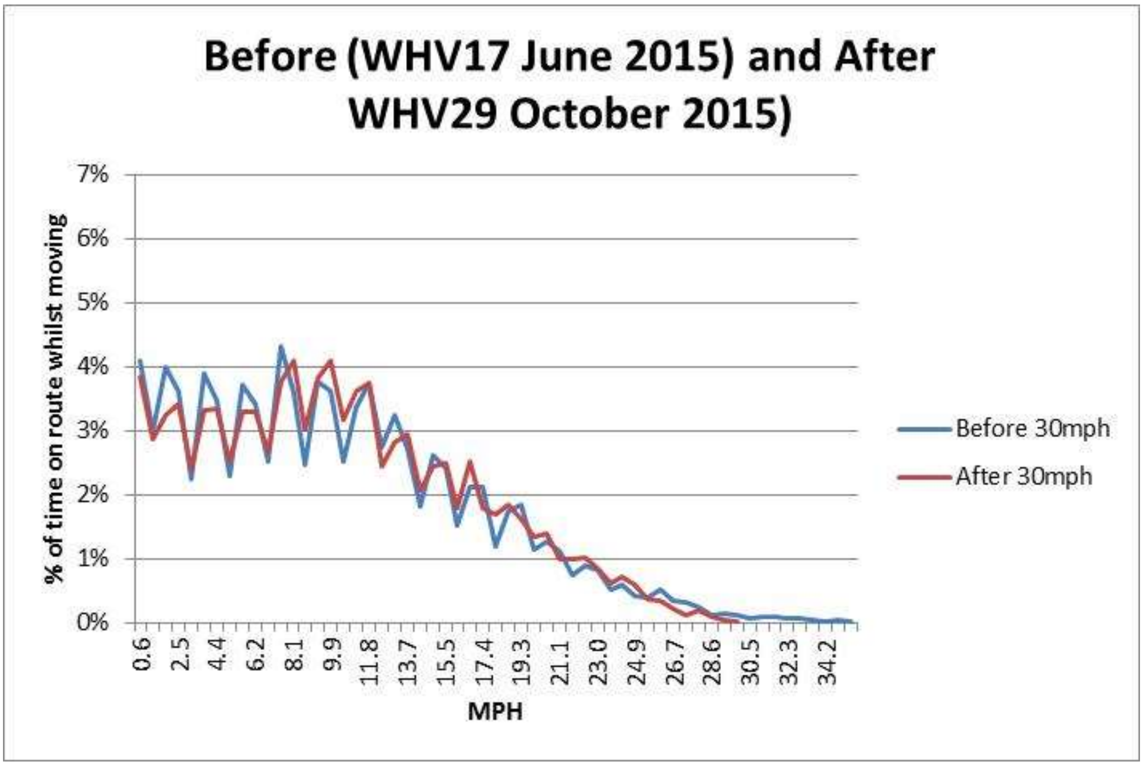


Figure 13 Changes in speed profile before- and after-ISA for 30mph sections of route 19

A similar profile exists for route 486 for 20mph (Figure 14Figure 14) and 30mph (Figure 15) zones.

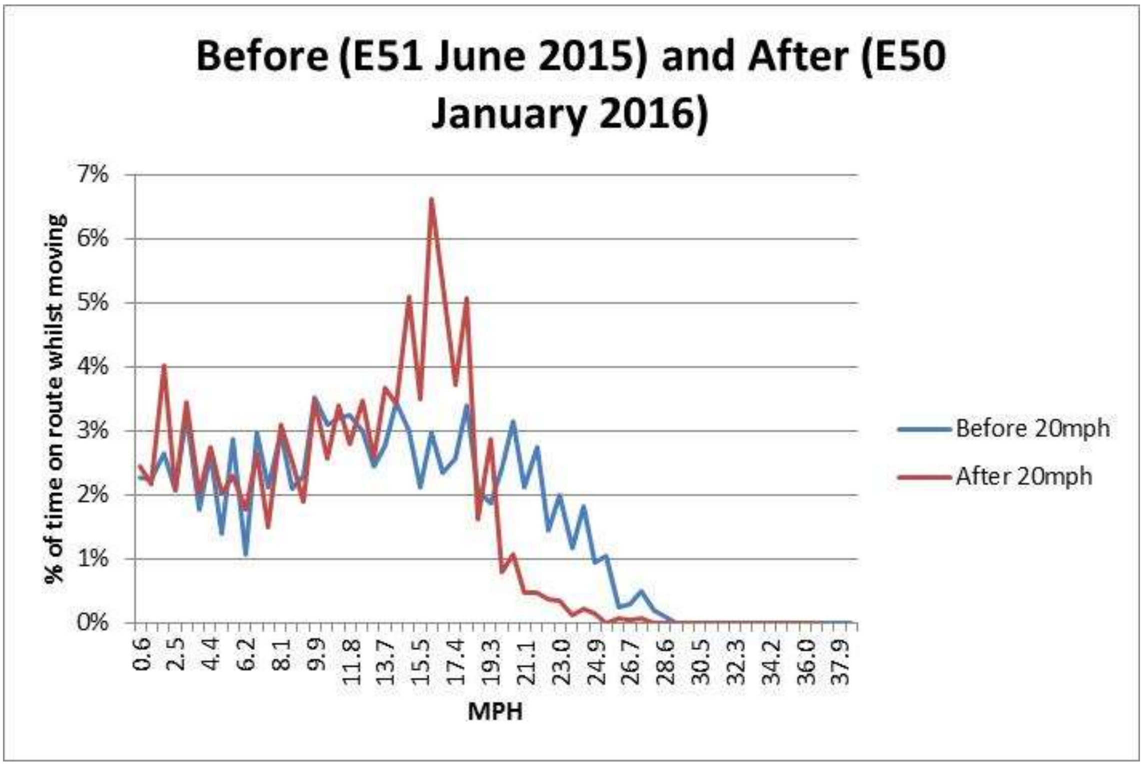


Figure 14 Changes in speed profile before- and after-ISA for 20mph sections of route 486

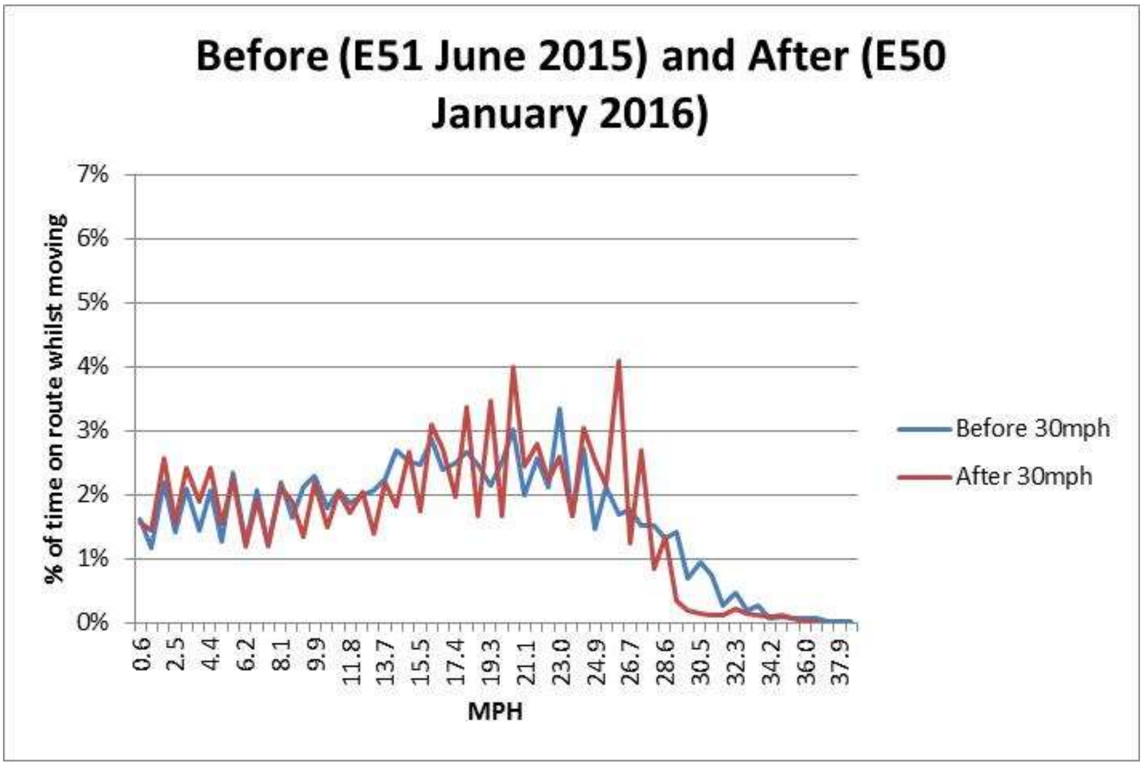


Figure 15 Changes in speed profile before- and after-ISA for 30mph sections of route 486

The percentage of time spent on route above the speed limit, both before- and after-ISA, is shown below for route 19 and 486 in Table 3 and Table 4 respectively. This data is based upon the graphs above which show data for one bus for one day. On route 19, the proportion of time spent above the speed limit in the 20mph zone reduced from around 15% to 1%, indicating notable higher speed before ISA implementation, and a substantial reduction in higher speed after ISA implementation. A broadly similar effect was found on route 486. Before-ISA, higher speed on route 486 was far less prevalent in the 30mph zones than in the 20mph zones; after-ISA, both limits showed a reduction in the proportion of time above the speed limit. These figures indicate that the ISA system appears to be largely, but not completely effective at limiting the speed to the speed limit, with less time spent at speeds above the speed limit after ISA was activated.

Table 3 Time duration above the speed limit on route 19 before- and after-ISA

	Before 20mph limit	After 20mph limit	Before 30mph limit	After 30mph limit
% time above 20mph	14.91%	0.95%		
% time above 30mph			0.48%	0.00%

Table 4 Time duration above the speed limit on route 486 before- and after-ISA

	Before 20mph limit	After 20mph limit	Before 30mph limit	After 30mph limit
% time above 20mph	17.77%	3.32%		
% time above 30mph			3.28%	1.14%

1.5 Cameras placed on vehicles by TRL (dashcam data)

To provide an independent measure of ISA effectiveness, TRL placed cameras in a sample of buses with a view to the front of the bus, including the speedometer. This enabled simultaneous 'truth' data, i.e. the front-view camera gives the location from which the speed limit can be determined, and the speedometer gives the only method of the driver understanding the speed, therefore is a truth which is not liable to GPS error. As the system is temporarily fitted to the buses and visible to the drivers, it is likely to have an observer effect, with drivers potentially lowering their speed.

This temporary camera system was placed on two buses on each route for a shift each, giving 6 end-to-end runs for each bus. The speedometer camera was viewed continuously and the peak speed of every instance of the bus exceeding the speed limit was noted.

An alternative method of collecting this data would be to take an ISA-equipped bus to a test track; however, this may lack reality and would not be affected by typical issues such as GPS inaccuracy caused by tall buildings. A further alternative would be to attempt to speed purposefully with ISA fitted, which raises legal and ethical concerns. For this reason, cameras were used to observe actual behaviour with minimal external influence. Furthermore as a research ethics issue and in order to obtain more realistic results, the identities of drivers observed to be above the speed limit were not recorded.

1.5.1 Route 486 'before' ISA dashcam observations

Higher speed was observed before the ISA equipment was operative. This occurred on nearly all runs, and was measured on three days across June and July 2015. From 12 end-to-end runs, 69 cases of higher speed were found, normally with between 4 and 6 instances in each run. If a 10% speed tolerance were included, then 34 cases of higher speed were identified. This validates a need for measures to improve speed limit compliance and indicates that higher speed is a common if fleeting occurrence. Normally these instances of higher speed were relatively fleeting, forming a very small proportion of all bus travel time, which suggests that the impact upon overall journey time of limiting this speed to the speed limit will be small. In the 'before' measurement higher speed occurred at all speed limits except the Bexleyheath bus depot (10mph), which was too short a distance to allow for reasonable measurement. The highest observed speed was 35mph in a 30mph zone (of which there were several cases). Speeds of 30mph were found in the 20mph zone on Stadium Rd adjacent to the Queen Elizabeth Hospital. Figure 16 indicates the bus speed at around 35mph travelling eastbound on Hillreach Road (B210), the speedometer is circled in red.

Figure 16 Example case of 'before' ISA speed above the speed limit on route 486

On route 486, higher speed tended to be confined within 10mph of the posted speed limit (see Figure 17), with higher exceedances at lower speed limits than at higher speed limits. Note that only those instances of speed above the speed limit are shown.

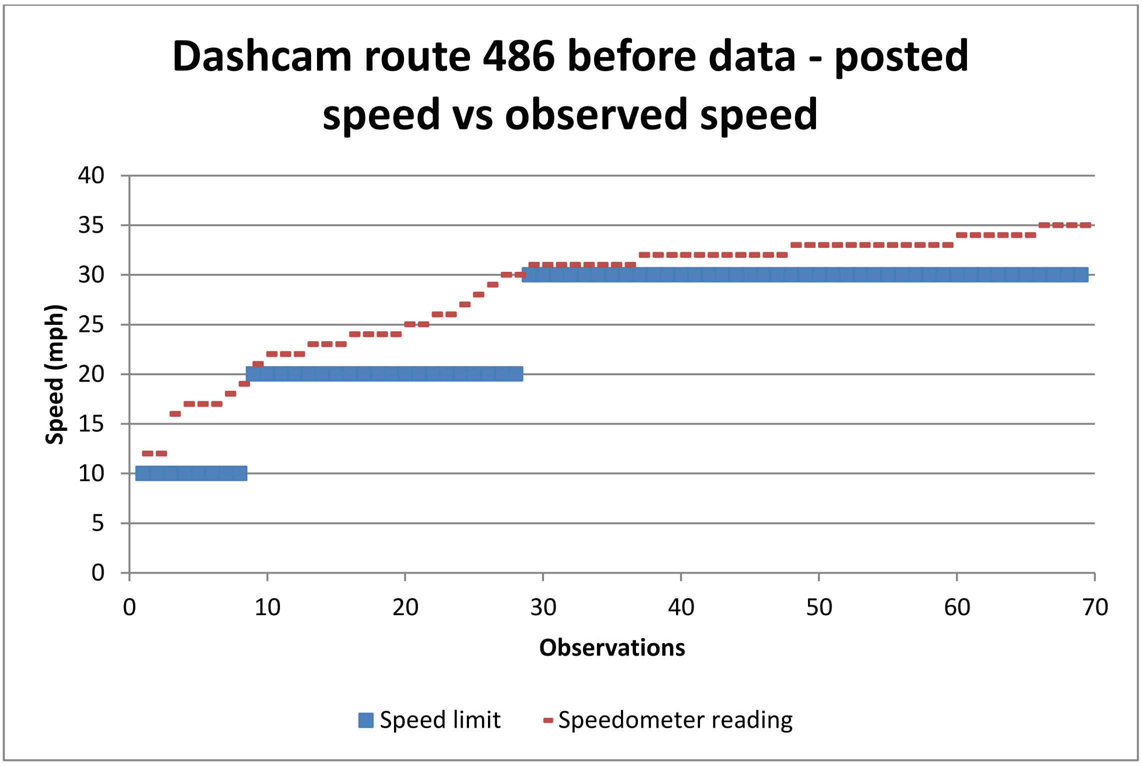


Figure 17 Route 486 observed dashcam speeds

1.5.2 Route 486 'after' dashcam observations

After measurements were taken from the one working route 486 bus fitted with ISA, bus E50. Six end-to-end measurements were taken, resulting in only one instance of higher speed on the downward stretch of a hill (around 34mph in a 30mph zone), which suggests the bus was travelling under the influence of gravity (note the driver always has the option of using the brakes). This limited study suggests that the ISA system appears to operate effectively. This one instance can be seen in Figure 18. Note the illuminated roadside speed warning on the road ahead.

Figure 18 ISA-equipped route 486 bus travelling above the speed limit

1.5.3 Route 19 before-ISA dashcam observations

Instances of higher speed were observed before the ISA equipment was operative. Instances of speed above the limit occurred on all runs, and were measured on two days in July 2015. From 12 runs, 113 cases of higher speed were observed, primarily in 20mph zones (7 cases were in 30mph zones). If a 10% tolerance were included, then 55 cases of higher speed were identified. The 30mph zones were more towards central London and were busier, giving little opportunity to accelerate the bus above the speed limit. Higher speed was usually observed over relatively short distances. There were two cases observed of a bus in a 20mph zone reaching 31mph. Figure 19 indicates the route 19 bus travelling at 31mph in a 20mph zone whilst passing a zebra crossing on Rosebery Avenue whilst heading towards the Battersea end of the route. The speed readings (both digital and analogue viewable on this bus) are indicated within the red circle. Note that this design of bus also includes a digital speed reading which increases the accuracy of records.

Figure 19 Example case of before-ISA higher speed on route 19

On route 19, higher speed tended to be confined within 10mph of the posted speed limit (see Figure 20). Note that only those instances of speed above the limit are shown.

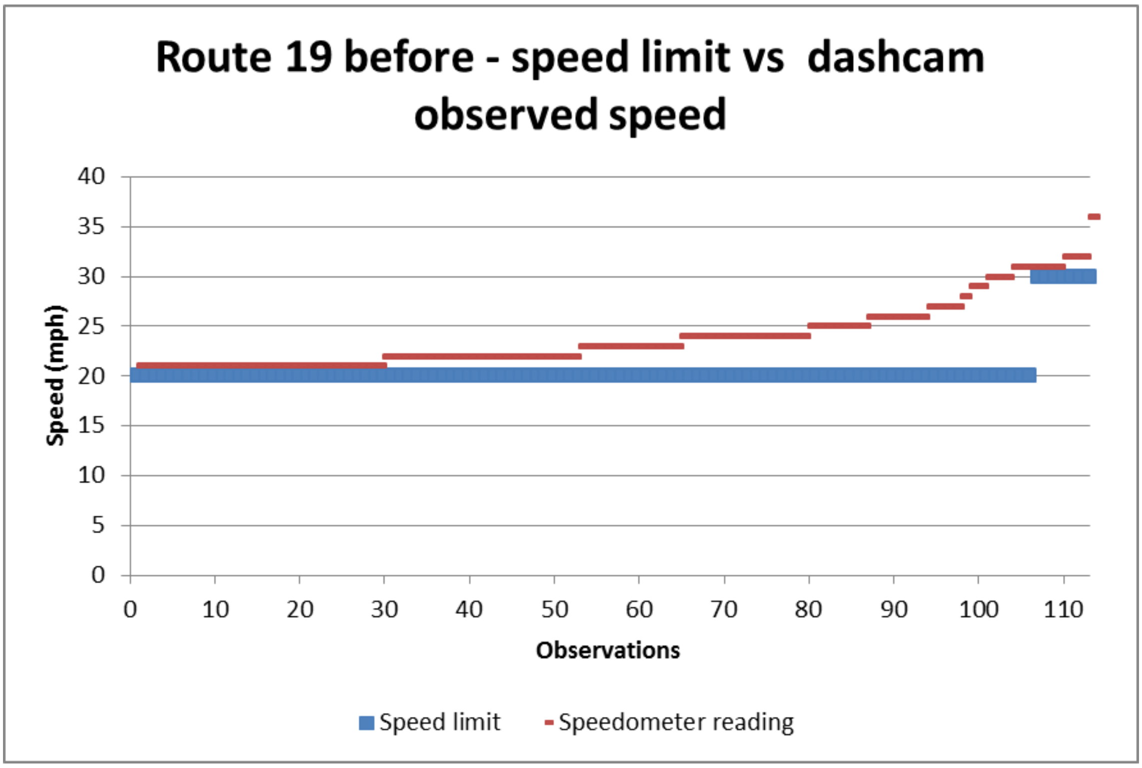


Figure 20 Route 19 before-ISA observed dashcam speeds

1.5.4 Route 19 after-ISA dashcam observations

Following the switching on of the ISA system, the dashcam operation was re-run using the same two buses with 6 end-to-end runs each (Figure 21). This found that speed above the speed limit still occurs with a similar frequency as the 'before' scenario; however, the level of that speed is constrained largely within the 10% tolerance included of the ISA system. There were occasions where this was exceeded and these were generally downhill (suggesting the influence of gravity, although note that the driver can always apply the brakes). After ISA implementation there were 26 cases of the 10% tolerance being exceeded whereas before there were 55 cases, a reduction of greater than half.

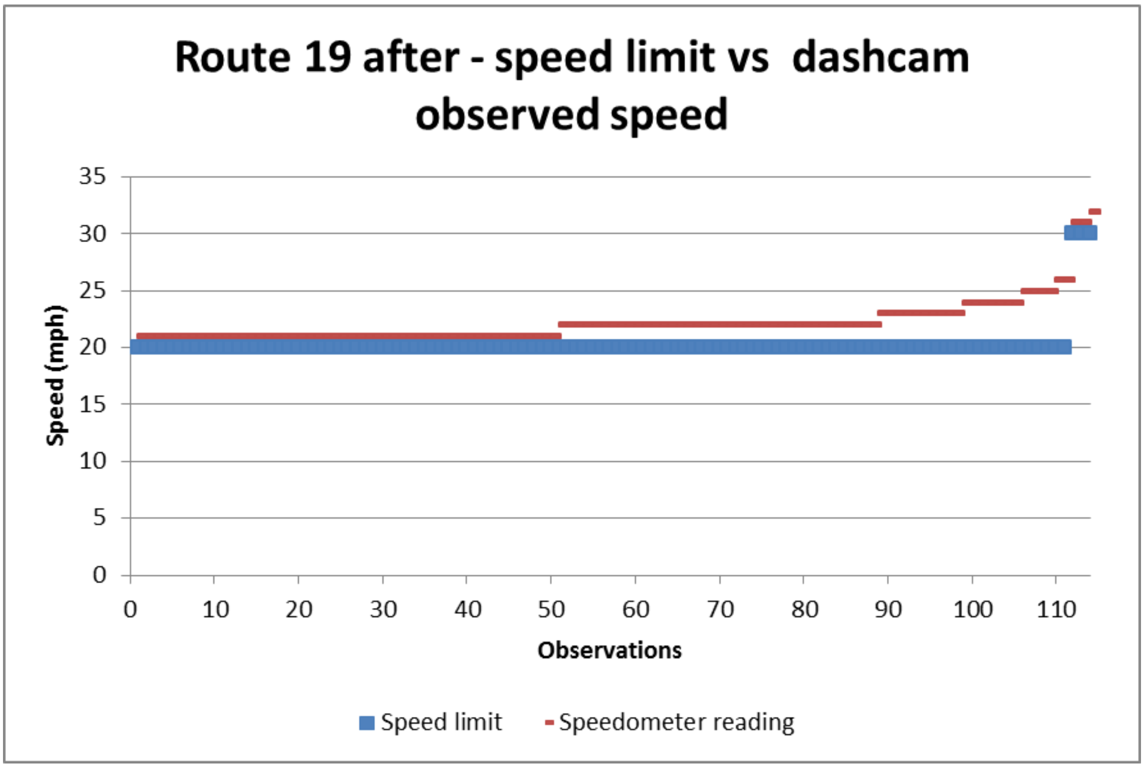


Figure 21 Route 19 after ISA observed dashcam speeds

1.5.5 Speed limit zone of higher speed events

Table 5 indicates the proportion of dashcam higher speed events as a proportion of approximate route distance. This indicates that lower speed limit areas have a disproportionately high number of higher speed events.

Table 5 Proportion of higher speed events in each speed zone

Route	Speed zone	Distance (m)	Proportion of distance	Number of dashcam higher speed events	Proportion of dashcam higher speed events
19	20mph zones	5342	40.1%	106	93.8%
	30mph zones	7964	59.9%	7	6.2%
486	10mph zone	380	2.6%	8	11.6%
	20mph zones	1181	8.0%	20	29.0%
	30mph zones	13245	89.5%	41	59.4%

1.6 Average between-bus-stop speed data provided by TfL

TfL provided average speed data between stops, which excludes dwell time on an hourly basis (therefore the speed is an average of those vehicles travelling in that hour between two locations), for a week's data in the before and after scenario (note that 'after' scenario data for route 486 was not available) for all buses on the route. This data was also used to answer Research Question 6 (see section6). This reveals that (for route 19), speeds above the speed limit still did occur after ISA was activated along some sections of 20mph road (Table 6).

Table 6 Mean bus higher speed

Route	Before/After ISA	Instances of mean bus speed over an hour above the speed limit	Notes
19	Before ISA	16	All occurred at 20mph zones at Highbury and Finsbury sections, all at mornings and late evenings.
	After ISA	7	
486	Before ISA	10	All occurred on Shooters Hill, all at mornings and late evenings.
	After ISA	N/A	N/A

1.7 Bus spot speeds measured by tube data

A separate part of this project covering Research Question 3 gathered the speed of all vehicles passing speed tubes placed along each bus route at locations where higher speed might be expected. Using video co-located with the tubes, buses (and their speeds) were identified. As can be seen in the results (shown in Table 7) this did find evidence of buses' higher speed before ISA was switched on. TfL advised that the ISA equipment was set to allow for a tolerance of 10% for the purposes of this trial, therefore figures in brackets in Table 7 are the number of cases of higher speed if those within a 10% tolerance are excluded. It should be noted that tube data is not 100% reliable, and can occasionally misquote speed where for example two vehicles pass over the tubes at the same time (either in the opposite or same direction), for this reason these individual spot speed results should be seen as indicative rather than conclusive.

The tubes can be seen by the drivers who may understand that they are for general traffic collection, but are commonly seen on the highway. For this reason they may have a small observer effect.

Please see the section covering Research Question 3 for further detail regarding the speed tube details.

Table 7 Bus 'spot speeds' data before- and after-ISA (route 19)

Route and speed	Before-ISA		After-ISA	
	Sample size	No. of buses with higher speed (with a 10% tolerance)	Sample size	No. of buses with higher speed (with a 10% tolerance)
Route 19 20mph	121	61 (41)	110	46 (29)
Route 19 30mph	121	9 (3)	121	6 (3)
Totals	242	70	231	52

In the before ISA scenario, 29% of buses were found to be above the speed limit, whereas this fell to 23% when ISA had been implemented.

Note that as the route 486 after data was not available we have excluded it from the total. However, the sample size before-ISA was 159, with 53 cases of higher speed (26 cases if a 10% tolerance was included).

2 Research Question 2 - Is ISA an efficient method of speed limit compliance?

2.1 Introduction

The Zeta Automotive Ltd Intelligent Speed Assistance (ISA) system as fitted to the buses used in the test is a method of limiting the speed of a vehicle fitted with the device to that of the speed limit of the road on which it is travelling.

A variety of methods exist to reduce or limit speeds and those working in transport, highway engineering, and enforcement have a choice of methods to use. The purpose of this research question is to advise on the relative merits of ISA when compared with other forms of infrastructure intervention speed management to determine whether ISA is an efficient solution.

This research question was answered by a literature review of the *efficiency* of a variety of speed limiting methods.

2.1.1 About the Zeta Automotive Ltd ISA equipment

Following discussions with the manufacturers of the ISA equipment regarding its capabilities, provided the technology works correctly the theoretical impact of the Zeta Automotive Ltd[9] ISA is that:

- It will exercise full speed limit compliance in equipped vehicles
- It will be effective for all areas where the speed limit is known by the system
- Its effectiveness will not diminish over time
- It may influence the speeds of other vehicles in the vicinity, especially those following behind

The fitment of ISA has an initial cost of purchase and installation and may have life costs associated with ensuring that the speed limit map data are kept current.

2.2 Methodology

Speed limits have long been applied to roads to reduce collision risk and severity. A variety of measures exist to limit speeds and these have often been the subject of research. A short literature review of key research on various speed limiting methods has been undertaken with the purpose of understanding the place for ISA within the wider toolkit of speed-limiting measures available for use in London. It should be noted that many studies report the average reduction in speed, rather than absolute speed, therefore creating difficulties in direct comparison with ISA which theoretically limits to a defined speed.

It should be noted that the typical road environment for London bus services is a mix of 20mph and 30mph zones, in densely populated urban areas along through-roads. The ISA system tested only limits speed to the posted speed limit and does not limit speed to a level

9 Note that other ISA devices may function differently

that is most appropriate for the prevailing conditions (it is understood that current technology does not allow for this).

2.3 Key findings

A discussion of the key findings is shown in Table 9. The speed control measures reviewed generally fall into two types:

- Infrastructure devices which reduce vehicle speeds because of the driver's desire to reduce discomfort
- Electronic enforcement which reduces speed to a limit because of the driver's desire to avoid a fine and points on their licence

No traditional methods to date can guarantee compliance with speed limits, the driver still risks discomfort or penalty for speeding but is not absolutely prevented from speeding. However, traditional measures do generally apply to all vehicles, whereas ISA does not. ISA is also the only speed control measure that is fitted directly to the vehicle, rather than fitted to the highway, which places the onus of fitment and operation with the vehicle operator.

No control measure examined can guarantee to limit the speed to the most *appropriate* speed given prevailing conditions. ISA should be efficient in limiting the speed of equipped vehicles to the speed limit.

On the basis of the findings, average speed cameras *may* be a more effective speed control measure than ISA as it limits speed effectively to the speed limit, applies to all vehicles and the effect is unlikely to diminish over time given penalties for speeding contraventions which it can detect. However, reports on the use of average speed cameras in urban areas were not found by the literature search therefore their effectiveness in such areas can only be assumed and may be subject to confounding factors. On this basis, ISA may offer the most effective method presently available and understood for limiting speed on fitted buses.

The remainder of the chapter discusses the detailed methodology and data evidence for answering Research Question 2.

2.4 Literature research detailed methodology and data

A literature search was undertaken. The methodology for this used the following procedure:

- Search planning
- Search terms/search criteria
- Search techniques
- Inclusion/exclusion criteria

2.4.1.1 Search Planning

The search plan starts with the search question. The question was, 'how does ISA compare with other available traffic calming measures for buses?'.

2.4.1.2 Search terms/search criteria

A first search of the types of traffic calming measures available was drawn from Traffic calming measures for bus routes (BP2/05 TfL, 2005), as these are the options available to Transport for London engineers when enacting traffic calming on bus routes and therefore are direct alternatives to ISA. These include:

Appearance and perception - also referred to as psychological traffic calming, whereby the visual representation of a road from the driver's perspective is such that they drive at slower speeds because it feels more comfortable and appropriate to do so).

Speed measurement devices - including vehicle activated signs and safety cameras (speed cameras) which detect a vehicle speeding and either issue an immediate visual warning, or send out an automated fine.

Horizontal deflections - including chicanes and pinch points, which are infrastructure devices which cause the vehicle to deflect around it requiring a slowing of speed to complete the manoeuvre.

Vertical deflections – including speed tables and speed cushions, which are infrastructure devices to cause an upwards and downwards jolt in vehicles that is uncomfortable for the drivers and passengers. Increased speed results in increased discomfort, therefore encouraging the driver to reduce speed.

We have not included prior research regarding ISA, as this work is a comparison with the envisaged operation of the new Zeta Automotive Ltd ISA equipment. From this list, a table of search terms was created (see Table 8).

Table 8 Search terms

Target Group	Intervention/Action	Outcome
Appearance and perception	• Psychological traffic calming	• Speed reduction • Distance • Time • Vehicle type
Speed measurement devices	• Speed camera • Safety camera • Average speed camera • Vehicle activated signs • Time over distance • Spot speed • Enforcement camera • Speeding • Compliance • Speed choice • Surfing • Speed indicator devices	
Horizontal deflections	• Chicane • Pinch point	
Vertical deflections	• Speed hump • Speed table • Speed cushion	

2.4.1.3 Inclusion/exclusion criteria

Other search parameters applied were:

- Dates (from 1990 onwards)
- Sources likely to be reliable (e.g. government sponsored research or peer-reviewed papers)
- Sources covering the UK only
- Types of technique prevalent in London for use on bus routes
- Reports in the English language

2.4.1.4 Search techniques

Research databases and key bibliography documents were used for the search, including:

- TRL internal database
- TRID http://trid.trb.org/
- Local Transport Note 1/05 – Traffic Calming Bibliography (DfT, 2005)

Search terms covered the items and inclusion parameters indicated in section 2.4.1.2.

Searches were limited to several key texts per target group.

Four key factors emerged and were explored in the literature for each method of speed limit control:

1. Reduction in speed at the point of speed control
2. Length of carriageway over which speed control methods are effective
3. Longevity of effect
4. Range of vehicles affected

Data collected and analysed in this exercise can be seen in Appendix A.

Table 9 Discussion of the effects of various traffic calming measures

Measure	Reduction in speed at the point of speed control	Length of carriageway over which speed control methods are effective	Range of vehicles affected by the measure?	Longevity of speed limit compliance?	Comment
ISA	Excellent speed control over all areas covered by its map	Excellent speed control over all areas covered by its map	Very effective on vehicles it is fitted to, with potential impact on surrounding vehicles depending upon their proximity	Effect should not diminish over time	ISA would appear to be an efficient solution to ensuring that equipped vehicles are compliant with the speed limit. They are likely to have a small, localised effect on following vehicles.
Physical (horizontal and vertical) traffic calming	Compliance can depend upon the size of vehicle and amount of deflection	Can result in acceleration and deceleration between measures, largely confined to the area of fitment	The size of the vehicle is important. Smaller vehicles have less mass and are therefore more affected by vertical deflections. However larger vehicles are more affected by horizontal deflections as they struggle for space to manoeuvre.	The effect lessens over time	Speed limit compliance applies only to areas of fitment. Measures can impose additional stress on bus drivers, passengers, and the vehicle. Horizontal deflections large enough for buses are unlikely to have a great impact on cars, and can have significant land-take.
Vehicle Activated Signs	Is shown to reduce speeds at the point of control	VAS effective over a short distance	Every vehicle is affected by VAS	Drivers rapidly ignore VAS after around a week	Impact is only in a small area and for a limited time but equipment is typically portable and can be relocated frequently
Psychological traffic calming	Some impact on speed	Depends on the measure	Impacts all drivers, hence all vehicles	Longevity of effect may diminish over time	Requires infrastructure, which may be visually intrusive
Fixed point speed cameras	Good control of speed to the limit	A small halo effect around the camera	Impacts all drivers, hence all vehicles	Effect lasts over time	Can limit speed at specific locations for all vehicles

	but fixed location				
Average speed cameras	Good control of speed to the limit over a fixed distance	Good control on roads with long sections, impact on urban areas less well understood	Impacts all drivers, hence all vehicles	Effect lasts over time	A good control method which affects all vehicles. Impact on traffic in urban areas is not well understood

3 Research Question 3 - What is the impact of ISA vehicles on the behaviour of surrounding traffic speeds?

3.1 Introduction

A key issue with ISA is that it only directly limits the speed of vehicles to which it is fitted. However it may also have an impact on other traffic, by restricting the speed of following vehicles and/or by creating a larger headway to the vehicle ahead.

This element of research looked first at vehicles in the immediate vicinity of buses (within its 'sphere of influence') and then the speeds of all traffic.

To measure the impacts of ISA on speeds of other vehicles, TRL placed speed tubes at ten locations along the routes. This was done for both the 20mph and 30mph roads, for a one-week period before ISA was introduced and a one-week period afterwards. The periods were chosen to avoid school holidays, which are known to have different traffic characteristics. Two control speed tubes were also placed on roads near to each route to understand and isolate general changes. It should be noted that Route 486 data were not collected after ISA installation due to technical problems with the ISA equipment, which would have required data collection around the Christmas period which may have adversely affected the findings.

Note that the bus is only likely to have an impact upon traffic where that traffic cannot overtake. ISA-equipped buses cannot directly slow other traffic if the bus is in a bus lane or there is an open lane beside it.

The impact of ISA was explored with regards to determine the following:

1. The speed of vehicles within the bus 'sphere of influence'
2. Average speed of all traffic
3. Platoon length behind the bus
4. Gap between bus and following vehicle
5. Gap between bus and vehicle in front

The speed of vehicles in traffic will be limited by any vehicles in front if there are no opportunities to overtake (such as an adjacent lane). Buses with ISA should not be able to exceed the speed limit in almost all situations which may have the effect of slowing traffic behind it, leading to slower general speeds that in turn may improve road safety. However, there are likely to be limits to this given the relatively low proportion of buses in the general vehicle fleet, the limited time that buses might be above the speed limit without ISA, and the long distances required for vehicles behind to concertina together to have an impact upon their speed.

3.2 Method

Speed tubes were placed in strategic locations along the route, where higher speed was expected, and the proximity of vehicles following buses was examined. The buses were identified on video cameras adjacent to the speed tubes and this was correlated to the data records extracted from the speed tube, allowing for the speed of the bus, the speed of other vehicles, and headway of surrounding vehicles to be understood. This was undertaken both before and after ISA implementation so that a comparison could be undertaken. Before and after data was collected for Route 19, but only before-ISA data was available for route 486.

3.3 Key findings

Although only based on a sub-sample for Route 19, at the three 20mph locations the results suggest that the introduction of ISA did reduce the speed of some vehicles in the platoon (sphere of influence) behind the bus with the proportion of vehicles in the platoon exceeding the speed limit in 20mph zones falling from 51.1% to 42.0%. However, for the three 30mph locations, the introduction of ISA had only a negligible effect on platoon speed.

Overall vehicle fleet speed change related to ISA was inconclusive, which is the expected outcome given the relatively low proportion of buses as part of the overall number of vehicles, and the small speed reductions in buses as a result of ISA found by this study.

Platoon length behind buses was longer after-ISA, with the average platoon length increasing from 1.2 to 1.6 vehicles in the 20mph zone (a much smaller difference in platoon length was observed in 30mph zones). None of the changes in platoon length were statistically significant.

The gap between the bus and any following vehicle did not change significantly, which suggests that drivers are not responding to ISA by driving closer to the bus.

A vehicle gap did open up between the bus and the vehicle in front in the 20mph zones (not the 30mph zones), which suggests that the slower ISA-equipped buses could not keep up with vehicles in front.

3.4 Further methodological detail relating to this data

3.4.1 Method of data collection

Vehicle speed information for all vehicles was recorded by placing speed tubes and cameras at specified locations on the two bus routes. A diagram of this setup can be found in Figure 22. The counters used pneumatic tubes to register the passing of vehicles, and calculated speed, direction, headway and vehicle axle count for each vehicle.

To collect information regarding the vehicles within the immediate vicinity of the bus, cameras captured footage of vehicles passing the tube counter, which was used to identify the precise time that a bus passed the tube. The timestamp from the video data was matched with data from the tube counters, which enabled filtering of the speeds and headways of vehicles from the tube counters for the vehicle ahead and the five vehicles behind each bus.

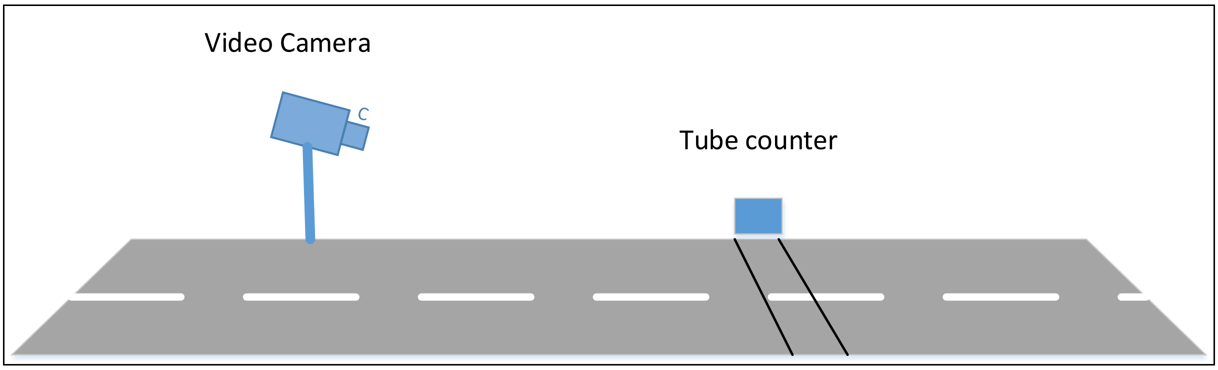


Figure 22 Method of data collection

3.4.2 Criteria for location selection

It was impracticable to measure the speed of all vehicles on every part of each route. The selection criteria set to choose suitable sites for tube counts were:

- Single lane in the direction of measurement, as this forces traffic to either stay behind the bus or overtake into oncoming traffic. Multiple lanes (or a bus lane) would effectively remove the bus from general traffic.
- A mixture of 20mph and 30 mph zones
- Free flowing traffic (limited congestion)
- Sites with some opportunity to exceed speed limits

3.4.3 Tube locations

The tube locations and rationale are indicated in Table 10 below, and a map of each route and tube location shown in Figure 23 and Figure 24. Note that in the maps, red circles indicate tube counter locations on the route, and yellow circles indicate control sites near to but off the route.

Table 10 Tube location description

Route	ID No	Location	Speed limit	Rationale	Borough
19	1	Sloane St, just north of Cadogan Gardens on the single-lane road	30mph	Buses may have time to accelerate to their full speed, and it is immediately followed by a multi-lane road	Kensington & Chelsea
19	2	Sloane St, around 200m north of Cadogan Gardens	30mph	Drivers will have the opportunity to overtake buses and may choose to speed	Kensington & Chelsea
19	3	Rosebery Avenue, just south-west of Pine St	20mph	Potential for traffic to reach maximum speed, and is on a 20 mph road	Islington

Route	ID No	Location	Speed limit	Rationale	Borough
19	4	Rosebery Avenue, around 50m south of Arlington Way	20mph	Opportunity for free-flowing traffic	Islington
19	5	Highbury Grove at Aberdeen Lane	20mph	Opportunity for free-flowing traffic	Islington
19	12	Beaufort St	30mph	Buses may have time to accelerate to their full speed	Kensington & Chelsea
19 control route	6	Cliveden Place (tube between Sedding St and Bourne St)	30mph	Comparable with Sloane St area	Kensington & Chelsea
19 control route	7	Islington Green, just north of junction with Gaskin Street	20mph	Comparable with Highbury Grove	Islington
486	8	Hillreach at around No 48) between Woodhill and Woodrow	30mph	Potential for vehicles bunching behind the bus, or higher speed down the hill	Greenwich
486	9	Shooters Hill Rd between Baker Road and Gilbert Close	30mph	Potential for vehicles bunching behind the bus, or higher speed down the hill	Greenwich
486	10	Shooters Hill Rd between Constitution Rise and Craigholm	30mph	Potential for vehicles bunching behind the bus, or higher speed down the hill	Greenwich
486	11	Shooters Hill Rd, east of Eaglesfield road	30mph	Opportunity for overtaking between central barriers	Greenwich
486 control route	13	Shooters Hill Rd, just west of Zangwill Rd.	30mph	Comparable with the rest of Shooters Hill Rd	Greenwich
486 control route	14	Artillery Place, east of Repository Road	30mph	Comparable with Hillreach	Greenwich

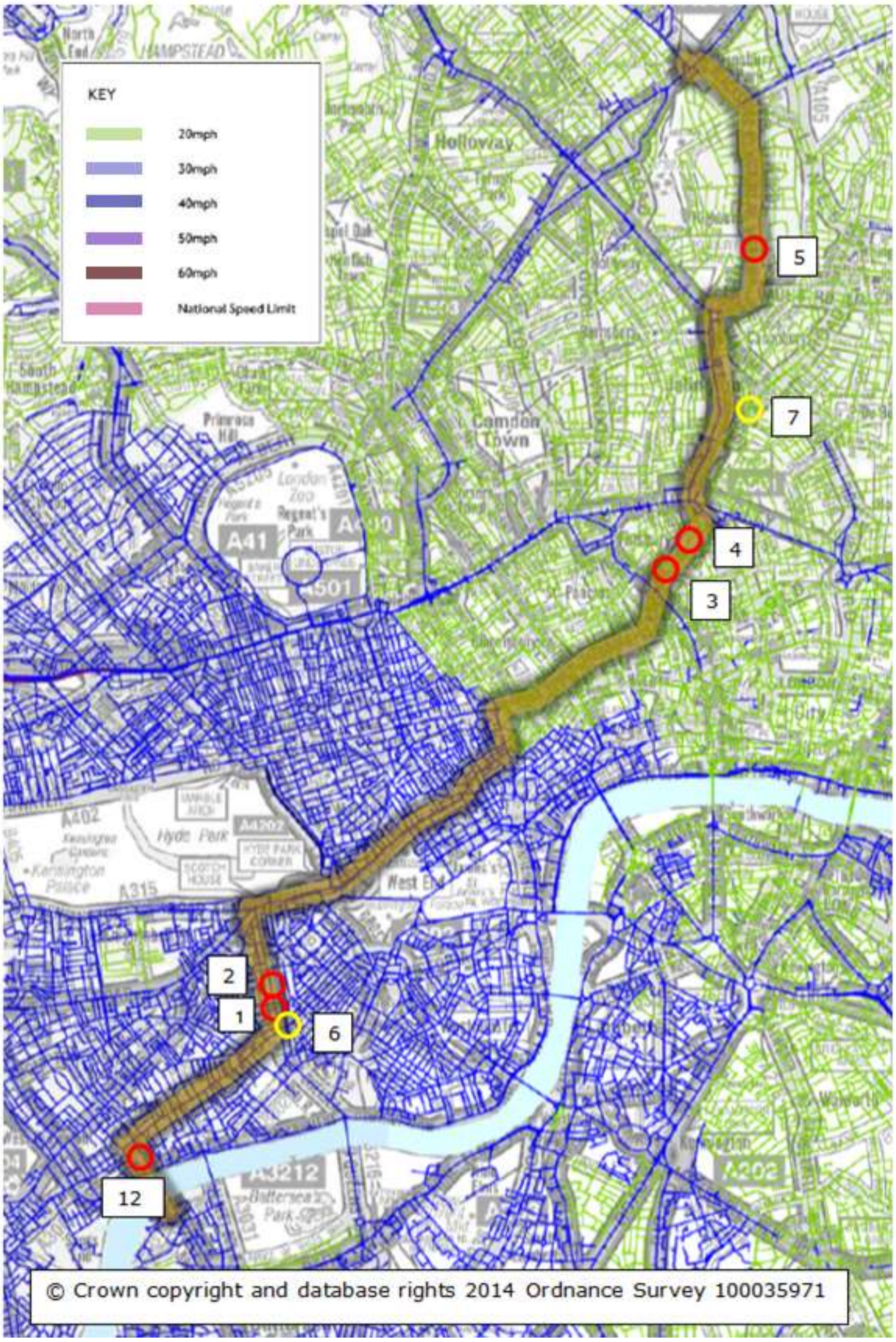


Figure 23 Route 19 map and tube locations

Figure 24 Route 486 map and tube locations

3.4.4 Dates of collection

Dates of collection were chosen to avoid school holidays in order to avoid any influence of these periods on traffic volumes and speed (Table 11). Note that no collection was possible on route 486 after ISA installation.

Table 11 Dates of data collection

Before ISA, route 19 and 486	**00:00:00hrs 1st June 2015 to 23:59:59 hrs 7th June 2015**
After ISA, route 19 only	00:00:00hrs 5th October 2015 to 23:59:59 hrs 11th Oct 2015

3.4.5 Determining the sphere of influence

A vehicle was defined to be in the 'sphere of influence' (i.e. its speed has the potential to be affected by the speed of the bus) of the bus in front if it reacted to any changes in the speed of the bus. In the VISSIM[10] microsimulation tool, the 'look ahead distance' is used to represent such a concept and the recommended value for this parameter is 20 to 30 metres. Based on this information and using typical urban speeds, a threshold of 5 seconds for the gap was chosen to distinguish whether or not a vehicle was in the 'platoon' behind the bus. The gap was defined to be the time between the rear axle of a vehicle and the front axle of the following vehicle.

Figure 25 shows an example of a platoon with four vehicles, where the gap between each vehicle is less than 5 seconds. Figure 26 shows an example where there is no vehicle within 5 seconds of the bus in front.

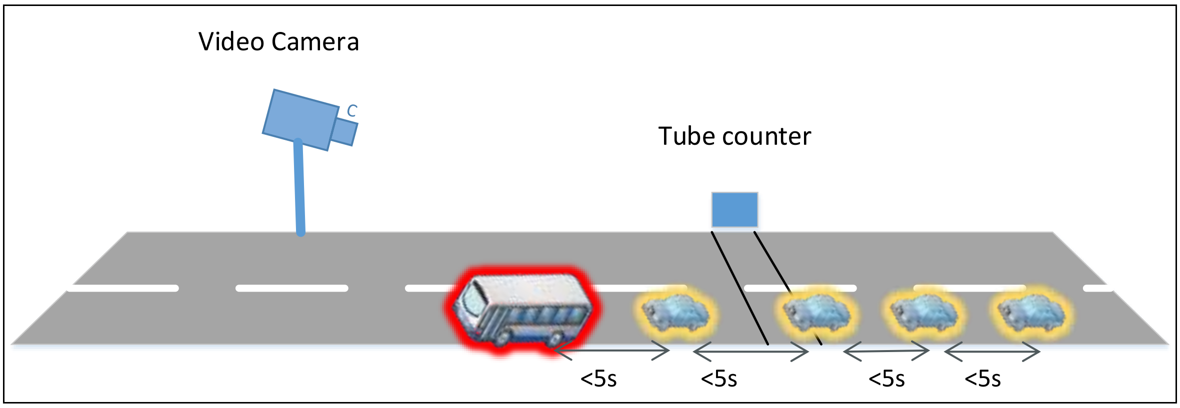


Figure 25 Example of four vehicles in platoon

[10] VISSIM is a traffic flow simulation software package utilised by Transport for London

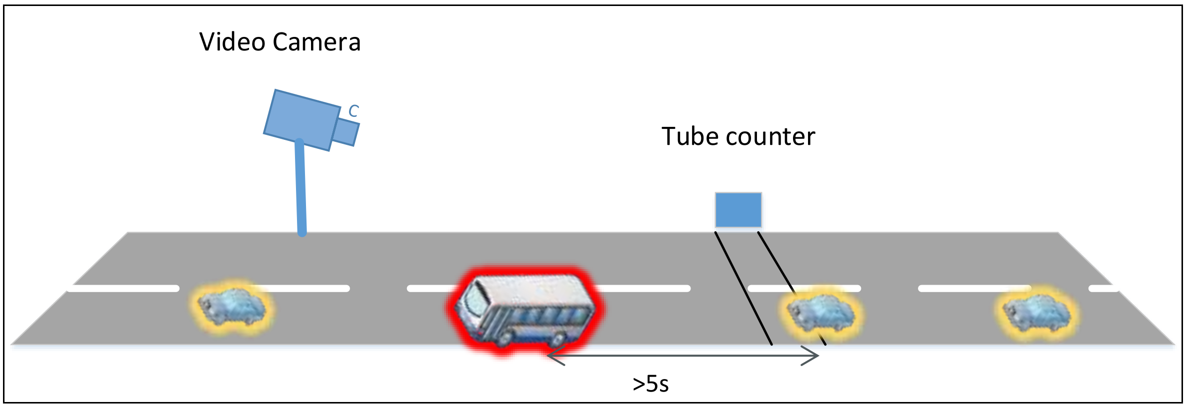


Figure 26 Example of no vehicles in platoon

3.4.6 Sampling method

The sampling methodology was to select the first instance of seeing the relevant bus to the time and direction (A to B and vice versa) profile indicated in Table 12 for each tube site for each day; this allowed 400 samples to be collected from 10 sites over 7 days for both Route 19 and Route 486.

Table 12 Direction of travel for measurements

Time	05:00	08:40	12:20	16:00	19:40	23:20
Direction	AB	BA	AB	BA	AB	BA

Each sample is defined as observing a bus on the video and correlating this to a tube data record, and including the one vehicle in front, and 5 vehicles behind in the sample. The sample size (the number of buses) collected is shown in Table 13. This data was then further cleaned to remove any observations with tube data anomalies (vehicles with more than six axles, speeds over 60mph, gaps less than 0.1 seconds).

Table 13 Sample size (subset of full sample)

Route and speed limit	Before sample size	After sample size
Route 486 30mph	159	Not collected
Route 19 20mph	121	110
Route 19 30mph	121	121

3.5 Detailed findings

3.5.1 The speed of vehicles within the bus 'sphere of influence'

The speeds of buses and also the speeds of following vehicles were captured from the tube counter data. Observations with zero platoon length (see Figure 32) were filtered from this analysis. Figure 27 shows for the sub-sample the average speeds of buses and vehicles in the platoon for Route 19, split for the three 20mph sites and the three 30mph sites.

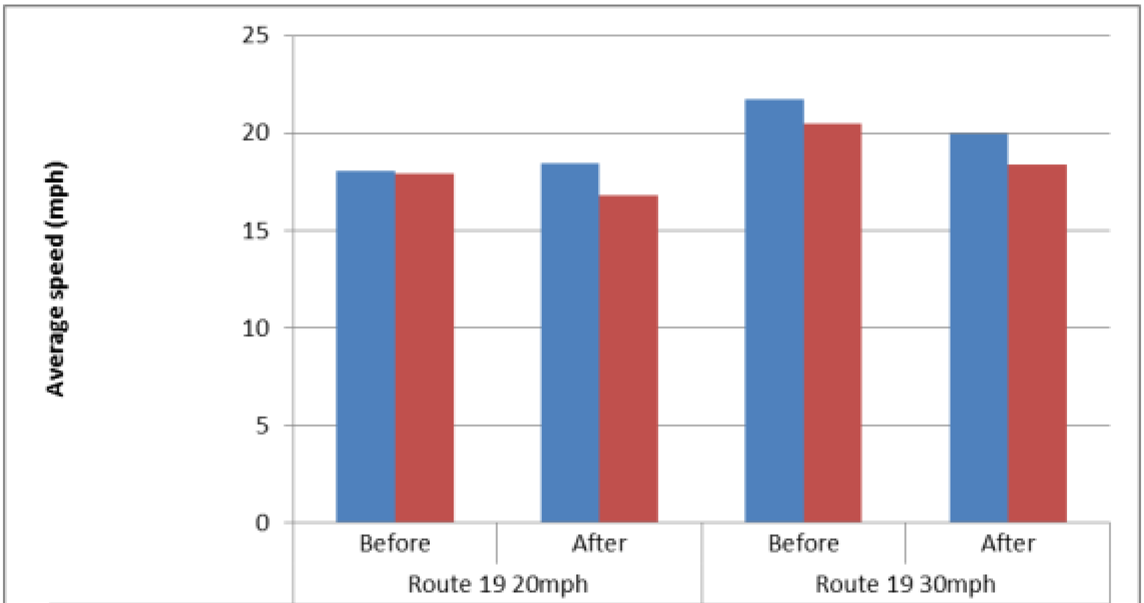
Figure 28 shows the same information for the sub-sample, but also alongside the average speeds of all traffic from the full sample. Bus average speeds were generally slower than general traffic speeds, and the average speeds of vehicles following the bus were slower still. It could therefore be said that the buses had a slowing effect upon vehicles in the platoon behind.

For the sub-sample on the 20mph sites, there was no significant difference in the average bus speed before- and after-ISA, although there was a statistically significant decrease after-ISA in average speed of vehicles in the platoon (p=0.05) from 17.88 mph to 16.79 mph. Figure 29 shows the cumulative distribution of speeds for vehicles in the platoons behind buses on the 20mph sites; this suggests that proportion of vehicles in the platoon exceeding the speed limit reduced from 51.1% to 42.0%, as indicated by the line on the graph at 20mph.

For the sub-sample on the 30mph sites, after-ISA there was a statistically significant decrease in both average bus speed (p=0.10) and in average platoon speed (p=0.01). However, the cumulative distribution graph (Figure 30) suggests that this change was largely due to random variation in the sample with more observations around 10-15 mph after-ISA (which were substantially below the speed limit and therefore likely not to be an effect of the introduction of ISA). The proportion of vehicles in the platoon travelling above the speed limit was similar after-ISA (12.0%) as it was before-ISA (14.1%).

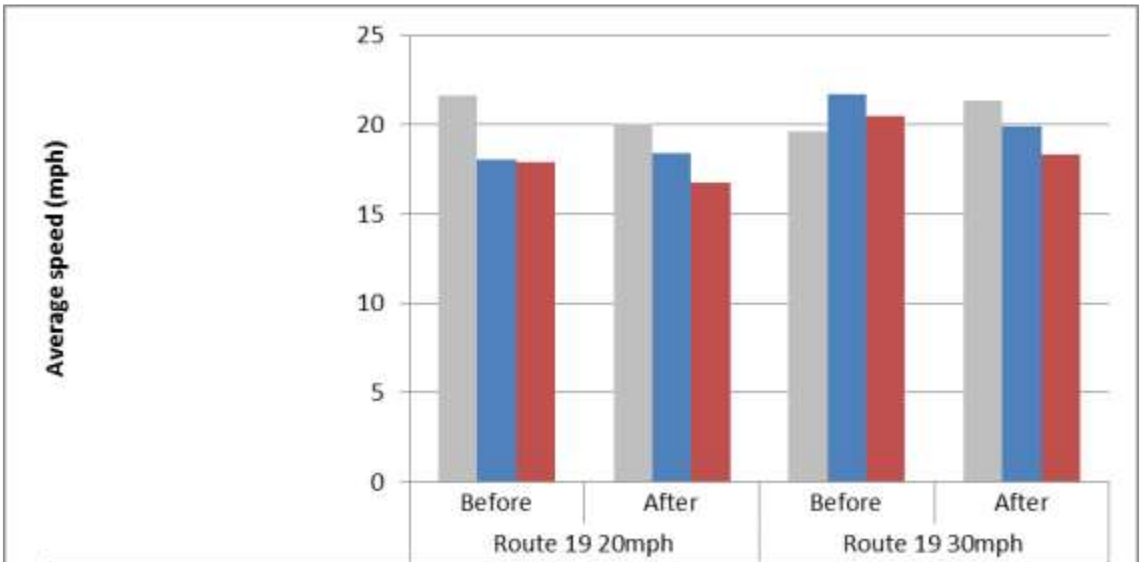
In summary, although only based on a sub-sample for Route 19, at the three 20mph locations the results suggest that the introduction of ISA did reduce the speed of some vehicles in the platoon behind the bus. However, for the three 30mph locations, the introduction of ISA had only a negligible effect on platoon speed.

It is important to note that the ISA does not have an effect below the speed limit, and an examination of data by time of day reveals that the largest difference between the before and after speeds of following vehicles occur when average speeds are naturally higher than the speed limit (typically mornings and evening on route 19).



	Route 19 20mph Before	Route 19 20mph After	Route 19 30mph Before	Route 19 30mph After
Bus	18.06	18.42	21.72	19.93
Vehicles in platoon	17.88	16.79	20.50	18.37

Figure 27 Average speed of buses and vehicles in platoon before- and after-ISA, Route 19 (subset of full sample)



	Route 19 20mph Before	Route 19 20mph After	Route 19 30mph Before	Route 19 30mph After
Average speeds of all vehicles	21.63	20.07	19.66	21.36
Bus	18.06	18.42	21.72	19.93
Vehicles in platoon	17.88	16.79	20.50	18.37

Figure 28 Average speed of all traffic (full sample), alongside average speed of buses and vehicles in platoon before- and after-ISA, Route 19 (subset of full sample)

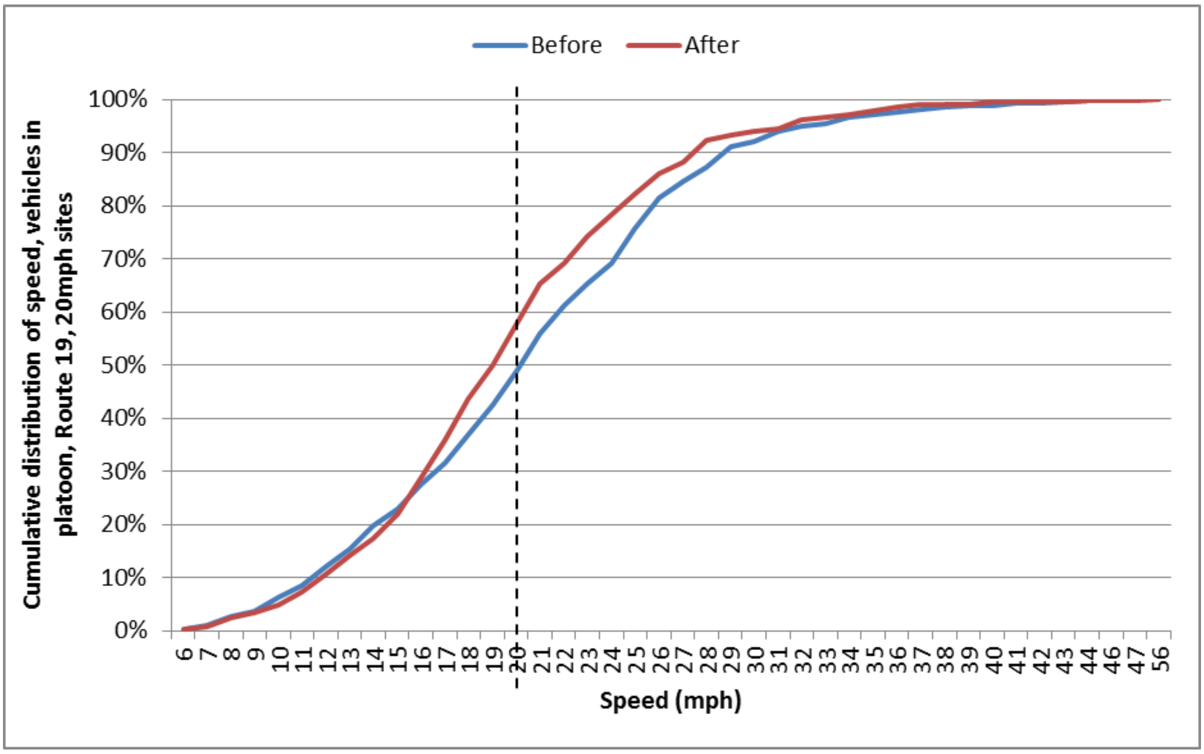


Figure 29 Cumulative distribution of speed of vehicles in platoon at 20 mph sites before- and after-ISA, Route 19 (subset of full sample)

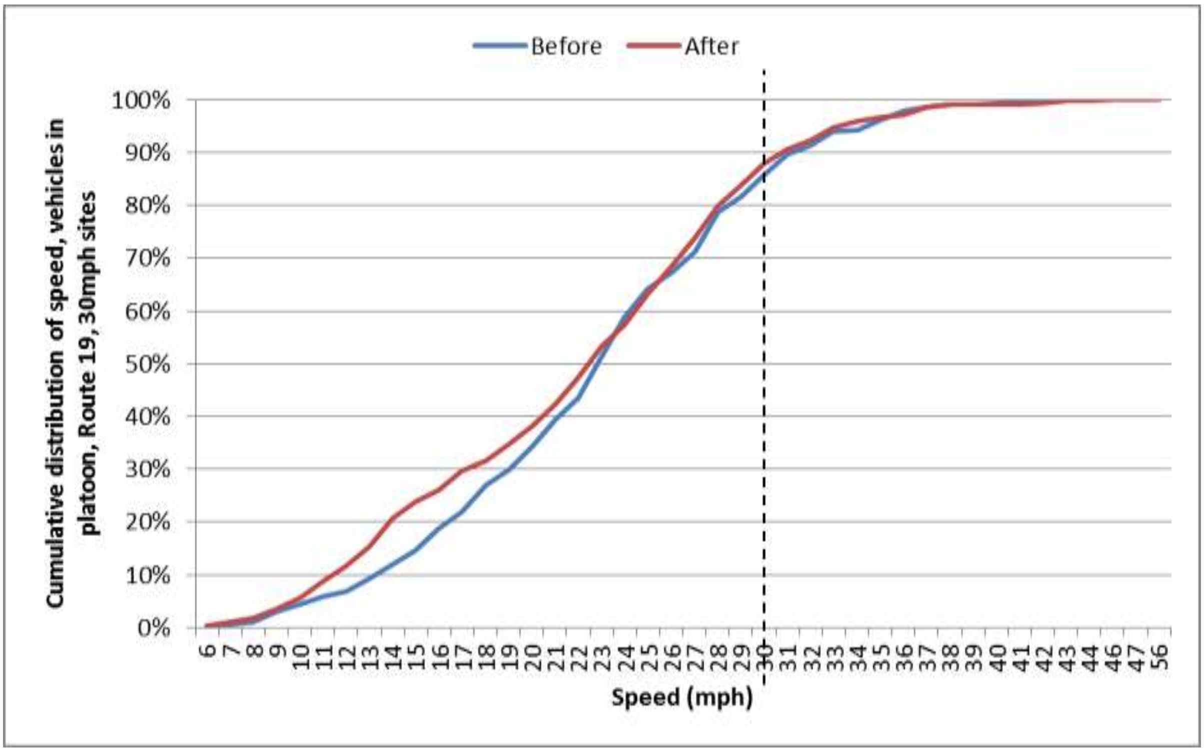


Figure 30 Cumulative distribution of speed of vehicles in platoon at 30 mph sites before- and after-ISA, Route 19 (subset of full sample)

3.5.2 *Average speed of all traffic*

It might be expected that ISA would have an effect of lowering overall average speeds. However, using the example of tube Site '12', 123,135 vehicles passed the tube location at 6mph or above during seven days of monitoring, of which just 1.4% were Route 19 buses (1,764 observations). Given that buses form only a small percentage of all traffic, the potential impact of ISA-equipped buses on overall average traffic speeds is small. It should also be noted that ISA works to limit speeds above the speed limit, therefore any effect on following vehicles would only occur where bus speeds are (without ISA) above the speed limit.

Figure 31 shows the average speed for each of the tube counter locations on Route 19; this is shown for the full one-week period, both before and after the introduction of ISA. It is notable that the average speeds for all vehicles (i.e. not just buses) were higher than the speed limit for Site 4 and Site 5. Of the six main sites, three had an increase in average speed (+0.5%, +4.2%, +1.0%) and three sites had a decrease in average speed (-2.1%, -1.4%, -1.8%). This mixture of increases and decreases is inconclusive regarding the impact that the introduction of ISA may have had on average speeds.

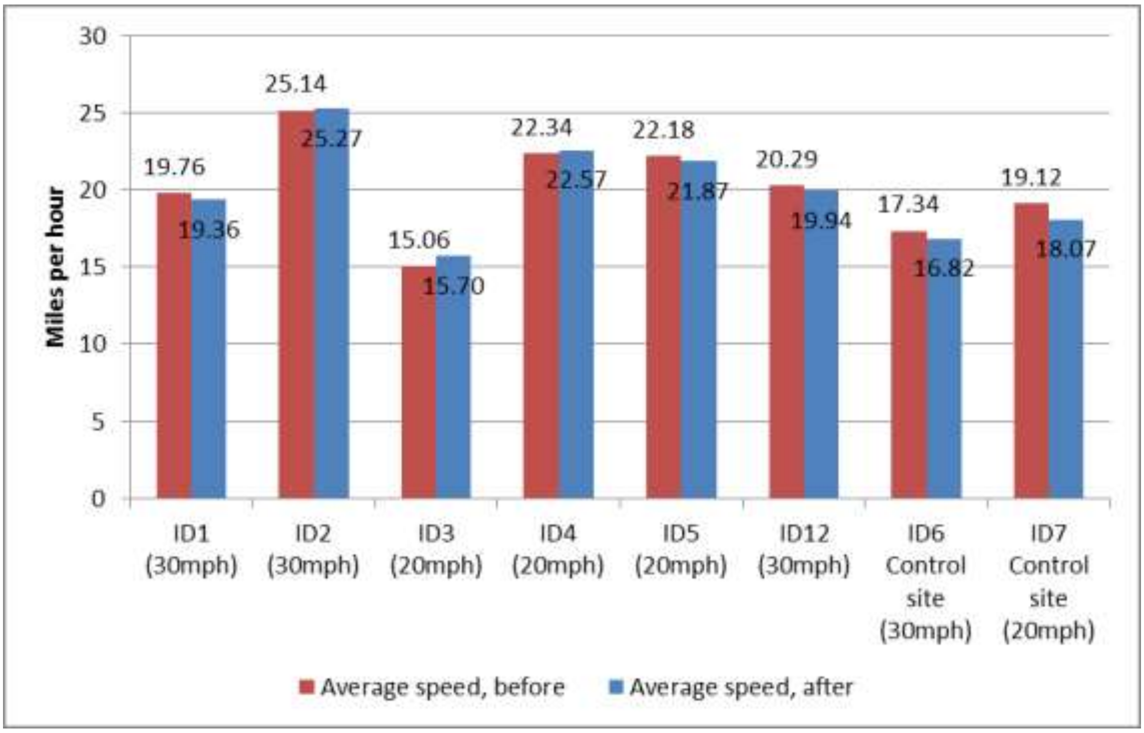


Figure 31 Average vehicle speeds (full sample)

Average speeds tend to mask the effect of different flows at different times of day, and the impact this has upon speed. Speeds tend to err towards the upper end of the range when the vehicle flow is lower, allowing the driver the ability to travel closer to their desired speed. Appendix B holds graphs of before and after speeds by time of day which illustrate this.

Table 14 gives the average speeds, standard deviation of speeds and the proportion of observations that were over the speed limit, both on Route 19 and Route 486 for all sites. Of the six main sites, four sites had a decrease in the proportion of observations over the speed limit and two sites had an increase in the proportion of observations over the speed limit.

Site 7 on the control route (i.e. no ISA in the after survey) experienced the largest change in the proportion of observations over the speed limit (decreasing from 43.2% to 35.2%); this again was inconclusive regarding the impact of ISA.

Table 14 Average vehicle speeds (full sample)

Route	ID No	Location	Speed limit	Before			After			% change in average speed
				Average speed	Standard deviation	Proportion over speed limit	Average speed	Standard deviation	Proportion over speed limit	
19	1	Sloane St, just north of Cadogan Gardens on the single-lane road	30mph	19.76	6.04	4.9%	19.36	5.97	4.1%	-2.1%
19	2	Sloane St, around 200m north of Cadogan Gardens	30mph	25.14	6.22	18.8%	25.27	6.03	18.2%	0.5%
19	3	Rosebery Avenue, just south-west of Pine St	20mph	15.06	4.23	12.0%	15.70	4.34	16.5%	4.2%
19	4	Rosebery Avenue, around 50m south of Arlington Way	20mph	22.34	5.97	67.6%	22.57	5.78	69.5%	1.0%
19	5	Highbury Grove at Aberdeen Lane	20mph	22.18	5.8	65.6%	21.87	5.6	63.4%	-1.4%
19	12	Beaufort St	30mph	20.29	6.66	7.4%	19.94	6.59	6.4%	-1.8%
19 control route	6	Cliveden Place tube to between Sedding St and Bourne St	30mph	17.34	5.58	1.2%	16.82	5.6	1.0%	-3.1%
19 control route	7	Islington Green, just north of junction with Gaskin Street	20mph	19.12	5.72	43.2%	18.07	5.64	35.2%	-5.8%
486	8	Hillreach at around No 48) between Woodhill and Woodrow	30mph	30.21	6.4	52.7%	N/A	N/A	N/A	N/A
486	9	Shooters Hill Rd between Baker Road and Gilbert Close	30mph	27.19	6.99	32.7%	N/A	N/A	N/A	N/A

Route	ID No	Location	Speed limit	Before			After			% change in average speed
				Average speed	Standard deviation	Proportion over speed limit	Average speed	Standard deviation	Proportion over speed limit	
486	10	Shooters Hill Rd between Constitution Rise and Craigholm	30mph	27.29	6.27	31.2%	N/A	N/A	N/A	N/A
486	11	Shooters Hill Rd, east of Eaglesfield road	30mph	30.54	6.03	56.5%	N/A	N/A	N/A	N/A
486 control route	13	Shooters Hill Rd, just west of Zangwill Rd.	30mph	30.05	5.49	48.1%	N/A	N/A	N/A	N/A
486 control route	14	Artillery Place, east of Repository Road	30mph	25.53	5.74	18.2%	N/A	N/A	N/A	N/A

3.5.3 Platoon length behind the bus

Figure 32 below indicates the distribution of platoon length for each location before- and after-ISA. For example, on Route 19 in the 20mph zone, 8.6% of observations had a platoon length of 5 or more vehicles before-ISA and this increased to 18.4% after-ISA. Whilst after-ISA data for Route 486 was not available, before-ISA it had a broadly similar profile to that of the Route 19.

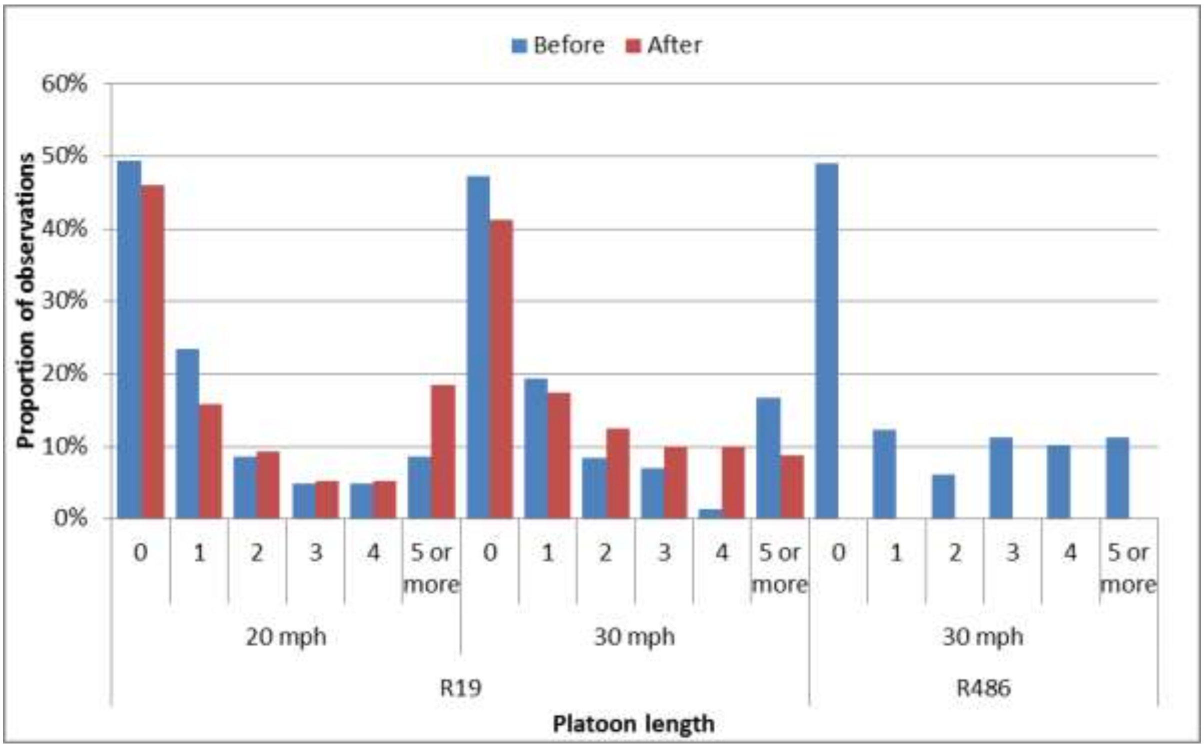


Figure 32 Distribution of platoon length (subset of full sample)

The average platoon length behind the bus can be seen in Figure 33, and this indicates that average platoon length increased from 1.2 to 1.6 vehicles for the 20mph zone. This difference was not statistically significant (although it was nearing significance, with a p value[11] of 0.12). It would appear to indicate a potential effect of greater bunching behind the bus, which was most prevalent after 7pm, probably due to higher average road speeds at this time. For the 30mph zone, there was also no significant difference in average platoon length before and after introduction of ISA.

[11] The p-value is defined as the probability of obtaining a result equal to or 'more extreme' than what was actually observed, assuming that the null hypothesis is true (i.e. there is no effect). So if the p-value is 12%, this indicates that if you assume the null hypothesis is true, you would expect to obtain your observed sample estimate, or more extreme, 12% of the time. A test result is statistically significant when the sample statistic is unlikely enough relative to the null hypothesis that we can reject the null hypothesis for the entire population.

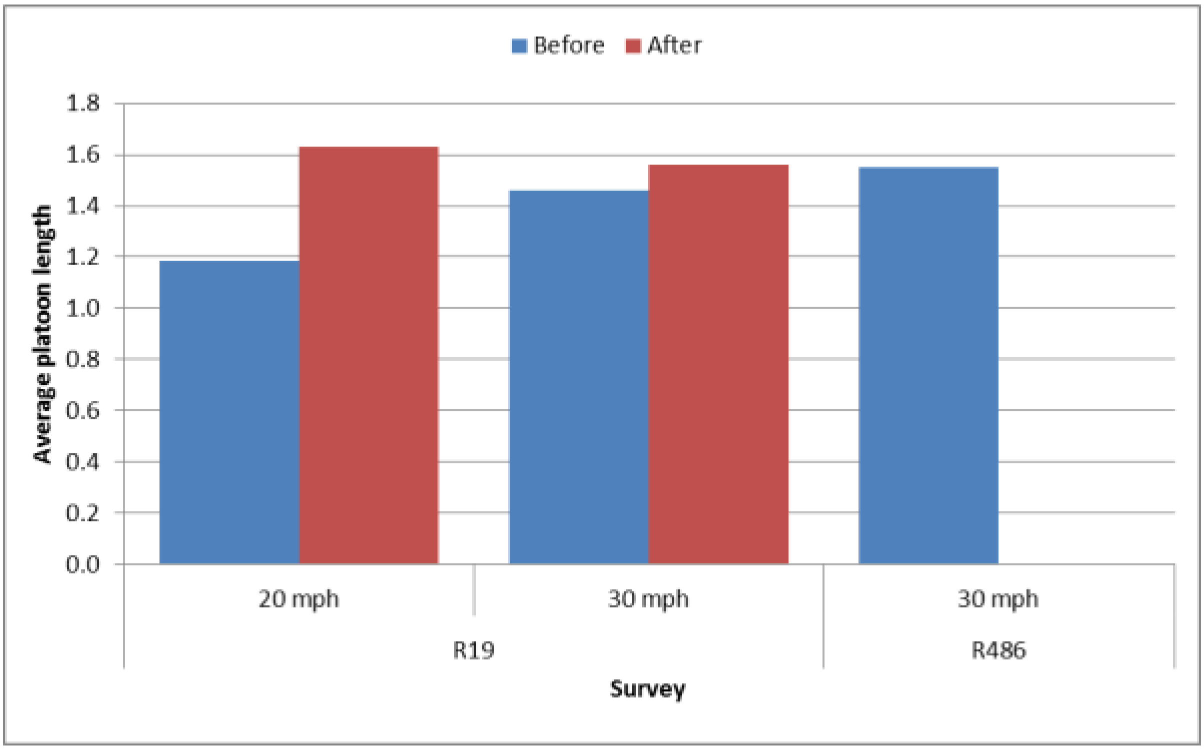


Figure 33 Average platoon length (subset of full sample)

3.5.4 Gap between bus and following vehicle

The average gap between the bus and all vehicles behind in a platoon did not change significantly ($p=0.16$ in 20mph zone) between the before and after scenarios, despite the previous indication of longer platoons. This suggests that a potential concern that drivers would drive closer to the bus in frustration was not supported by the data.

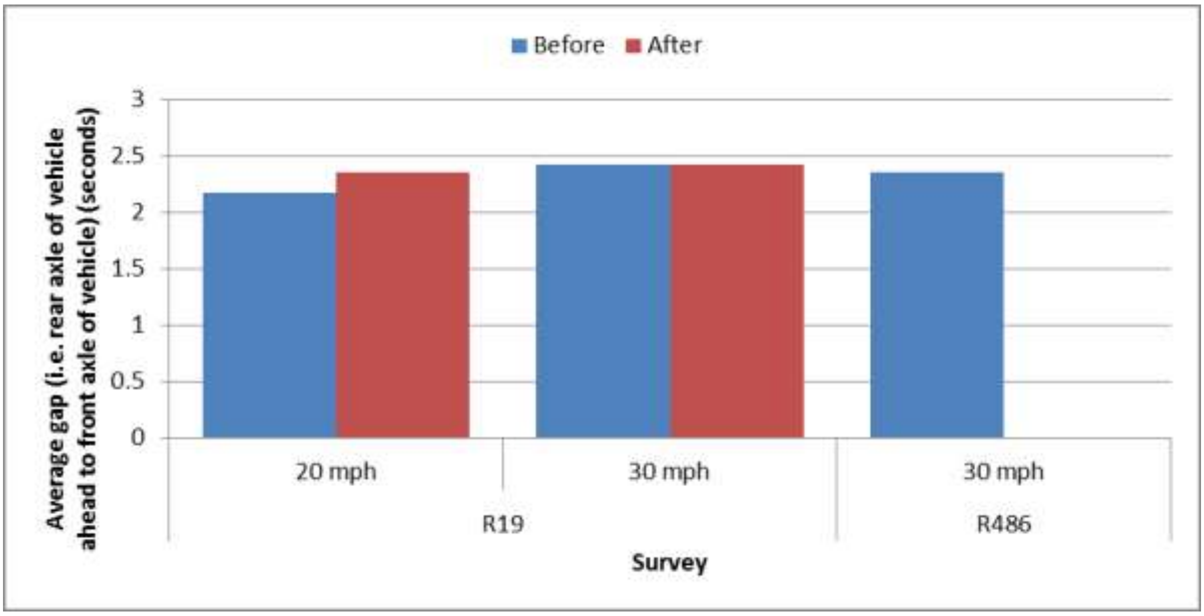


Figure 34 Average gap between vehicles in platoon behind bus (subset of full sample)

3.5.5 Gap between bus and vehicle in front

Data regarding the gap (in seconds) to the vehicle in front of the bus was also examined, as this would indicate if the bus was perhaps struggling to keep up with traffic. This is shown in Figure 35, which indicates that in the 20mph zones in the after scenario, the bus was indeed further away from the vehicle in front, and this was statistically significant at the 90% level ($p=0.08$). There was no significant difference for the 30mph zone.

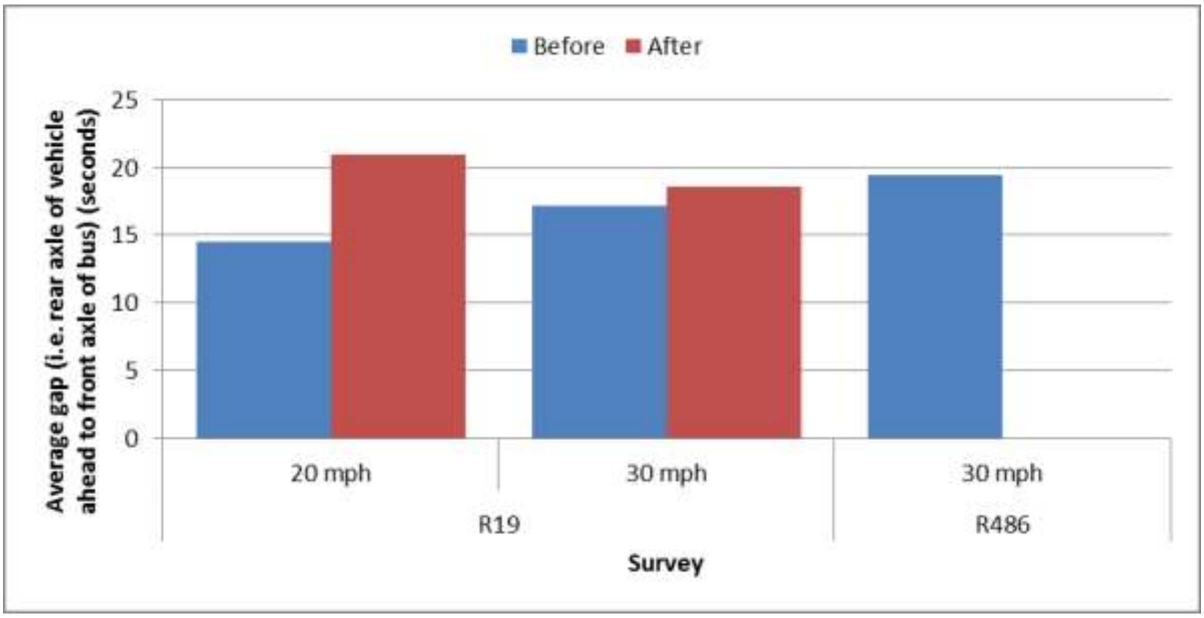


Figure 35 Average gap from bus to vehicle in front (subset of full sample)

4 Research Question 4 - What is the impact of ISA vehicles on the behaviour of surrounding vehicle actions?

4.1 Introduction

A potential negative impact of ISA implementation on selected vehicles within a traffic network is that the desired speed of nearby vehicles that do not have ISA may be higher than that of ISA-equipped vehicles. The disparity in speeds may lead to inappropriate driving behaviour such as overtaking by the non-equipped vehicles.

In order to measure inappropriate behaviour by other drivers, cameras were fitted to the front and rear of ISA-equipped buses (two on each route) and this was viewed at a later time to understand the impacts. Cameras were fitted for a week before ISA implementation, and a week afterwards (after a period of bedding in), and captured 84 hours of operation for each route over the course of a week which were later viewed by researchers. This included periods of bus operation throughout the day and night, and from the start and end of the bus route (this captured both 20mph and 30mph zones — note that the 10mph zones are bus-only). Due to delays in equipping buses serving route 486 with operational ISA equipment, data were not available for collection after ISA installation on this route.

Without the opportunity to communicate directly with road users, it is difficult to understand the reasons why any given road user overtook a bus, or their choice of where and how to do so, and if this was influenced by the impact of ISA. Buses without ISA are not constantly travelling at speeds above the posted speed limit therefore there are few situations where the ISA would actually have an impact, for this reason all vehicles overtaking were counted and a comparison made.

By the nature of bus operations in London which have frequent stops, it is not unusual for buses to be overtaken. Observations of the video data looked at how that overtaking procedure was performed by drivers.

The speed of the bus at the time of each overtaking manoeuvre was unknown and is perhaps irrelevant as a frustrated driver might not overtake at the point at which they feel held up but at the next available opportunity. For this reason all overtaking was graded using a risk scale, to identify changes in overtaking behaviour by risk level.

General overtaking was also recorded, as this can give an indication of increased overtaking even if the manoeuvre was appropriate. Note that whilst the word ‘overtaking’ is used, this also applies to any situation where the bus was undertaken (i.e. passed on the nearside).

4.2 Methodology

Researchers extracted data by viewing bus-mounted video and assessing all overtaking behaviour, and extracted 84 hours for each route in the before ISA and the same amount after ISA across a range of times during the day.

4.2.1 Measuring general overtaking

London’s roads are complex, with lanes of various widths (some allowing overtaking without passing into the opposing lane) and lane types. Drivers were deemed to have passed the bus if they travelled on ahead of the bus in the same direction for a reasonable distance (i.e. they were not alongside to enter a filter lane for example), or if they were attempting an overtaking manoeuvre and aborted it. Further information collected included the hour, direction, speed limit, vehicle type, if the bus was mostly stationary at the time of the start of the manoeuvre (i.e. lower than walking pace, perhaps either slowing or starting from a bus stop) or moving, and if the passing vehicle passed into the lane of oncoming traffic. Each case of overtaking was assessed and noted, and additional consideration was given to those overtaking manoeuvres which were considered inappropriate.

4.2.2 Recorded behaviour

The following behaviours were extracted from the video footage:

- Vehicle type passing the bus: cycle, car, van, lorry, bus, motorcycle
- Bus action: bus stationary, bus moving
- Passing vehicle action: opposing lane entered, no opposing lane entered
- Speed limit zone: 20mph, 30mph
- The hour of day

4.2.3 Inappropriate overtaking

Additionally, inappropriate overtaking (passing) behaviour was rated on a 5-point scale of severity:

1. No risk of collision
2. Minor alteration in course or speed
3. Large alteration in course of speed
4. Severe avoiding action
5. Collision

Given the subjective nature of such a measurement, a sample of the data was cross-checked to ensure independent rater reliability (which was confirmed by this check).

Each route (route 19 and 486) has different characteristics in terms of speed limit and road layout which leads to different speeds and overtaking opportunities. For this reason each is reported separately below.

4.3 Key Findings

Overall, frequency of overtaking buses appeared to be largely similar before- and after-ISA, albeit with a slightly greater proportion of overtaking occurring in the opposing lane after-ISA. This suggests that ISA did not induce additional drivers to overtake but might have had a slight impact upon their propensity to take risk. No clear numerical link was found between the implementation of ISA and observable outcomes of riskier overtaking from the video.

The remainder of the chapter discusses the detailed methodology and data evidence for answering Research Question 4.

4.4 Further methodology and data detail

4.4.1 Fitment of cameras

Cameras were fitted to the front and rear of four buses (two on each route), and were connected to a digital video recording device with a hard drive which enabled data to be extracted from the buses easily. Figure 36 indicates the position of this video equipment.

Figure 36 Position of outboard cameras

Figure 37 provides the duplex video view from the front (left) and rear (right) of the bus.

Figure 37 Typical view from bus cameras

4.4.2 Total overtaking

On route 19, in a period of 84 hours, the bus was overtaken 11,949 times before-ISA and 10,238 after-ISA (Table 15).

The proportion overtaking in the same lane, vs. those overtaking in the opposite lane was remarkably similar before- and after-ISA (see Table 16), as was the proportion overtaking when the bus was stationary vs. the bus moving at the time of being overtaken before- and after-ISA. This suggests that overall ISA had little effect upon the method of overtaking, which might have pointed towards increased risk taking.

Table 15 Method of overtaking before- and after-ISA

Scenario	Number of vehicles overtaking the bus	Entered opposing lane	Did not enter opposing lane	Bus stationary	Bus moving
Before	11949	14.7%	85.3%	96.43%	3.57%
After	10238	14.8%	85.2%	96.23%	3.77%

The number and proportion of each modal type is shown in Figure 38. This indicated a large drop in car overtaking in the after scenario; the causes of this are unknown.

Table 16 Proportion of vehicles overtaking before- and after-ISA

	Cycle	Car	Van	Lorry	Bus	Motorcycle
Before sample size	3145	5739	1119	240	286	1420
Before modal share	26.3%	48.0%	9.4%	2.0%	2.4%	11.9%
After sample size	2777	4450	1175	228	272	1336
After modal share	27.1%	43.5%	11.5%	2.2%	2.7%	13.0%

Riskier overtaking manoeuvres might reasonably be linked to when the bus is moving.

Figure 38 indicates the number of vehicles overtaking when the bus in moving, this shows increases in both motorcycle and cycle overtaking however in absolute numbers these are relatively small and don't allow a significance test.

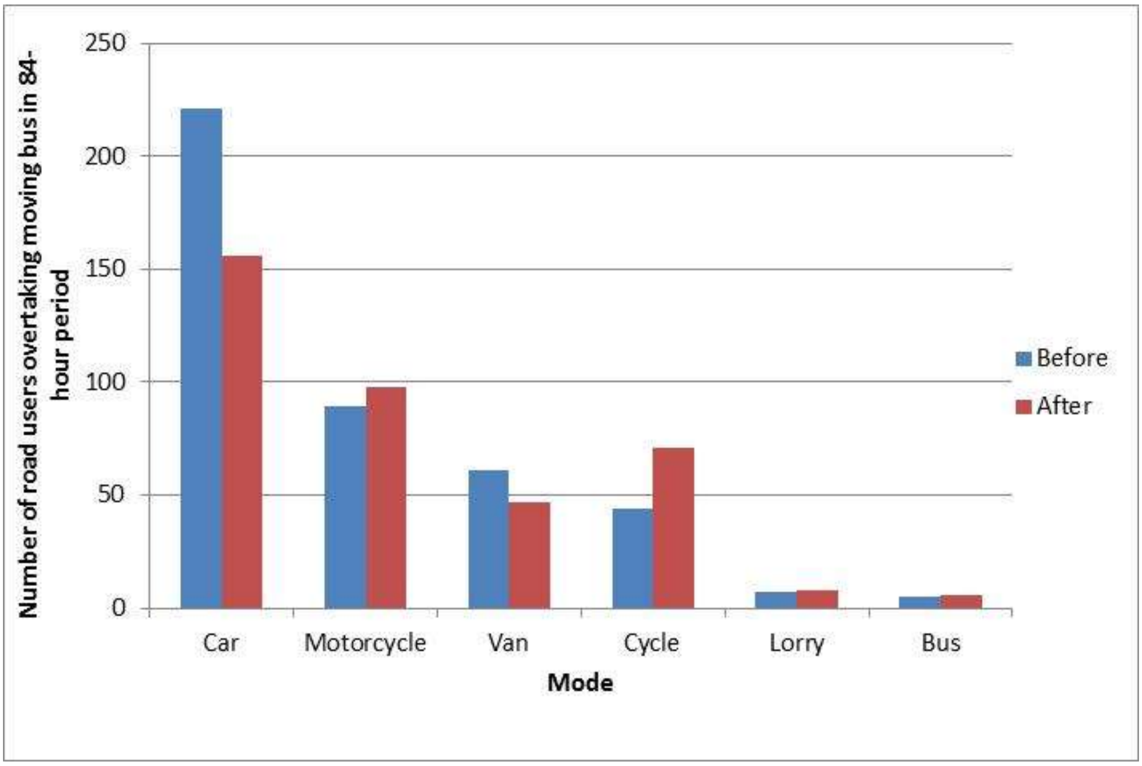


Figure 38 Proportion of sample overtaking when bus is moving

4.4.3 Total inappropriate overtaking

Each overtaking manoeuvre was given a score (see section 4.2.3). Each score at level 2 or above was further examined, and a short description of each was written in order to gain an understanding of the nature of each manoeuvre.

Note that data after ISA installation were not collected for route 486, therefore no comparison can be made. However, route 486 had 55 'before' ISA cases of inappropriate overtaking, whereas route 19 had 66 cases, suggesting that before ISA there were few differences.

4.4.4 Findings

4.4.4.1 Sample size

There were fewer cases of inappropriate overtaking found in the after scenario (39) than the before scenario (66). At the start of the project it was hypothesised that because of the speed-limiting influence of ISA inappropriate overtaking would have increased (in both number and severity) in the after scenario. The reasons for the apparent reduction in such incidents may be due to:

- ISA having little effect, because higher bus speed was found to be generally small and fleeting for buses on route
- The timing of year, with the after scenario measurements taken in greater levels of darkness (October for the after scenario, June for the before scenario)
- General natural variation

- Subjective nature of this data extraction, whereby the differences between levels of risk are open to minor levels of interpretation

The lower number of general traffic vehicles found in the after study led to fewer vehicle-to-vehicle interactions, as risky overtaking is often associated with the slowing of oncoming traffic.

4.4.4.2 Proportion at each speed limit

There appeared to be a slight increase in inappropriate overtaking in the 20mph zones (see Table 17). This might be as expected from information elsewhere in this report which found that ISA is most effective in 20mph zones; however, the difference was slight.

Table 17 Route 19 overtaking at each speed limit before- and after-ISA

Speed limit	Before		After	
	Count	Proportion	Count	Proportion
20mph	38	58%	25	64%
30mph	28	42%	14	36%
Total	66		39	

4.4.4.3 Bus moving or stationary

A measurement (see Table 18) was made of whether the bus was moving or not at the time of the inappropriate overtaking manoeuvre (the bus at walking speed near a stop was taken as 'stationary' as it was recognised many overtaking manoeuvres would occur in anticipation of a full stop by the bus at a bus stop). The proportion of inappropriate overtaking occurring when the bus was moving and when it was stationary was the same before- and after-ISA.

Table 18 Bus movement before- and after-ISA

Bus condition	Before		After	
	Count	Proportion	Count	Proportion
Moving	25	38%	15	38%
Stationary	41	62%	24	62%
Grand Total	66		39	

4.4.4.4 Risk level

The level of risk involved in the overtaking manoeuvre was measured (see Table 19). Level 1 overtaking is not reported here as this is general overtaking with no perceived increase in risk, as reported earlier. Whilst the overall number of overtaking incidents rated at level 2 decreased after-ISA, the proportion increased, suggesting that those riskier overtaking manoeuvres that do occur are done so in a less risky manner in the after scenario. This is counter to expectations.

Table 19 Risk level before- and after-ISA

Risk level	Before		After	
	Count	Proportion	Count	Proportion
2. Minor alteration in course or speed	49	74%	36	92%
3. Large alteration in course of speed	15	23%	3	8%
4. Severe avoiding action	2	3%	0	0%
Grand Total	66		39	

4.4.4.5 Time of day of risk incidents

Figure 39 indicates the proportion of incidents in each hour band. The morning peak appears to be a common time for inappropriate overtaking manoeuvres both before- and after-ISA, with events during the remainder of the day occurring rather randomly. Note that buses did not generally run in substantial numbers before 6am.

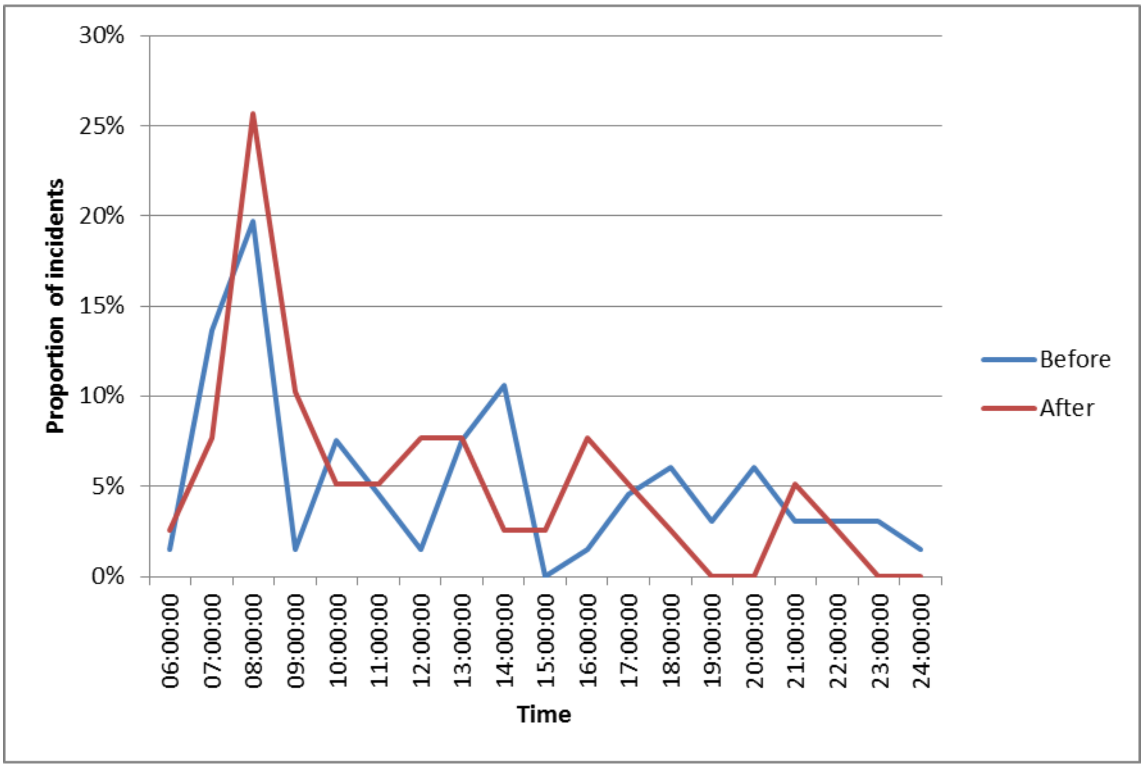


Figure 39 Timing of incidents

4.4.4.6 Vehicle entering opposing lane

A vehicle entering the opposing lane could be seen as increasingly risky, and a slight proportional increase was found following the fitment of ISA (Table 20).

Table 20 Route 19 Opposing lane entry before- and after-ISA

Vehicle entered opposing lane to overtake	Before		After	
	Count	Proportion	Count	Proportion
No	26	39%	12	31%
Yes	40	61%	27	69%
Grand Total	66		39	

4.4.4.7 The type of vehicle overtaking

The type of vehicle instigating any inappropriate overtaking manoeuvre was also assessed and there was no substantial change when comparing before and after ISA (Figure 40).

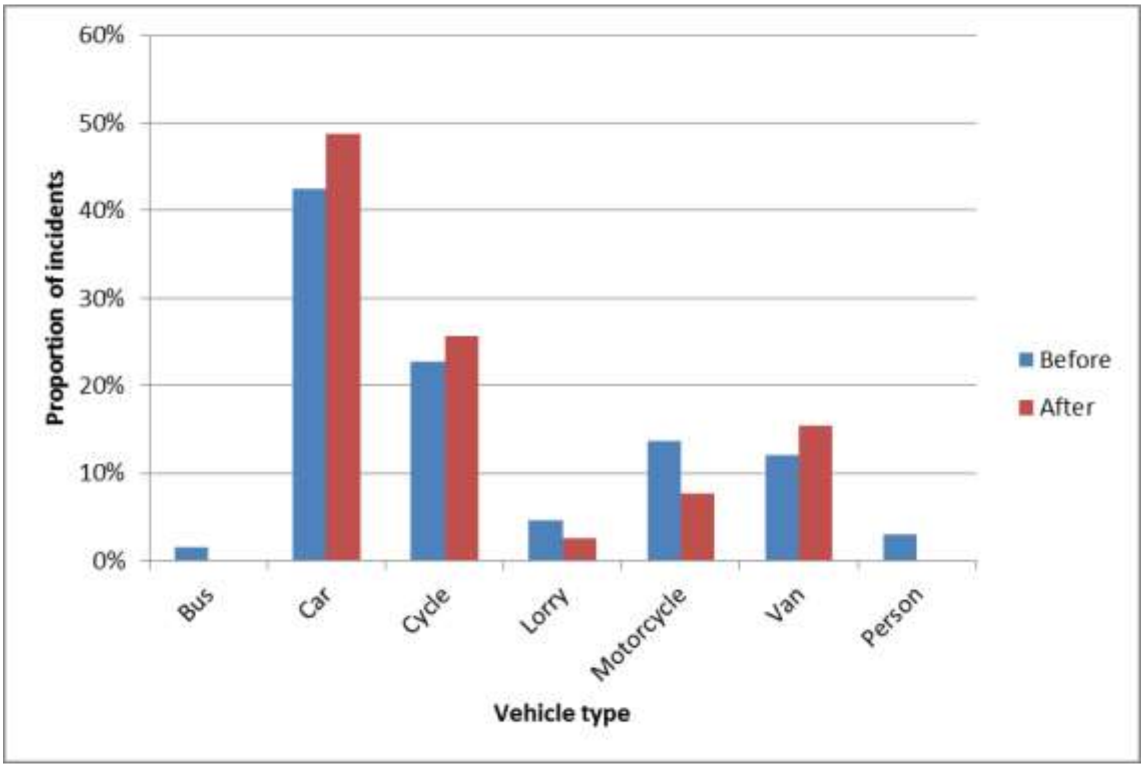


Figure 40 Route 19 type of vehicle instigating incidents before- and after-ISA

5 Research Question 5 - What are the benefits and disbenefits of ISA for TfL?

5.1 Introduction

The potential for ISA-induced speed reductions have obvious societal benefits both in reducing the risk and severity of collisions, and potentially reducing noise, vibration, and air pollution. It also has the potential for negative outcomes, such as triggering unsafe behaviour in other drivers and increasing journey times. Two key measures which TfL are assessed against are emissions and safety, and this section describes the impact in these domains. Evidence was primarily drawn from speed and journey time data, as speed can be related to both emissions and safety.

5.2 Journey time changes - introduction

A potential impact of reducing the ability for buses to exceed the speed limit is that it will increase journey times, and this may have the disadvantage of reduced convenience for passengers, and the need to increase the number of buses on a route to maintain frequency and that this would be an increase in cost to TfL.

Overall journey times for both before ISA-implementation and after ISA- implementation were calculated for both routes using iBus data.

As was found with regards to Research Question 1, the majority of higher speed without ISA occurred in 20mph zones, with little impact in 30mph zones. As roads in London are largely 30mph any changes in journey time are likely to apply more on routes with 20mph zones.

5.3 Methodology

The methodology for this work was to use data from other parts of this report regarding the scale of journey time changes from ISA implementation and to extrapolate any journey time change to the whole bus fleet.

5.4 Findings

The iBus data for one representative vehicle on route 19 (WHV17 - a Tuesday in June 2015) found a 0.11mph theoretical speed difference between having and not having ISA. Subsequent before/after data comparison on a whole week of data for journey times, once alterations were made to account for general vehicle speed changes, found a 0.12mph change in speed. At a previous average speed of 8.43mph, a 0.12mph drop would mean a 1.4% decrease in speed therefore a similar number of buses required as an increase. Each bus route will be affected differently by ISA, dependent on its' before and after ISA average speed so it is not possible to calculate the potential impact across the London bus fleet by a simple extrapolation of findings from this trial. However, it is possible that any small marginal increase could be absorbed within existing turnaround times.

5.5 Potential impact upon number of operational buses required

Buses operated on behalf of TfL presently tend to operate on a 'number of buses per hour' basis, with an attempt to ensure the headways are even. The calculation of the number of buses required to service a route is the total return time of the end-to-end journey in minutes (including any layover required), divided by their headway. For example if the return journey was 152 minutes and there were 8 buses per hour, a total of 20.26 buses would be required, and therefore at least 21 buses would probably be put in to service to meet the peak vehicle requirement. The journey time in this example would have to extend to over 157 minutes (5 minutes more) for the number of buses to increase above 21, which would mean the expensive addition of more buses. Figure 41 indicates this stepped requirement for additional buses.

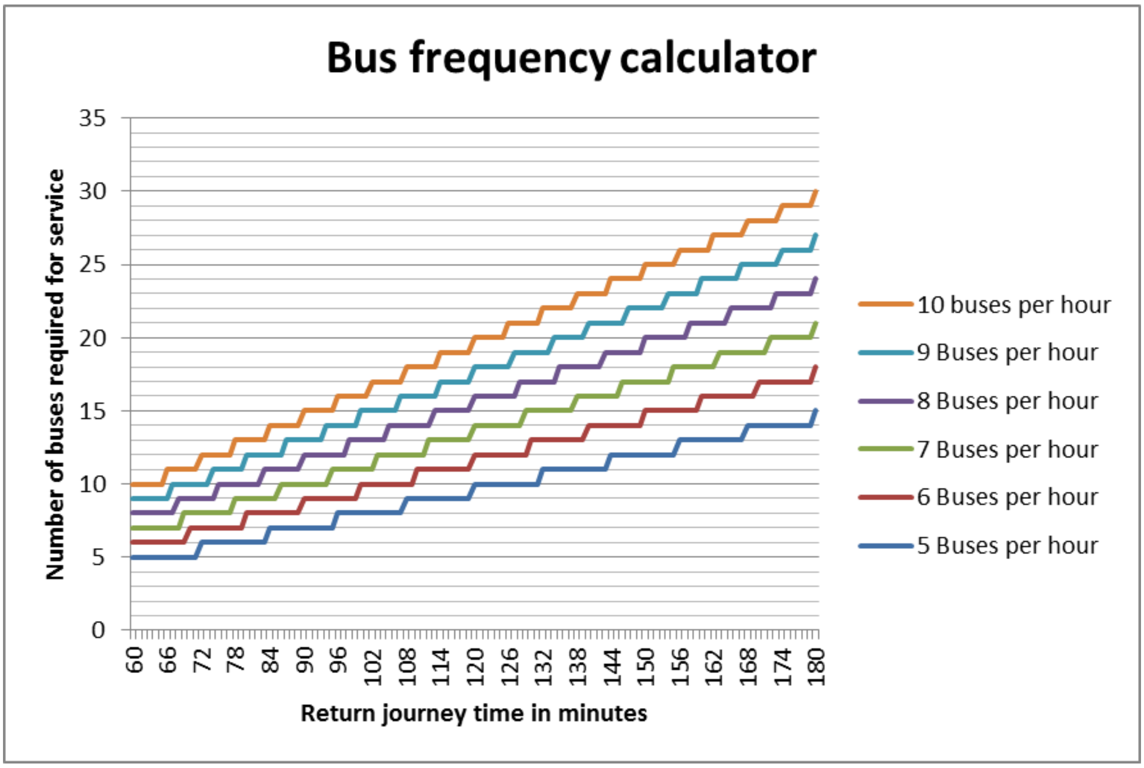


Figure 41 Stepped bus requirement

The theoretical reductions in speed caused by ISA mean that some additional buses may be required on some routes, and this depends entirely upon the journey time and frequency and how close the change in speed takes the bus requirement to the next step up in bus number. TfL could calculate this from iBus data for a wider variety of routes than those covered by this report by:

1. Using iBus data to calculate the theoretical reduction in speed brought by ISA
2. Calculating the revised journey time vs. the present journey time
3. Calculating the number of buses required as above
4. Determining if this requires additional buses over those already contracted as part of the service.

Care should be taken as the theoretical reductions in speed are generally expected to be low across the fleet given the fleeting nature of higher bus speed events found in other areas of this report. This increase in time may fall well within the general variance of journey times. Buses may also only be travelling above the speed limit to the next queue, therefore the time 'lost' by adhering to the speed limit may be illusory.

Where additional buses are required, the cost of this can be compared against the cost of collisions saved and the cost of ISA implementation, which could form part of any cost benefit analysis.

It might also reasonably be assumed that the journey time performance of any bus journey has been adequately assessed by both TfL and the bus operating company when agreeing to a contract, and that journey time would not include any requirement to operate a bus above the speed limit. Any time difference from higher speed would therefore simply add to the time a bus is stood at its turnaround point, unless the higher speed was to mitigate delays along a route that were unforeseen at the time of planning the route, such as congestion (in which case, tackling congestion would be a priority). It is plausible that the increasing conversion of 30mph zones to 20mph zones across London would increase the time required for a bus to complete an end-to-end journey and therefore routes will need to be re-planned on that basis. ISA has the potential to reveal any journey planning anomalies.

5.6 Emissions - introduction

In order to evaluate the effect of ISA, emissions rates have been evaluated from speed data collected from in-service buses.

5.7 Methodology

The speed traces, together with the location (longitude and latitude data) were taken from iBus information provided by TfL. A procedure was set to automatically examine the satellite data files and extract the appropriate records. These were then stored in an Excel spreadsheet. It was noted that the speed data was only recoded as integers (rounded to a whole number). As this could cause artificial steps, producing accelerations and decelerations, the speed traces were smoothed using a T4253H filter. An example of the smoothing is shown in Figure 42.

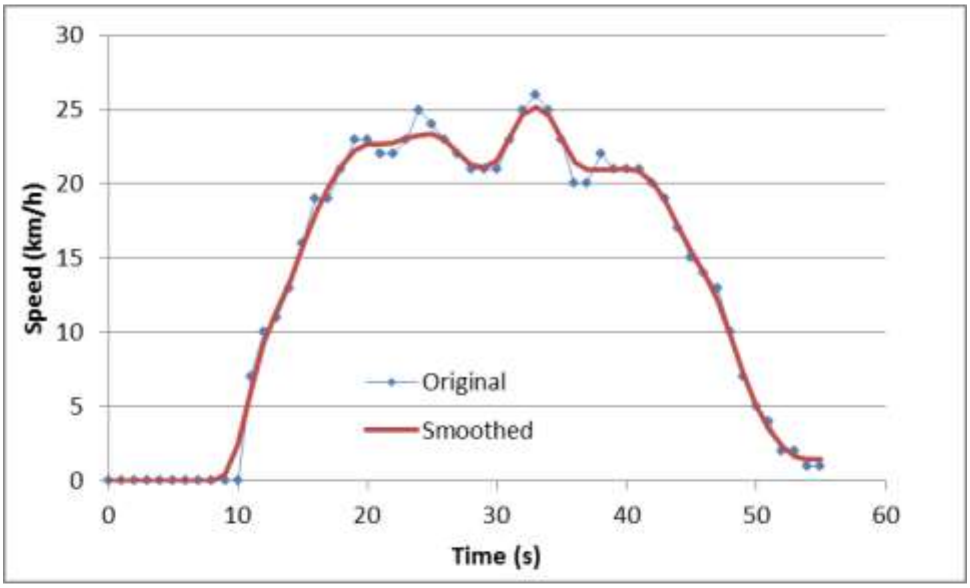


Figure 42 Speed trace before and after smoothing

5.8 Findings

The analysis has shown contradictory results. For Region 1 to the north of bus route 19, there has been a small decrease in emissions and fuel consumption – CO_2 and fuel consumption decreasing by 4.5%. However, for Region 2 towards the middle of route 19, the results show an increase of about 10% in NO_x and PM emissions, whereas CO_2 and fuel consumption are almost the same.

Additional analysis is required on the data to try to determine if these changes are due to changes in traffic conditions or due to ISA. Also, due to the large variance exhibited from the data examined, a larger database may need to be examined to fully evaluate the effect of ISA. Note that the data provided here is necessarily modelled as the research was purely observational, and may not fully match real-world or chassis dynamometer emissions testing.

It should also be noted that these relate to 20mph zones only (across which ISA is most active on this route), so cannot be extrapolated across the bus network which heavily utilises 30mph zones.

5.9 Emissions data discussion

The smoothed speed traces were used as input into PHEM (Passenger car and Heavy duty Emission Model). Each trace was run through PHEM for a medium sized Euro V bus. The resulting outputs included the overall trip emissions and also the second-by-second emissions. As each trip was different, the second-by-second results were used to populate the original speed trace files (which also contained the position data).

5.9.1 Emissions comparisons

As each iBus file started and ended at different locations, with varying trip lengths, to allow the emissions to be compared, data over set sections were extracted. Two sections were identified which corresponded to the location of the 20mph speed limits (see Figure 2):

Region 1 – northern 20mph section

Region 2 – central 20mph section

5.9.2 Emissions results

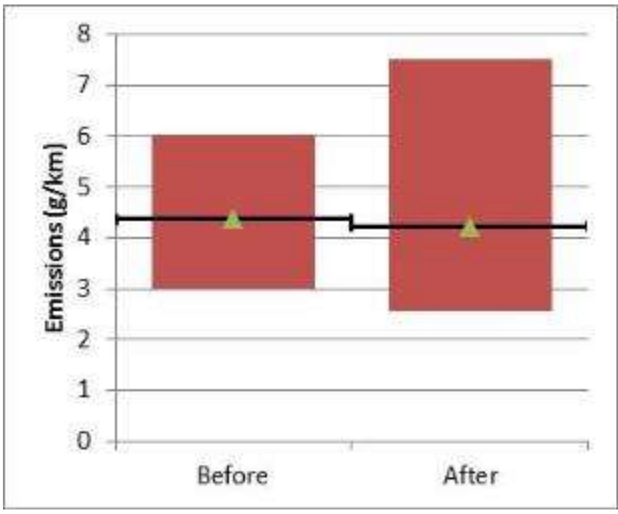
The resulting emissions over each sub-trip have been extracted, summated over the trip and tabulated. The overall results are presented in the next sections.

5.9.2.1 Region 1

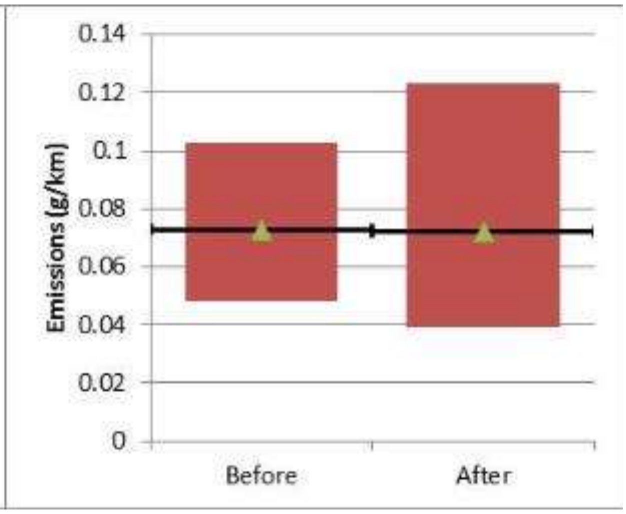
The overall statistics for Region 1 are presented in Table 21. The table includes the change in average emissions and fuel consumption – there is a small reduction in the emissions and also the amount of fuel consumed. However, there is a large variance in the results. This is illustrated graphically in Figure 43. The columns show the variation in the results. This is much larger than the observed changes.

Table 21 Minimum, maximum and average results before and after the introduction of ISA for Region 1

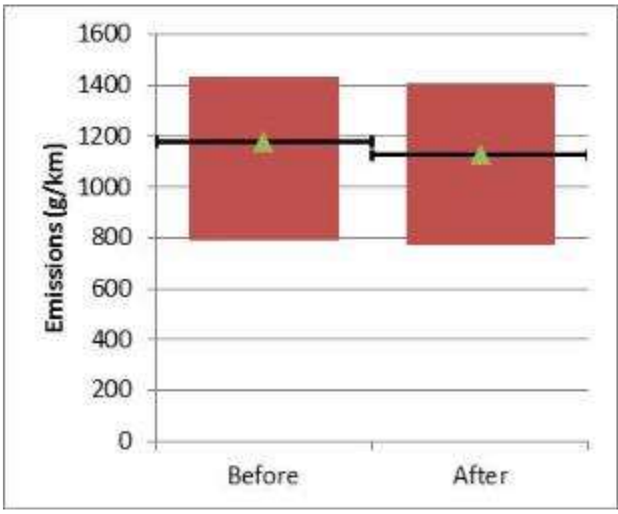
Parameter	Stage	Min	Max	Average	Change
NO_x	Before	3.007	6.018	4.365	-3.2%
	After	2.563	7.501	4.227	
PM	Before	0.048	0.103	0.073	-1.3%
	After	0.039	0.123	0.072	
CO_2	Before	791.0	1434.5	1178.6	-4.6%
	After	770.9	1407.3	1124.9	
FC	Before	252.0	456.8	375.2	-4.5%
	After	245.4	448.4	358.2	



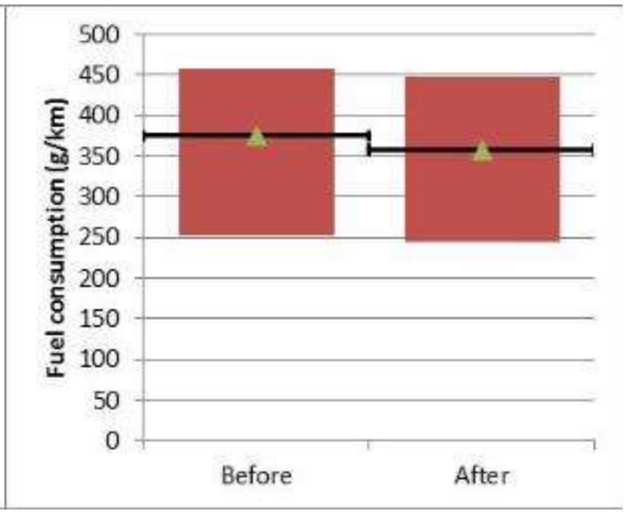
a. NOx emissions



b. PM emissions



c. CO_2 emissions



d. Fuel Consumption

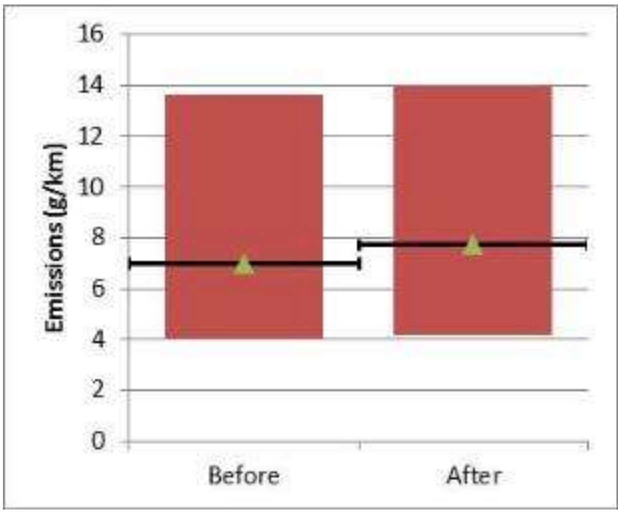
Figure 43 Comparison of the emissions before and after the introduction of ISA for Region 1

5.9.2.2 Region 2

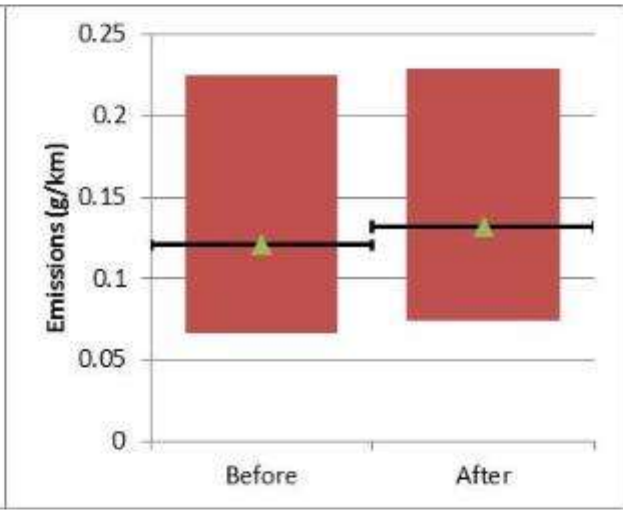
Similarly for Region 2, the overall statistics are shown in Table 22. For this region, there is an increase in NO_x and PM emissions, with very little change in CO_2 emissions and fuel consumption. The variations of the results are shown graphically in Figure 44, which again show a large variance in the results.

Table 22 Minimum, maximum and average results before and after the introduction of ISA for Region 2

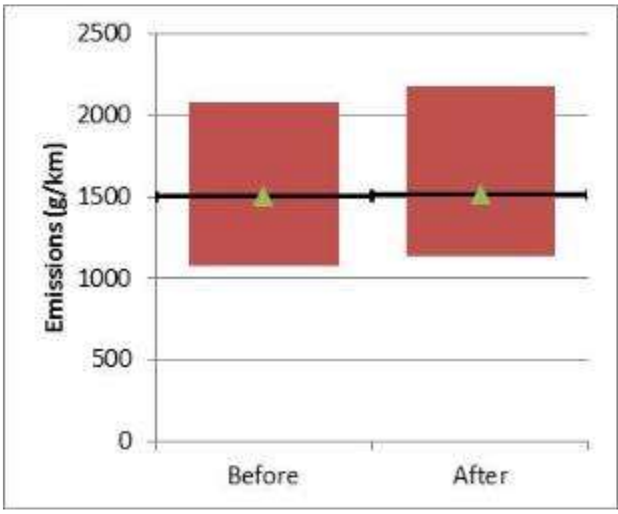
Parameter	Stage	Min	Max	Average	Change
NO_x	Before	4.074	13.663	6.973	10.8%
	After	4.192	13.968	7.724	
PM	Before	0.066	0.225	0.121	9.2%
	After	0.075	0.229	0.132	
CO_2	Before	1077.6	2082.7	1501.6	0.7%
	After	1135.3	2184.5	1512.1	
FC	Before	343.5	664.9	478.6	0.7%
	After	361.7	697.3	482.1	



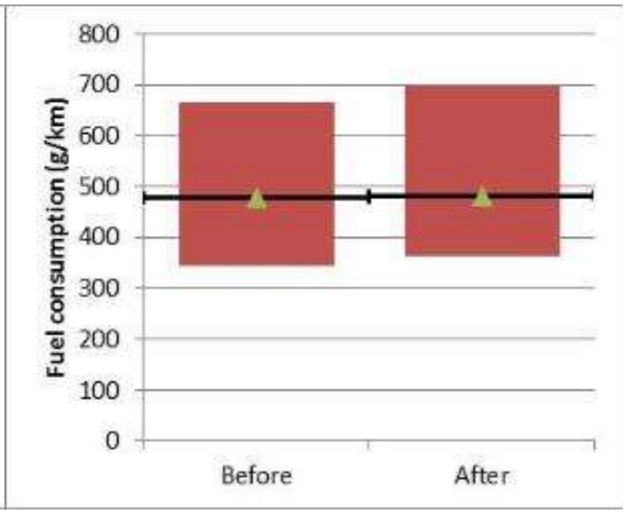
a. NOx emissions



b. PM emissions



c. CO_2 emissions



d. Fuel Consumption

Figure 44. Comparison of the emissions before and after the introduction of ISA for Region 2

5.10 Safety - introduction

Previous TRL research[12] has concluded that a 1mph reduction in speed equates to around a 5% reduction in collision frequency. ISA has the potential to reduce bus speeds but only to the speed limit, drivers may compensate by driving faster in other locations (but still within the speed limit), thus reducing the impact of safety improvements.

5.11 Methodology

Figure 45 indicates three theoretical states:

[12] Taylor, M. C., Lynam, D. A. and Baruya, A. (2000), TRL Report 421 – The Effects of Drivers' Speed on the Frequency of Road Accidents. Crowthorne: TRL

1. Non-ISA bus – this follows a normal profile up to the 20mph limit and then exceeds it for some time
2. ISA-equipped bus – this follows a normal profile up to the 20mph limit and then does not exceed 20mph
3. Compensated speed – this is the driver compensating for not being able to speed by exceeding their normal (and legal) speed in other places. Whilst speed and therefore risk is reduced at certain locations, it would also be increased in other locations.

For this reason the net speed will give the most appropriate measure of safety, and given the set distances between bus stops, safety can be calculated by the average speed (calculated from time) between bus stops. Time at bus stops is discounted because of the impact of passenger numbers on overall boarding times. Traffic conditions are far harder to isolate, therefore the average vehicle speed change across route 19 was removed.

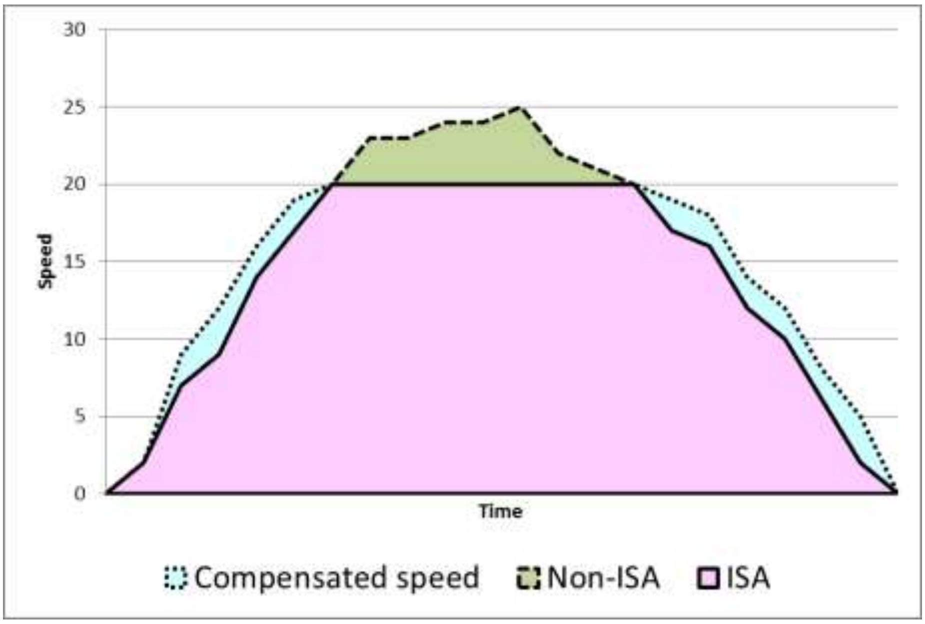


Figure 45 Theoretical changed speed profile

5.12 Findings

After taking into account general traffic speed changes, the overall mean speed of buses on route 19 reduced by 0.12mph after ISA when comparing to before ISA. This equates to a 0.6% reduction in casualties given the rule of thumb that a “1mph reduction equates to a 5% reduction in casualties” for general roads, and equates to a 0.72% reduction in casualties if a 6% reduction is used for urban roads with low average speeds, which is becoming increasingly common in London, with many road speed limits reducing from 30mph to 20mph.

STATS19 data on collisions involving buses and coaches covering a three-year period from 2012-2014 was examined. This revealed a 0.6–0.72% reduction in casualty numbers for the 3-year period (Table 23). Note that these figures include coaches, therefore are likely to over-represent the actual scale of casualty reduction that might be attributed to fitting London buses with ISA.

Table 23 Bus and coach related injuries 2012-2014

Accident severity	Count of Accident Severity over 3 years	1 year average	5% reduction in casualties	6% reduction in casualties	Cost per casualty	Total yearly value with 5% reduction in casualties	Total yearly value with 6% reduction in casualties
Fatal	40	13.3	0.08	0.096	£1,742,988.00	£139,439.04	£167,326.85
Serious	550	183.3	1.1	1.32	£195,863.00	£215,449.30	£258,539.16
Slight	5367	1789.0	10.734	12.8808	£15,099.00	£162,072.67	£194,487.20
Grand Total	5957	1985.7	11.914	14.2968		£516,961.01	£620,353.21

A similar calculation was also undertaken for the safety impact on following vehicles, and this was found to be negligible once the small reduction in speed was factored into the additional following vehicles and given the lower likelihood of injury from a car collision compared to a bus collision.

5.13 Speed data discussion

Deriving the changes in collision or injury numbers is complex. Without the benefit of a long-term STATS19 analysis of an 'after' scenario, potential changes in injury levels are generally calculated as a function of the change in mean speed. As has been found elsewhere in this report, ISA only directly impacts upon the bus, and has a minor sphere of influence around it on other vehicles. Therefore, the impact of ISA does not reduce the mean speed of all vehicles as might be expected for other forms of traffic speed control (such as speed humps or average speed cameras). For this reason impacts are only related to the bus and any influenced vehicles, rather than to all vehicles. This should also be treated with caution, as whilst ISA may reduce bus speed and allow the driver more time to avoid collisions, the same might not be said of other vehicles which are not fitted with ISA and may cause a bus collision.

Note that the average reduction in bus speed relates to on-route buses only. It was found that considerably higher speeds (often above the speed limit) were found off route. The inclusion of an ISA system which covered all of London for all buses would have a larger impact on reducing bus mean speed.

Several variant 'rules of thumb' exist but each brings a different potential casualty reduction level. Several potentially useful rules are cited below. Where appropriate these can be applied against the Department for Transport's values for injury level which are used to assign a value to potential impacts.

In terms of cost-benefit analysis, the ISA equipment is likely to be fitted to each bus and remain with that bus when it is sold, buses in London might have a typical lifespan of 5 to 7 years, therefore cost might reasonably be spread over this timeframe unless other arrangements for equipment were found. The actual costs of the ISA equipment were not known for this study.

5.13.1 A 1mph increase in speed leads to a 10-15% increase in crash frequency

One study of urban areas, which may apply better to a London scenario, is that a 1mph increase in average speed may lead to a 10-15% increase in crash frequency (Taylor, Lynam & Baruya, 2000). It might be argued that the reverse would also be true, and that a 0.12mph reduction in bus mean speed would lead to a 1.2-1.8% decrease in crashes. However given that many crashes may occur without injury, and the number of bus crashes is unknown, calculations of value would not be possible. Furthermore this is confounded because this rule applies to the average speed of all vehicles, and that roads with a small speed variance are safer than those with larger variance[13] (Aarts & van Schagen, 2006), i.e. there may be a decrease in safety because of the larger variance in traffic speed brought by ISA.

5.13.2 Speed as a contributory factor in bus collisions

The key functionality of ISA is to reduce vehicle speed to the speed limit, but there are questions regarding how this contributory factor relates to bus actions resulting in injury. In

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13 CPR 1398, A summary of the evidence on the costs and benefits of speed limit reduction, Lawson et al, Transport Research Laboratory, 2012

terms of reduction in collisions, the STATS19 data for London from the start of 2012 to the end of 2014 was examined and only found 11 cases of a bus having a causal factor of speed in excess of the speed limit resulting in injury, from nearly 6000 vehicle injury incidences involving buses. This is many magnitudes less than other causal factors such as distraction or failing to look properly.

6 Research Question 6 - What are the benefits and disbenefits of ISA for the bus operator?

6.1 Introduction

This research question is addressed by two parameters:

- Fleet journey times
- Bus fuelling data

6.2 Fleet journey times methodology

Journey times are important for bus reliability and the number of buses required on a service, which has a direct impact upon operator profitability. Journey times are available for the times between the starts from each stop. This is subject to waiting time at the stops which is independent of any effect from ISA. For this reason, average speed between stops which excludes this stoppage time is shown below.

Speeds between specific bus stops were measured for route 19 both before and after ISA for a week using iBus data supplied by TfL, to understand if changes related to ISA were identifiable. Speeds on any given section may be subject to specific local traffic impedances, including traffic works or temporary blocks. This was not undertaken for route 486 as only one bus was fitted with a working system in the after scenario, which would give no greater information than the separate iBus data for that bus (E50) which is reported in Research Question 1.

Speeds are based upon a mean of grouped speeds as this was the data available from TfL, and are therefore indicative. It should be noted that these speeds include time spent accelerating and decelerating, and are not spot or maximum speeds.

Speeds in the before scenario between the Finsbury TH to Sadlers Wells bus stops were found to differ substantially so a different week was chosen for that data. It is likely that some local works impacted upon the speeds.

6.3 Fleet journey time key findings

Overall average speeds of buses fell, particularly at 20mph zones (see Table 24) where the largest reduction was 2.16mph, whereas spot speeds on nearby speed tubes did not show the same level of fall. This suggests that ISA was effective in lowering bus speeds on the 20mph roads.

6.4 Bus fuelling methodology

Bus fuelling data is available from a variety of sources including:

- Bus operator data from both the ‘fuel nozzle’ readings
- Onboard ‘mix telematics’ system

Note that ‘after’ data was not calculated for route 486 as only one bus was fitted with ISA and this would not have been statistically reliable.

6.4.1 Bus operator fuel data

A key source is the refuelling records provided by the bus operator. This data may hold some inconsistencies as accurate records, particularly for previous years, are not always available, and the buses used on each route are subject to change, can alter naturally in performance, some are hybrids which have dramatically lower fuel usage, and may be subject to driver behaviour and passenger loading influences.

Fuelling for each bus is recorded automatically on electronic records by the bus operator, and these are examined for three scenarios:

- The second week in June 2014
- The second week in June 2015
- Several weeks after ISA switch on (dates of collection week beginning 5th October 2015)

6.5 Bus operator fuel data key findings

Statistical tests (t-tests) were conducted separately for 15 diesel vehicles and 14 hybrid vehicles on route 19 to compare the average fuel consumption with and without ISA. The tests showed that there were no statistically significant differences between the before and after data ($p>0.25$ for all four tests).

The findings of the fuel data indicate no detectable difference between ISA off and ISA on, with readings largely similar and the standard deviation of readings clearly overlapping. This correlates with the low level of speed change seen since ISA activation. The outcome of this difference is that ISA will not noticeably alter fuel consumption, and thus cost, on these routes on the two bus types measured. This may not apply to other buses on other routes.

The remainder of the chapter discusses the detailed methodology and data evidence for answering Research Question 6.

6.6 Journey times detailed data

Overall route average speed of buses fell between the before and after scenarios (see Table 24), although this is likely to include some element of speed reduction because of ISA, and some general slowing of speeds across the route. This can be seen in Table 25 where if the general traffic average speed[14] reduction is removed from the reduction in average bus speed, the impact of ISA is in the region of a 0.12mph reduction in speed on average.

14 The general average traffic speed was calculated by removing outliers above 50mph as these may be perceived as anomalies in the data collection rather than actual speeds.

Table 24 Route 19 differences in speeds after-ISA when compared with before-ISA

Section of route	Speed limit (MPH)	Time of day		
		7am to 8pm	**8pm to midnight**	**Midnight to 7am**
Beaufort Kings Rd - Cheyne Wk	30	-0.24	0.06	-0.88
Cheyne Walk - King's Rd	30	-0.04	-0.05	-0.09
Hyde Pk Cnr Picc - Green Pk Sta	30	0.58	0.32	0.64
Green Pk Sta - Hyde Pk Cnr Picc	30	0.02	-0.03	0.48
Finsbury TH - Sadlers Wells	20	-1.40	-0.88	-1.29
Sadlers Wells - Finsbury TH	20	-0.50	0.18	-1.24
Highbury Aberdeen Pk - High Barn	20	-0.71	-0.68	-1.82
High Barn - Highbury Aberdeen PK	20	-0.37	-0.43	-2.16
Upper St Cross St – Islington TH	30	0.02	0.37	-0.10
Islington TH - Upper St Cross St	30	-0.18	-0.65	-0.09

Table 25 Route 19 estimated speed impact caused by ISA

	Before (mph)	**After (mph)**	**Difference between before and after whole route speeds**	**Average tube speed before for all vehicles**	**Average tube speed after for all vehicles**	**Difference between before and after tube speeds**	**Speed change as a result of ISA**
Whole route northbound	8.13	7.88	-0.25	20.015	19.878	-0.14	-0.12
Whole route southbound	8.73	8.41	-0.33	19.945	19.735	-0.21	-0.12

If the average of all whole route speeds here is used as a baseline, the impact of a 0.12mph average speed reduction means that buses will take 51 seconds longer (given a route length of 8.27 miles), this is a 1.4% increase in time.

Table 26 Time impact of ISA implementation

	Non ISA speed	**ISA speed**	**Difference**
8.27 mile route distance	8.29mph	8.17mph	-0.12mph
Time required	00:59:52	01:00:43	00:00:51

The impact of this change may not trigger a requirement for an additional bus, as 51 seconds may fit within the turnaround time. There may be a reasonable argument made that bus route timing and bus numbers should not require buses to exceed the speed limit to achieve time targets, therefore this time difference is in fact already included, and before-ISA levels of speed above the speed limit were merely allowing extra time at turnaround points.

Note that data for Route 486 was not available after-ISA so a comparison has not been made.

6.7 Detailed fuel data

The graphs below indicate the kilometres travelled per litre of diesel fuel consumed as a mean across bus types. The standard deviation (S.D.) which is an indication of the variability of the measurements across buses is shown to one decimal place.

The measurements were taken from buses on the fleet, sample sizes are indicated in Table 27.

Table 27 Sample size

Bus type	Sample size		
	2014 before ISA	2015 before ISA	2015 after ISA
Fuel nozzle Volvo B5H	14	13	13
Fuel nozzle Volvo B9TL	14	14	11
Fuel nozzle ADL E400	15	15	N/A
Mix tele Volvo B5H	N/A	14	15
Mix tele Volvo B9TL	N/A	15	15

6.7.1.1 Route 19 WHV/Volvo B5H series buses

Note that these graphs use a weighted average.

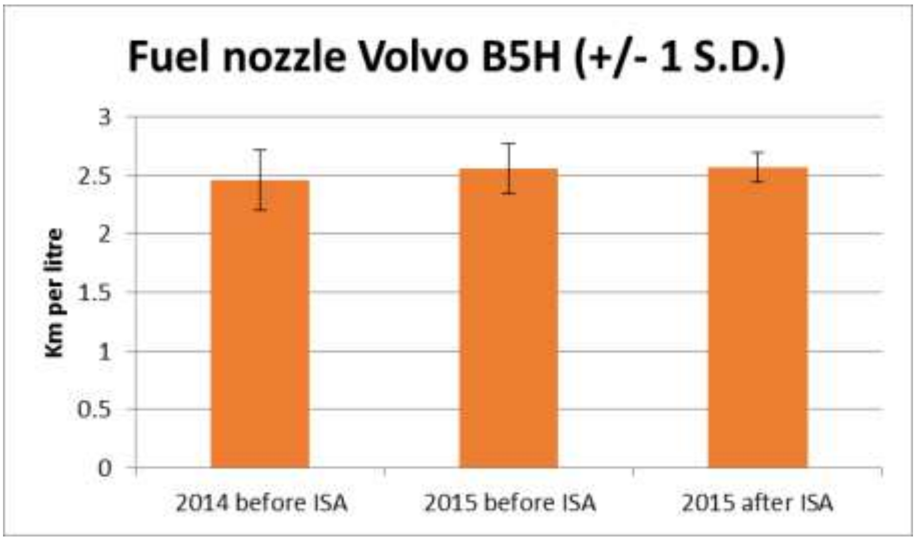


Figure 46 Route 19 Volvo B5H series buses fuel consumption from fuel nozzle measurements

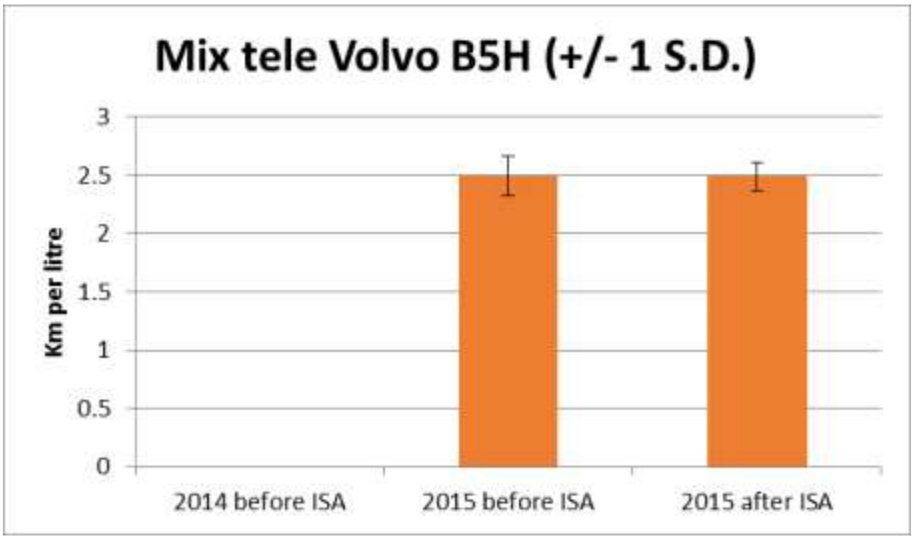


Figure 47 Route 19 Volvo B5H series buses fuel consumption from onboard mix telematics measurements

6.7.1.2 Route 19 WVL/Volvo B9TL series buses

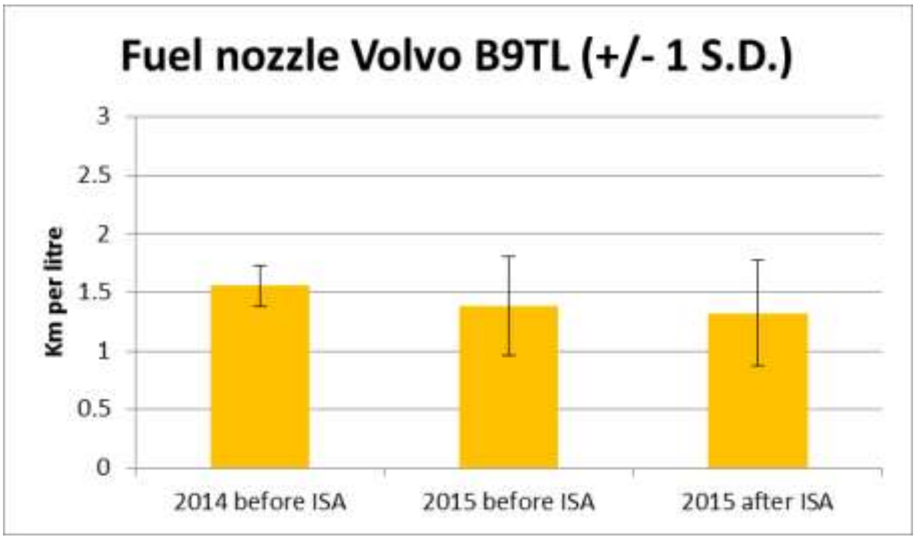


Figure 48 Route 19 Volvo B9TL series buses fuel consumption from fuel nozzle measurements

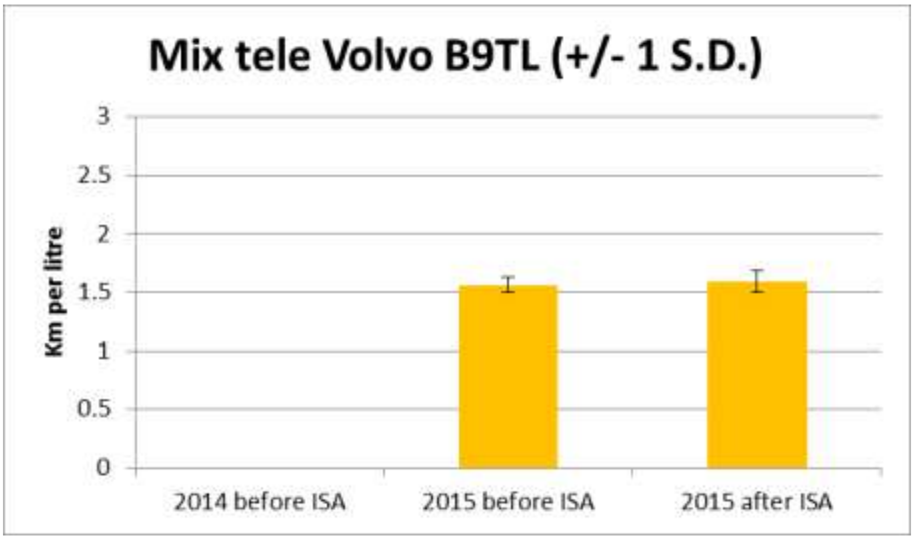


Figure 49 Route 19 Volvo B9TL series buses fuel consumption from onboard mix telematics measurements

6.7.1.3 *Route 486 E400 series buses*

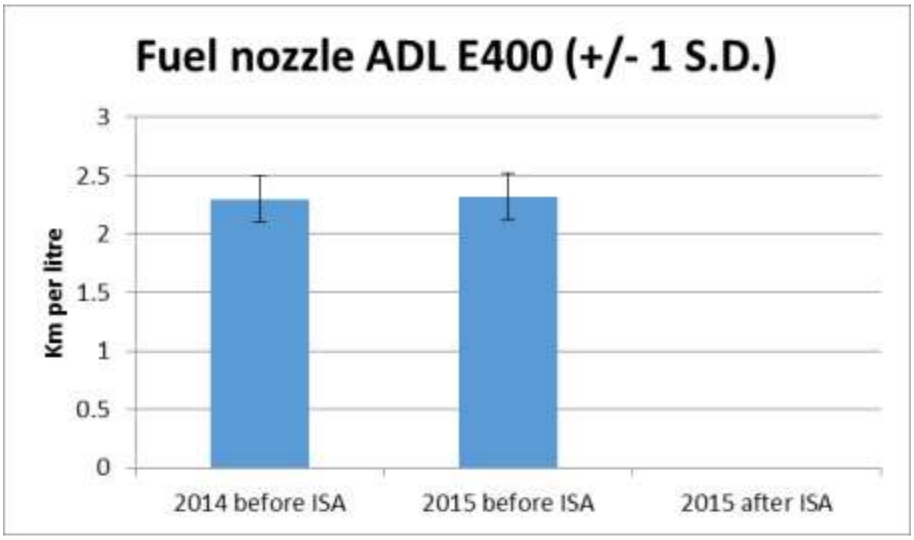


Figure 50 Route 486 ADL E400 series buses fuel consumption from fuel nozzle measurements

7 Research Question 7 – What are the benefits and disbenefits of ISA for the bus driver?

This research was undertaken by a separate organisation, 2CV. A copy of their summary reports is contained in Appendix C.

7.1 Introduction

2CV conducted research to explore the likely impact of ISA technology on bus drivers, were it to be fitted on TfL buses. 2CV's qualitative research focussed on understanding the experiences and perceptions of the bus drivers driving buses fitted with ISA technology.

The research objectives were:

- to understand, in depth, the bus drivers' and operators' perceptions of having the ISA technology on buses.
- to establish how the ISA technology on buses impacts drivers' experiences.

7.2 Methodology

A qualitative approach was taken to allow the exploration of bus drivers' reaction to the technology in detail and probe on certain points where necessary. The research was conducted in two phases to allow an understanding of how reaction to the technology changed over time.

2CV spoke to a total of:

- 61 drivers (30 in Phase 1 and 31 in Phase 2)
- eight managers/supervisors (in Phase 2)

Interviews were conducted at Stockwell and Northumberland Park bus garages and Finsbury Park bus station mess room.

7.3 Key Findings

7.3.1 Perceived benefits of ISA to bus drivers

- Bus drivers don't see any personal benefits of ISA for themselves as drivers but they do see the wider social good of ISA in improving road safety.

7.3.2 Perceived disbenefits of ISA to bus drivers

- Some feel that control of the bus is being taken away from them and this can lead to them feeling that they cannot be trusted. However, these feelings can subside over time when the drivers become used to the technology and better understand its role.
- Other road users can get frustrated with the bus driver for not driving fast enough and this can lead to aggressive behaviour on the road.

- Some worry about the impact of ISA on the gearbox.
- Some worry that they may struggle to keep to their schedules due to ISA and some have suggested that the schedules should be reviewed because of this.
- Some worry about getting complaints from passengers for not driving fast enough and this can add to their pressure.

7.3.3 *Gear change issues*

Some drivers had complained that the 20mph speed limit frequently coincides with a gear change, resulting in 20mph either being at too high an engine speed, or too low. Note that these buses are fitted with automatic gearboxes so the choice of gear does not rest with the driver.

TfL looked into this issue and it is related to the gear-change thresholds one of which is around 20mph, but these can be set by the manufacturer to avoid the 20mph speed for the new buses with ISA, resolving this problem.

Detailed methodology, data and findings can be found in full in Appendix C.

8 Research Question 8 – What are the benefits and disbenefits of ISA for the bus passenger?

This research was undertaken by a separate organisation, 2CV. A copy of their summary report is contained in Appendix D.

8.1 Introduction

In this section, 2CV's qualitative research focussed on understanding the experiences and perceptions of the bus passengers while travelling on buses fitted with the ISA technology.

8.2 Methodology

The qualitative research was conducted by conducting short interviews with customers on the buses fitted with the ISA technology. This was done in Phase 2 of the research project to give the drivers time to get used to driving the bus with the technology. 2CV spoke to a total of 18 bus customers altogether.

8.3 Key Findings

8.3.1 Perceived benefits of ISA to bus customers

- Bus customers see the good of ISA in improving road safety, once explained what it is and its purpose.
- They believe that ISA will make for more comfortable journeys as it will prevent drivers from driving too fast.

8.3.2 Perceived disbenefits of ISA to bus customers

- Bus customers don't see any disbenefits of ISA.

Appendix A Traffic calming literature review

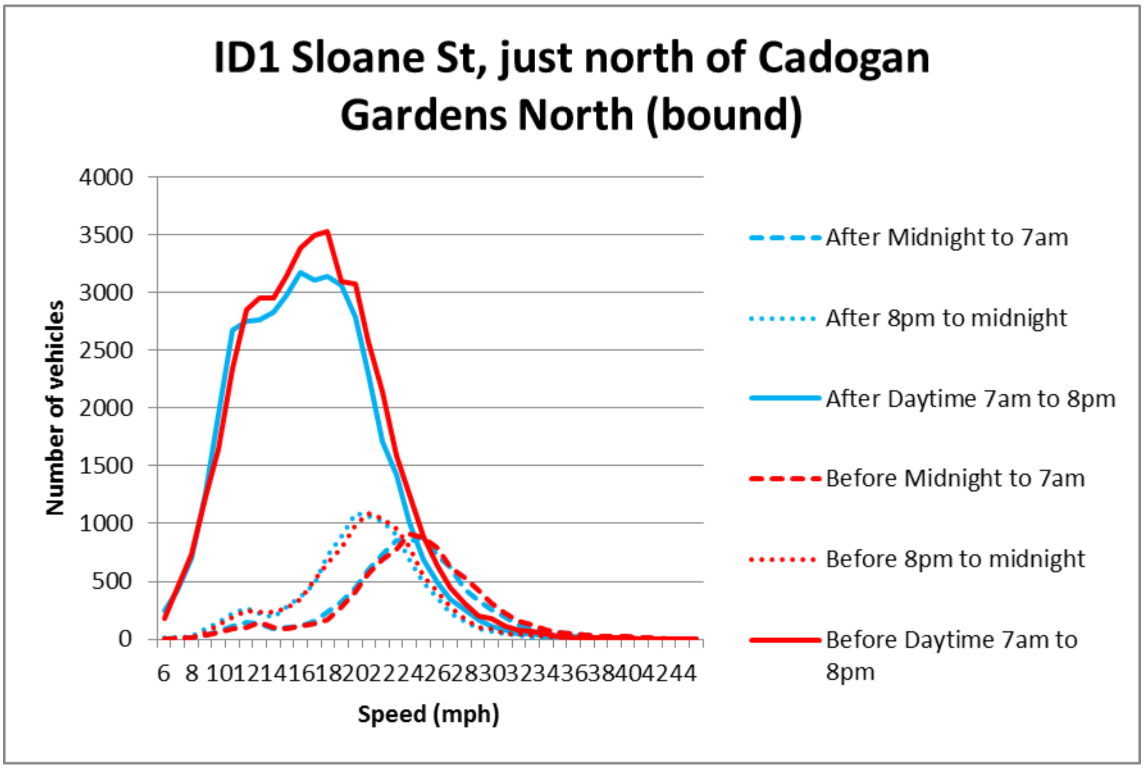
Target Group	Traffic calming measure	Source of literature	About the study	Reduction in speed at the point of speed control	Length of carriageway over which speed control methods are effective	Range of vehicles affected by the measure?	Longevity of speed limit compliance?	Discussion
Appearance and perception	Psychological traffic calming methods	Elliott, M. A., McColl, V. A., Kennedy, J. V., 2003 *Road design measures to reduce drivers' speed via 'psychological' processes: A literature review*. TRL564: TRL Ltd	A review of various psychological traffic calming measures design to reduce driver speed.	Psychological measures investigated in the review have generally produced smaller speed reductions than those from physical measures, although psychological measures may be more acceptable to drivers.	Distance of effect outside of the area of psychological traffic calming was not described.	As impacts upon different vehicle types were not mentioned in the report, it might be assumed that the impact is upon all vehicle types.	Their effects may lessen over time.	Psychological traffic calming can resolve the issue of noise/vibration and discomfort caused by vertical deflections; however their impact on speed is not nearly as high. They tend to be visually intrusive by nature which may not lend itself well to urban areas.
Speed measurement devices	Vehicle activated speed limit reminder signs	Webster, D. C., 1995 *Traffic Calming – Vehicle Activated Speed Limit Reminder Signs*. TRL177: TRL Ltd	This report gave details of measurements of speed results around various vehicle activated traffic signs in use on the public highway.	Speed reductions for buses were not measured in this study, however for HGVs (which may be broadly comparable to buses) the 85th percentile mean were reduced by between 0 and 1.5mph. Car speeds were reduced by around 2mph. Both the mean and 85% speeds were above the posted speed limit.	Vehicle speeds are reduced by a few mph at the sign and some of this reduction can be maintained for some distance downstream.	Appears to impact cars more than HGVs in the study, probably due to the higher general speeds of cars in before measurements.	This was not specifically cited in the report.	Vehicle activated signs do not rely upon placing infrastructure to slow drivers, thus does not necessarily hinder emergency service vehicles.
Speed measurement devices	Speed Cameras	Gorell, R., Sexton, B., 2004 *Performance of Safety Cameras in London*. PPR027: TRL Ltd	This study looked at the Killed and Seriously Injured figures for 77 speed camera sites within London covering distances of 400m either side of the camera on the same link. It did this on a 3-year before and after measurement.	The study did not explicitly state speeds, however did report an average 21% reduction in KSI figures.	The KSI figures were calculated for a 400m distance either side of the camera. It is not known why this distance was chosen.	As impacts upon different vehicle types were not mentioned in the report, it might be assumed that the impact is upon all vehicle types.	This was not specifically cited in the report.	The speed cameras were effective in reducing casualties; however, average speeds were not cited within the study therefore absolute figures for speed change are unknown.
Speed measurement devices	Average speed cameras	Institute for Road Safety Research, 2014. *Police enforcement and driving speed*. SWOV, the Hague.	Fact sheet reported on various measures including average speed cameras	A motorway study indicated a percentage of offenders of less than 1%. Studies on more comparable urban areas have not been found.	Speed reduction is sustained over the length of the measure.	As impacts upon different vehicle types were not mentioned in the report, it might be assumed that the impact is upon all vehicle types.	This was not specifically cited in the report.	Average speed cameras are the closest analogy to ISA, in that they can effectively reduce speeds to within the speed limit for a long distance. However these may have limited appeal in London as the distances between junctions are short and there are frequent traffic lights and junctions which may make them unsuitable for average speeds of buses. The literature search found no specific examples of studies undertaken in urban areas typical of bus routes.

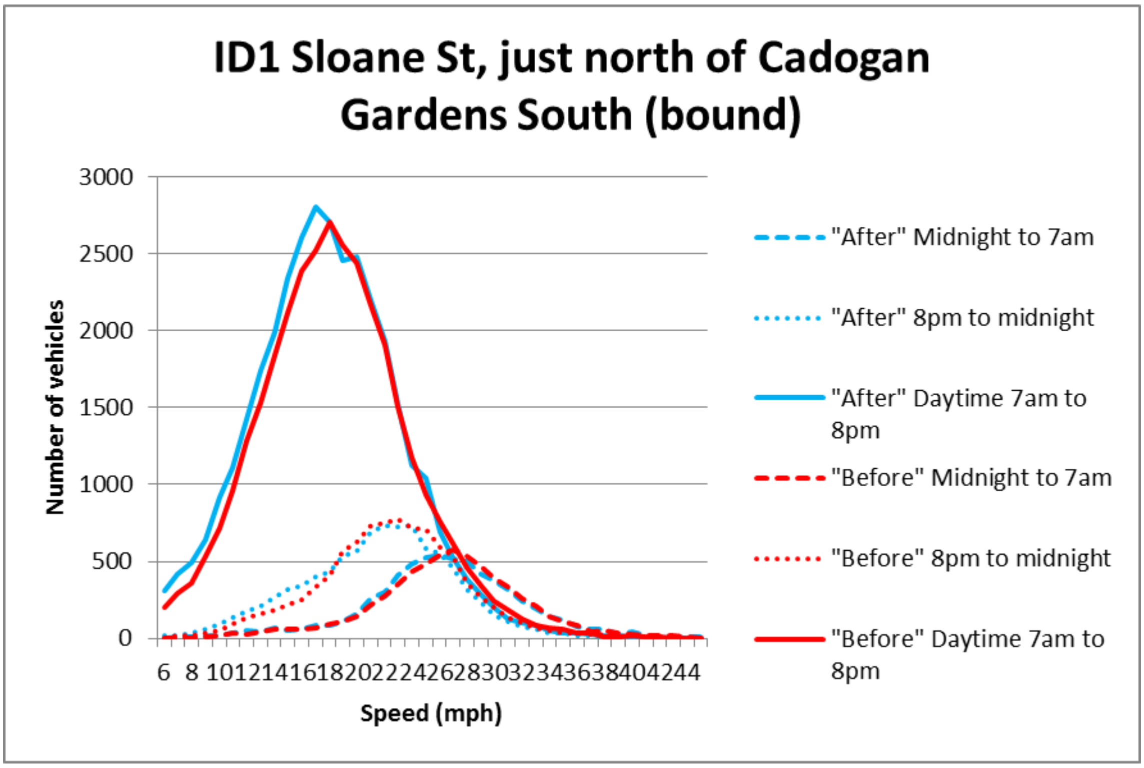
Target Group	Traffic calming measure	Source of literature	About the study	Reduction in speed at the point of speed control	Length of carriageway over which speed control methods are effective	Range of vehicles affected by the measure?	Longevity of speed limit compliance?	Discussion
Speed measurement devices	Speed indication device	LK Walter and J Knowles, 2008. *Effectiveness of Speed Indicator Devices on reducing vehicle speeds in London*, PPR314: TRL Ltd	This reported upon a study of the effect upon speed of vehicle-activated signs informing drivers of excess speed in the Royal Borough of Kingston upon Thames.	The study found an overall speed reduction of 1.4mph, and significant reductions in the numbers of drivers found above 30mph and 36mph. It was estimated that the speed reductions would result in a 5.6% reduction in collisions whilst the device was in operation.	The effect was also found to be relatively localised, with vehicles rapidly returning to their normal speed within 400m.	As impacts upon different vehicle types were not mentioned in the report, it might be assumed that the impact is upon all vehicle types.	The effect on speed reduction was found to decay rapidly, with the best effects in the first week.	Speed indicator devices do have an effect upon speed however this is relatively short lived in terms of time and distance.
Speed measurement devices	Speed cameras	Richard Allsop, 2010. *The effectiveness of Speed Cameras – A review of evidence*. RAC Foundation	This is a review of evidence regarding the effectiveness of speed cameras, therefore draws upon other sources of data.	At urban sites with fixed camera sites the average speed was reduced by 5.3mph and the 85th percentile speed by 7.7mph, and the proportion of vehicles exceeding the speed limit was reduced by 72%.	The impact of speed cameras away from the vicinity of the camera was not specifically covered by the report.	As impacts upon different vehicle types were not mentioned in the report, it might be assumed that the impact is upon all vehicle types.	This was not specifically cited in the report.	Bus drivers on a given route are highly likely to be aware of the location of speed cameras and may alter their speed at these points only, giving the opportunity to speed in other locations.
Horizontal deflections	Chicanes	Sayer, I. A., Parry, D. I., 1994 *Speed Control Using Chicanes – A Trial at TRL*. PR102: TRL Ltd	This report gave details of a trial of various chicane sizes held off-road at TRL	It is possible to reduce the speed of buses significantly by varying the dimensions of a chicane; however, because of the size of chicane needed to allow a bus to pass at 20mph, this would allow a car to travel at far higher speeds. In addition it was noted that the lateral acceleration on the vehicle (and the passengers within it) may easily reach levels of unease or generate handling problems.	The distance impact of the chicane was not examined in the trial report, however as a minimum it is expected that the requirement to slow for the chicane, and accelerate afterwards will bring a distance of speed reduction of several hundred metres for a bus.	Chicanes disproportionately impact larger vehicles (such as buses).	This was not specifically cited in the report.	Chicanes would take up considerable roadspace within London, create potential driver and passenger discomfort, and likely have a limited impact upon speeds outside of its immediate area.
Horizontal deflections and Vertical deflections	Traffic calming schemes in 20 mph zones	Webster, D. C., Mackie, A, M., 1996 *Review of Traffic Calming Schemes in 20mph Zones*. TRL215: TRL Ltd	The report looked at the impact of the as-then-new 20mph zones across the country, at sites which relied upon physical measures to reduce speeds. These physical measures include round-top humps, flat-top humps, raised junction tables, speed cushions, and a variety of other measures such as pinch-points, chicanes, mini-roundabouts and rumble strips.	Overall speeds fell on average by 9.3 mph, with average speeds at traffic calming measures (such as speed cushions) of 13.2mph, and speeds between traffic calming measures as 17.8mph. This indicates that these measures were successful in achieving compliance with 20 mph speed limits. It also found a 6.2% reduction in accidents for each 1 mph reduction in vehicle speed.	The speed reduction was found to be maintained along the length of the traffic calming, however the measures needed to be within about 100m apart to achieve the Department of Transport's 20mph zone design criteria.	Discomfort for bus passengers, and access for ambulance services was an issue raised in the report.	This was not specifically cited in the report.	The variety of physical measures worked well and reduced speeds to within 20 mph.

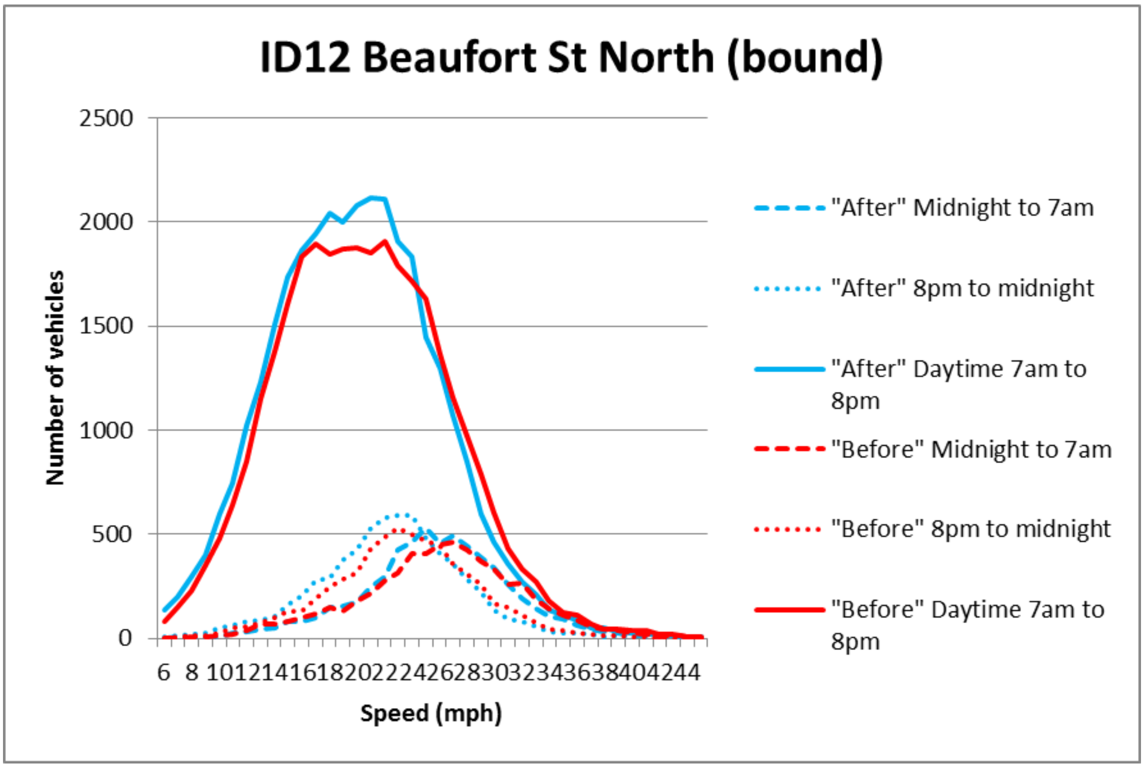
Target Group	Traffic calming measure	Source of literature	About the study	Reduction in speed at the point of speed control	Length of carriageway over which speed control methods are effective	Range of vehicles affected by the measure?	Longevity of speed limit compliance?	Discussion
Horizontal deflections and Vertical deflections	Various physical and non-physical (signs) measures aimed at reducing speeds in 20mph zones	Mackie, A, M., 1998 *Urban speed management methods*. TRL363: TRL Ltd	This review summarizes findings of various speed reduction measures in 20mph zones. This included using signs only, and using signs with traffic calming (such as horizontal and vertical deflections).	The key findings of this study were: "The most effective measures for controlling speed in urban areas are physical traffic calming measures, particularly speed humps. 20mph zones using such measures have generally achieved mean and 85th percentile speed reductions of around 10mph and mean speeds after installation of less than 20mph". Note a pre-measure speed was not reported.	Speed cameras were found to have only a localised effect. Physical traffic calming was found to be the best option in 20mph zones for reducing speeds.			This study concluded that in 20mph zones physical traffic measures worked best. However, these are known to create issues for buses. The study concluded that in-vehicle technology would be a further option when the technology became available.

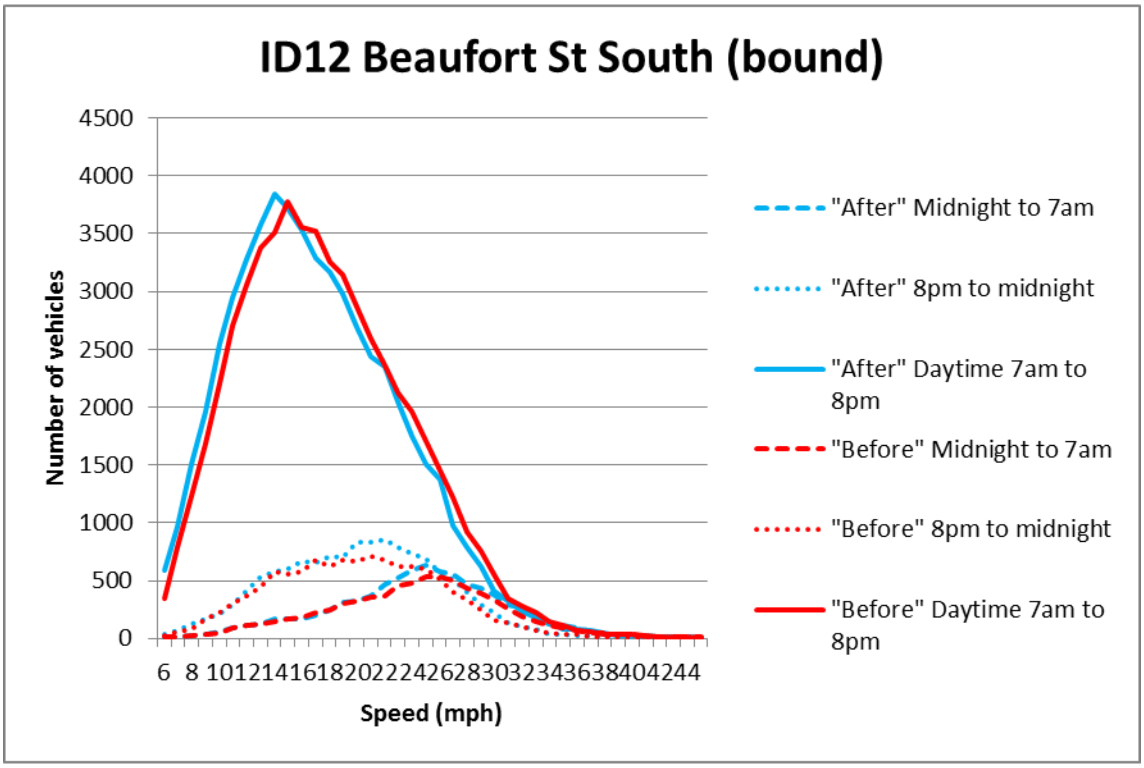
Appendix B Speed tube data by time of day, before and after ISA

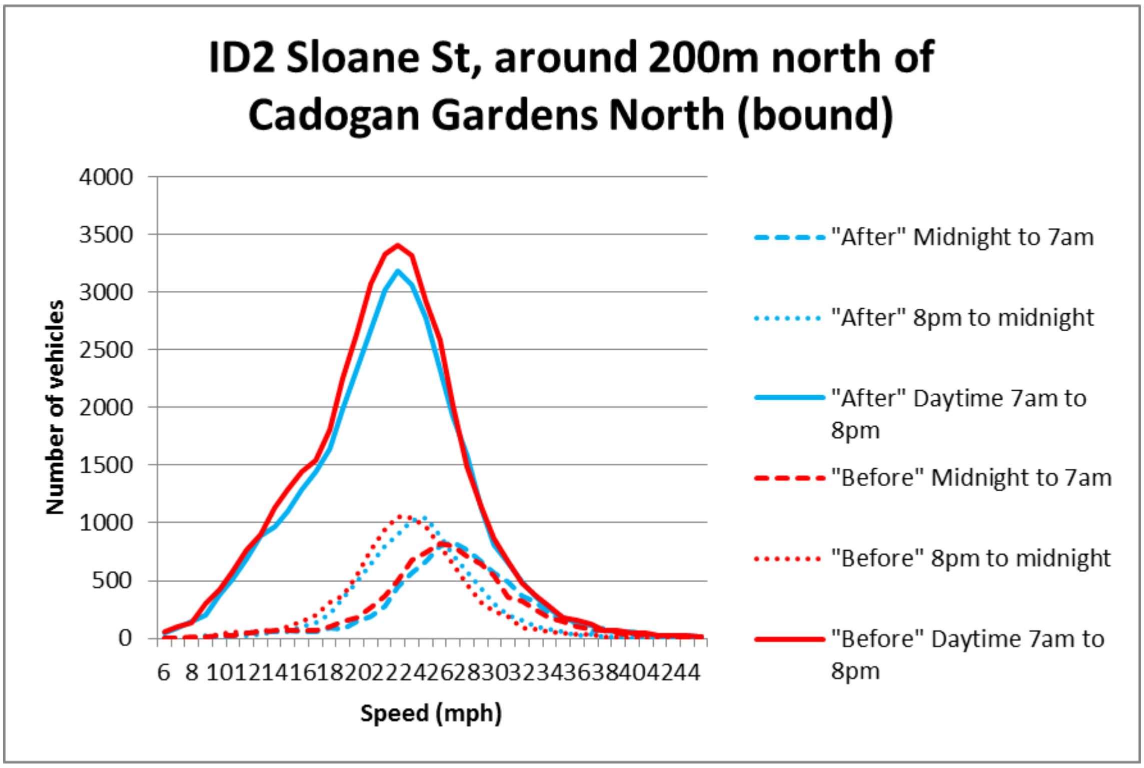
In the following graphs relating to route 19 the speed/frequency of vehicles passing over the speed tube has been shown (with vehicles below 6mph excluded as these are less reliable measurements). The data are very similar both before and after buses were equipped with ISA. The data have also been split by time of day, and this indicates that average speeds are higher in the early morning and evening, and lowest during the day. This correlates with expectations as the daytime is associated with increased traffic and lower speeds.

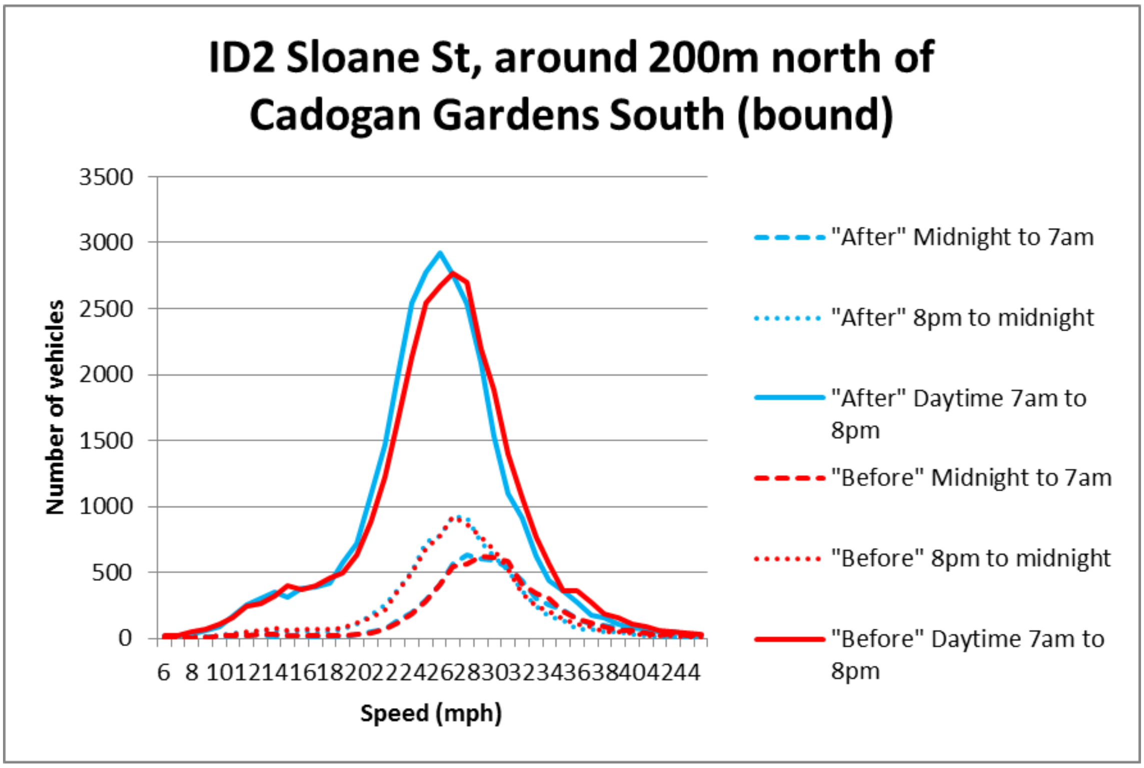


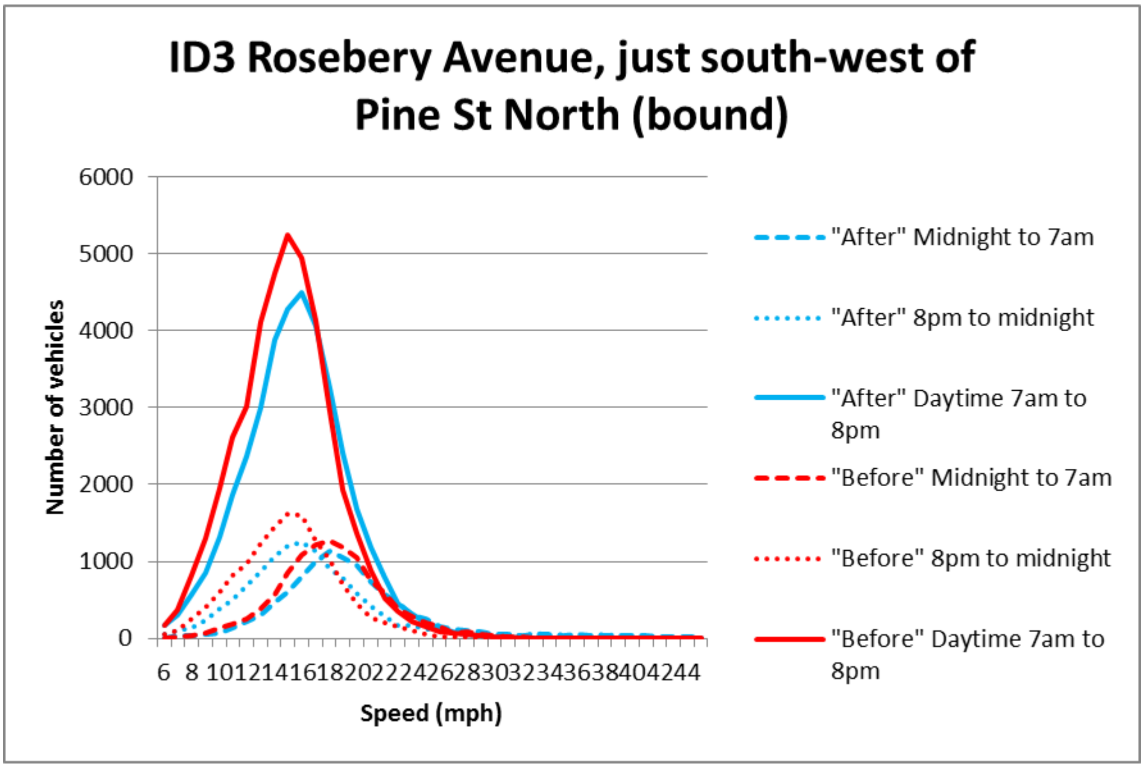

ID1 Sloane St, just north of Cadogan Gardens South (bound)
Number of vehicles
3000
2500
2000
1500
1000
500
0
6 8 10121416182022242628303234363840 4244
Speed (mph)
"After" Midnight to 7am
"After" 8pm to midnight
"After" Daytime 7am to 8pm
"Before" Midnight to 7am
"Before" 8pm to midnight
"Before" Daytime 7am to 8pm

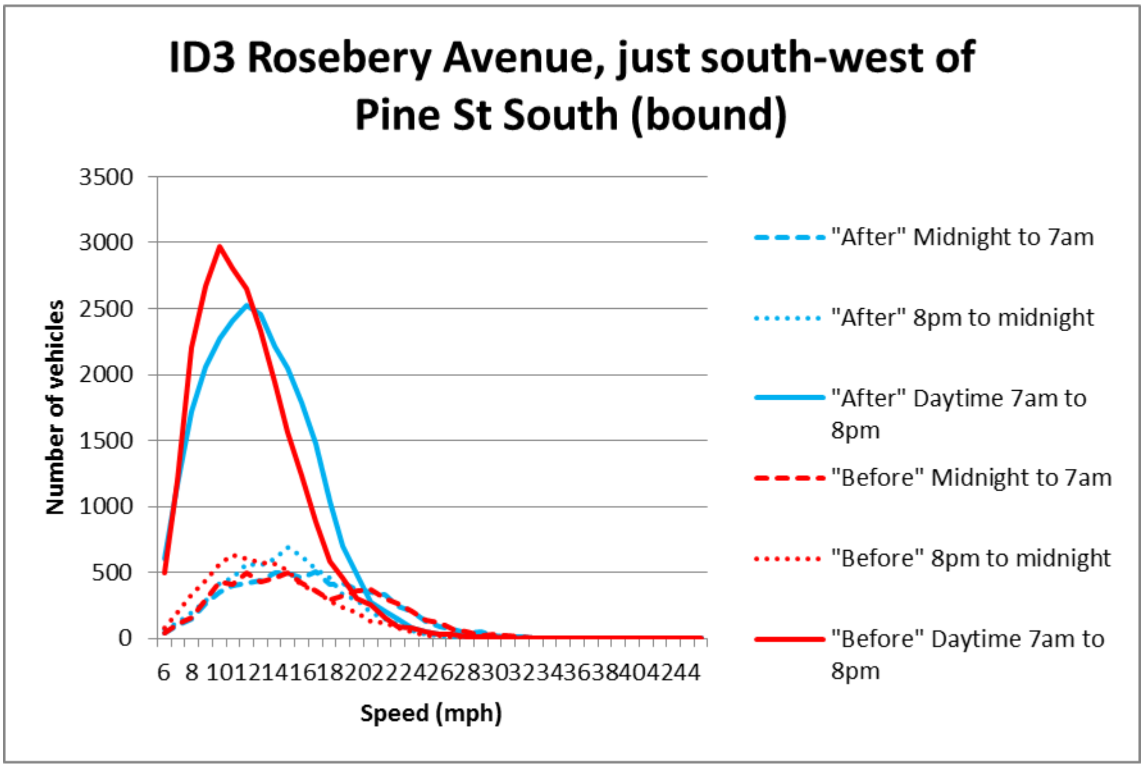

ID12 Beaufort St North (bound)
Number of vehicles
2500
2000
1500
1000
500
0
6 8 10121416182022242628303234363840 4244
Speed (mph)
"After" Midnight to 7am
"After" 8pm to midnight
"After" Daytime 7am to 8pm
"Before" Midnight to 7am
"Before" 8pm to midnight
"Before" Daytime 7am to 8pm

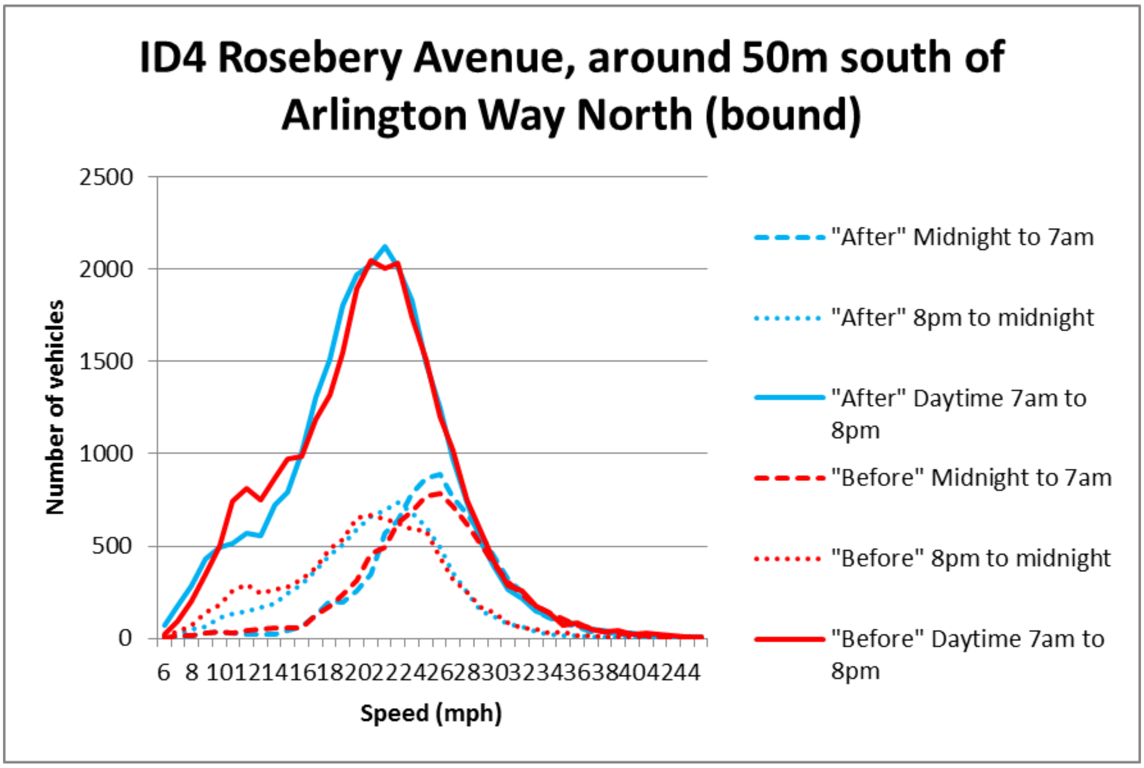

ID12 Beaufort St South (bound)
Number of vehicles
4500
4000
3500
3000
2500
2000
1500
1000
500
0
6 8 10121416182022242628303234363840424444
Speed (mph)
"After" Midnight to 7am
"After" 8pm to midnight
"After" Daytime 7am to 8pm
"Before" Midnight to 7am
"Before" 8pm to midnight
"Before" Daytime 7am to 8pm

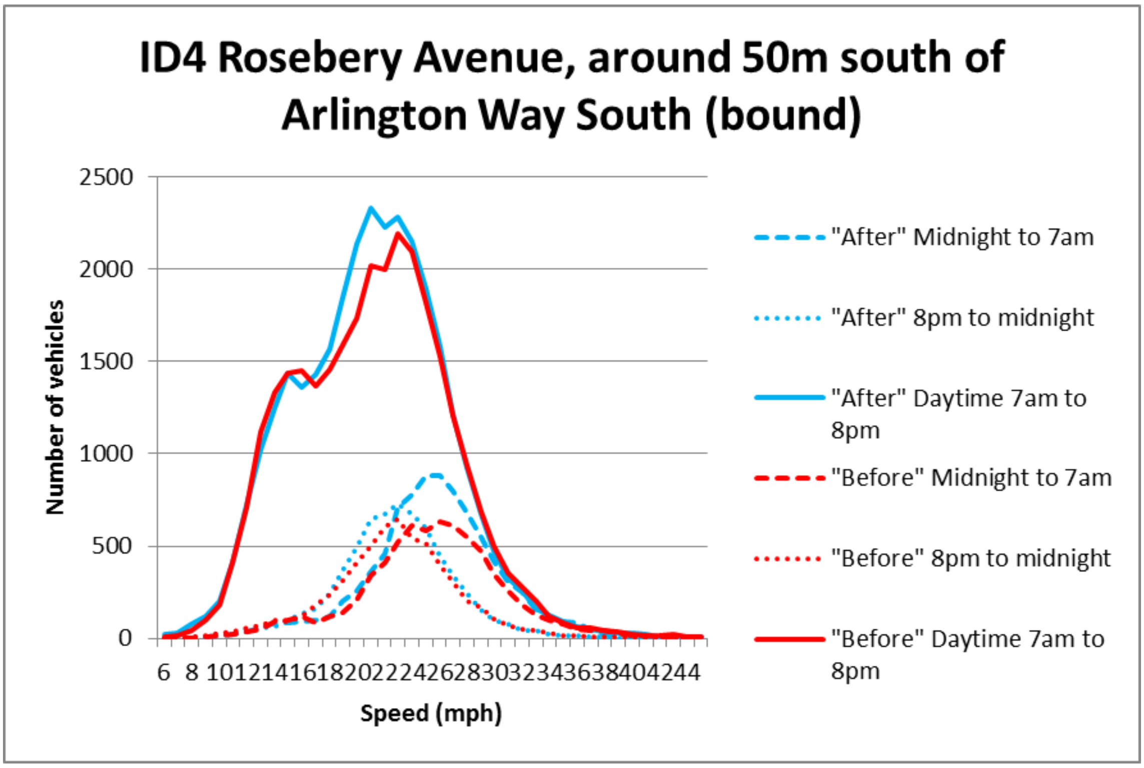

ID2 Sloane St, around 200m north of Cadogan Gardens North (bound)
Number of vehicles
4000
3500
3000
2500
2000
1500
1000
500
0
6 8 10121416182022242628303234363840424444
Speed (mph)
"After" Midnight to 7am
"After" 8pm to midnight
"After" Daytime 7am to 8pm
"Before" Midnight to 7am
"Before" 8pm to midnight
"Before" Daytime 7am to 8pm


ID2 Sloane St, around 200m north of Cadogan Gardens South (bound)
3500
3000
2500
2000
1500
1000
500
0
Number of vehicles
6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Speed (mph)
"After" Midnight to 7am
"After" 8pm to midnight
"After" Daytime 7am to 8pm
"Before" Midnight to 7am
"Before" 8pm to midnight
"Before" Daytime 7am to 8pm

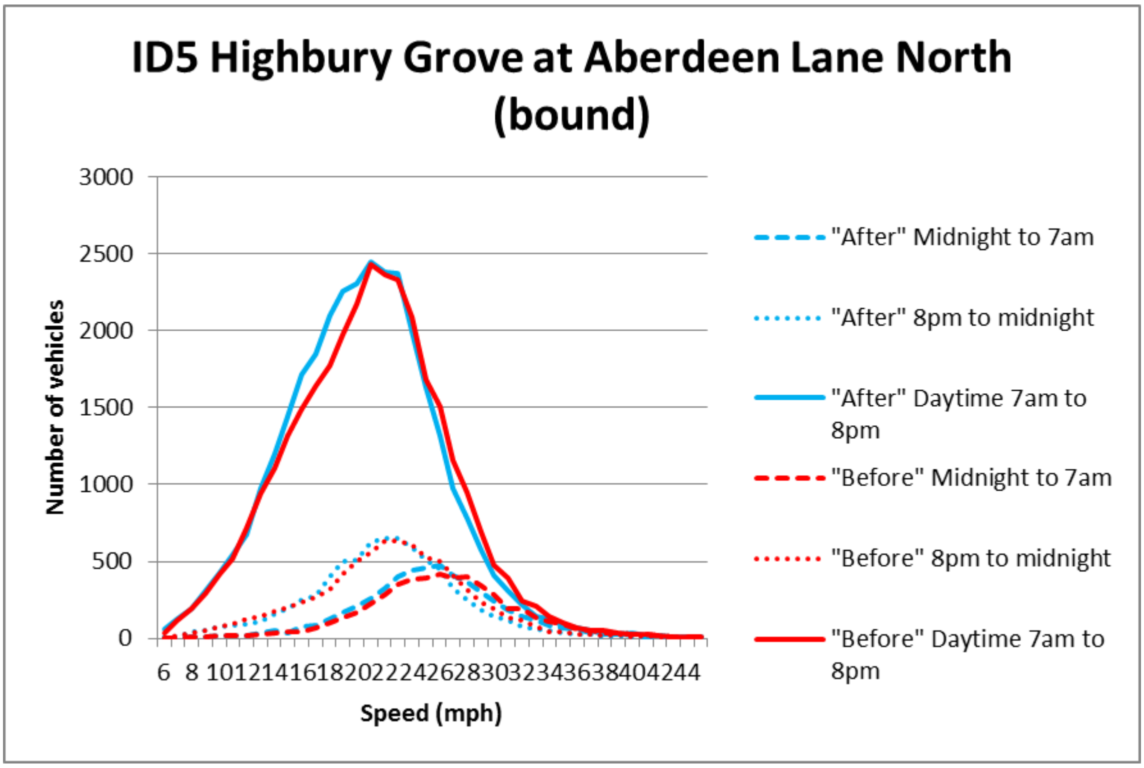

ID3 Rosebery Avenue, just south-west of Pine St North (bound)
6000
5000
4000
3000
2000
1000
0
Number of vehicles
6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Speed (mph)
"After" Midnight to 7am
"After" 8pm to midnight
"After" Daytime 7am to 8pm
"Before" Midnight to 7am
"Before" 8pm to midnight
"Before" Daytime 7am to 8pm


ID3 Rosebery Avenue, just south-west of Pine St South (bound)
Number of vehicles
3500
3000
2500
2000
1500
1000
500
0
6 8 10121416182022242628303234363840424 4
Speed (mph)
"After" Midnight to 7am
"After" 8pm to midnight
"After" Daytime 7am to 8pm
"Before" Midnight to 7am
"Before" 8pm to midnight
"Before" Daytime 7am to 8pm

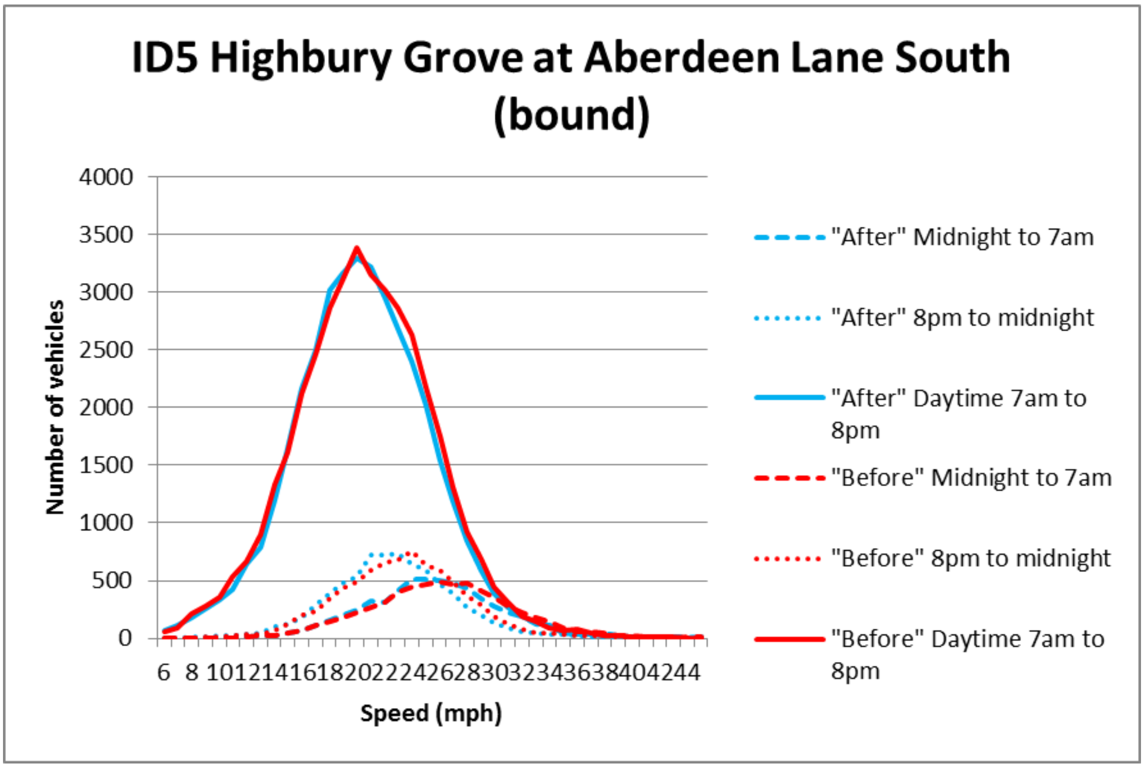

ID4 Rosebery Avenue, around 50m south of Arlington Way North (bound)
Number of vehicles
2500
2000
1500
1000
500
0
6 8 10121416182022242628303234363840424 4
Speed (mph)
"After" Midnight to 7am
"After" 8pm to midnight
"After" Daytime 7am to 8pm
"Before" Midnight to 7am
"Before" 8pm to midnight
"Before" Daytime 7am to 8pm

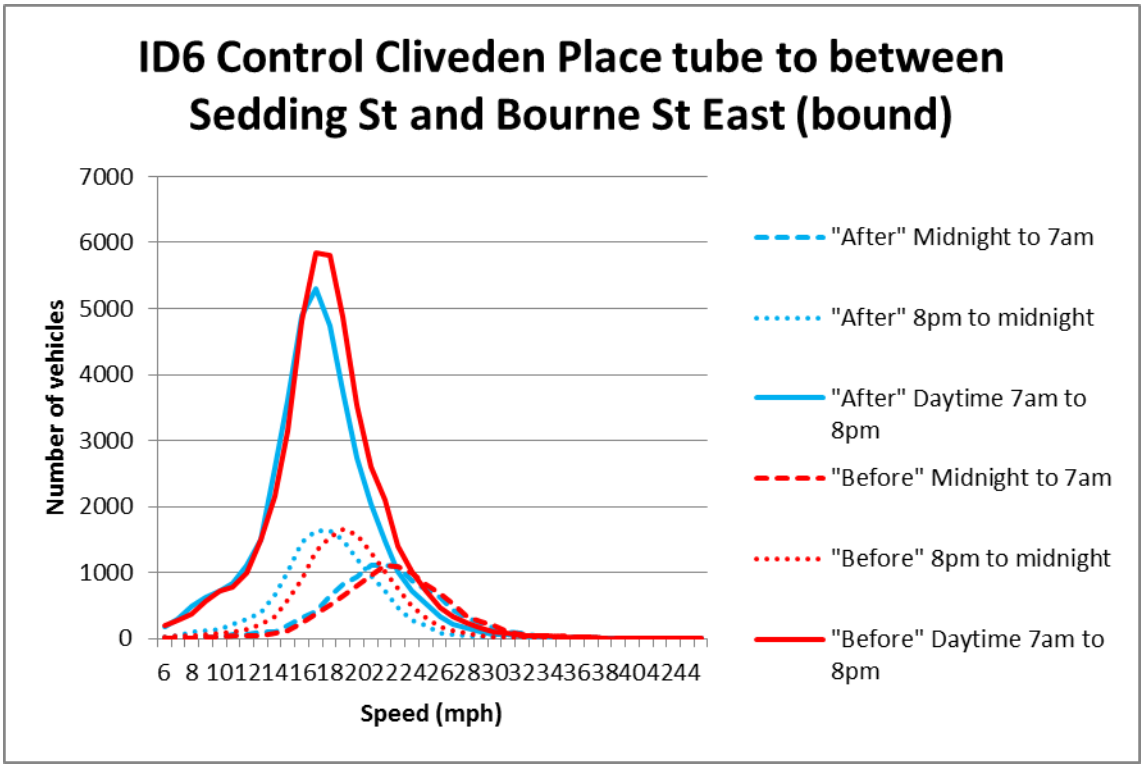


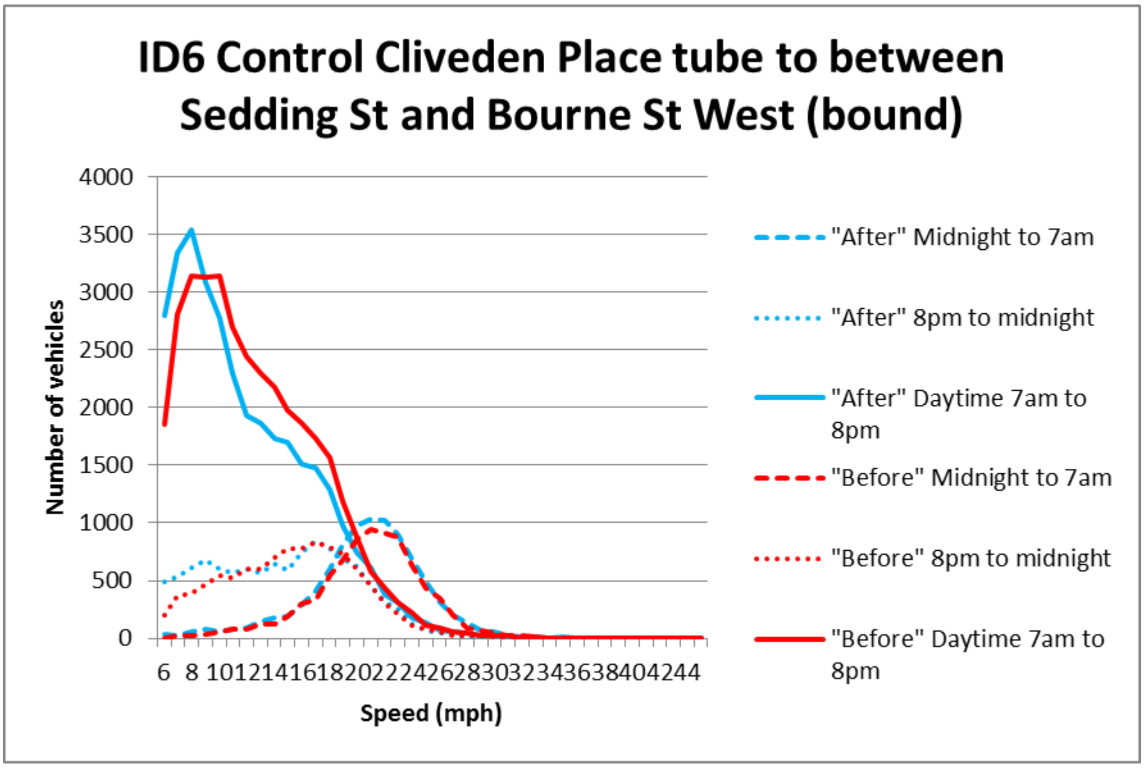
ID4 Rosebery Avenue, around 50m south of Arlington Way South (bound)
2500
2000
1500
1000
500
0
Number of vehicles
6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Speed (mph)
"After" Midnight to 7am
"After" 8pm to midnight
"After" Daytime 7am to 8pm
"Before" Midnight to 7am
"Before" 8pm to midnight
"Before" Daytime 7am to 8pm

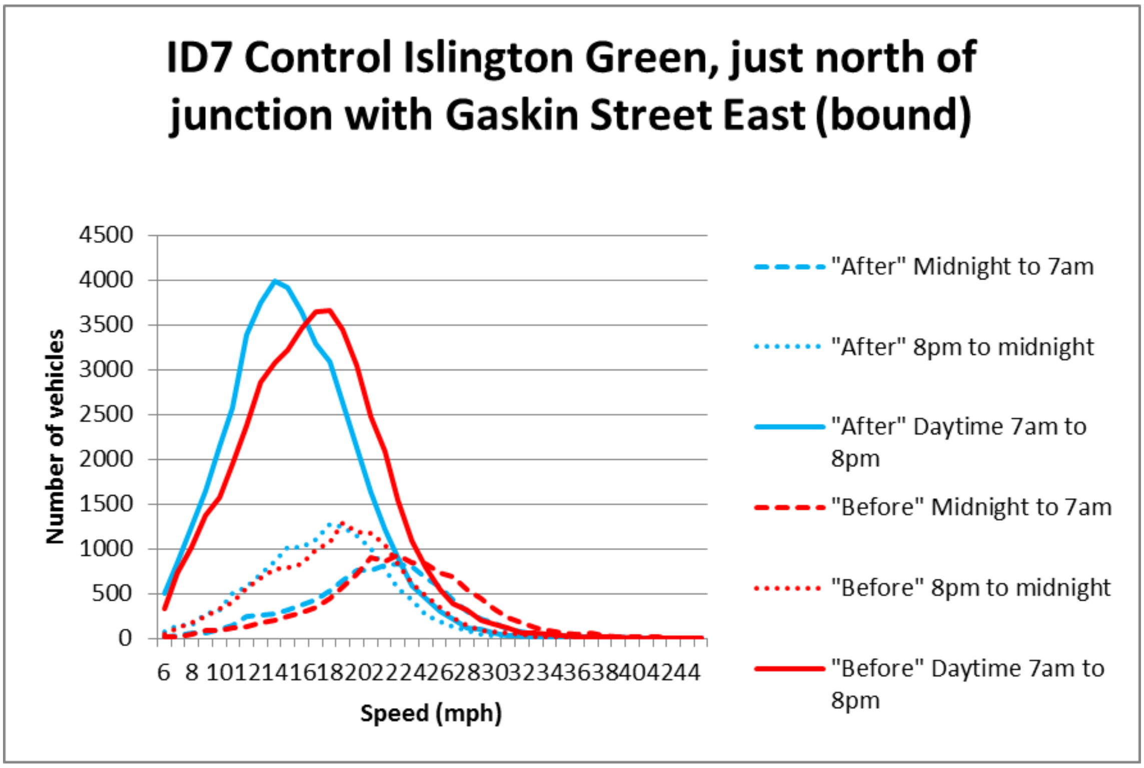


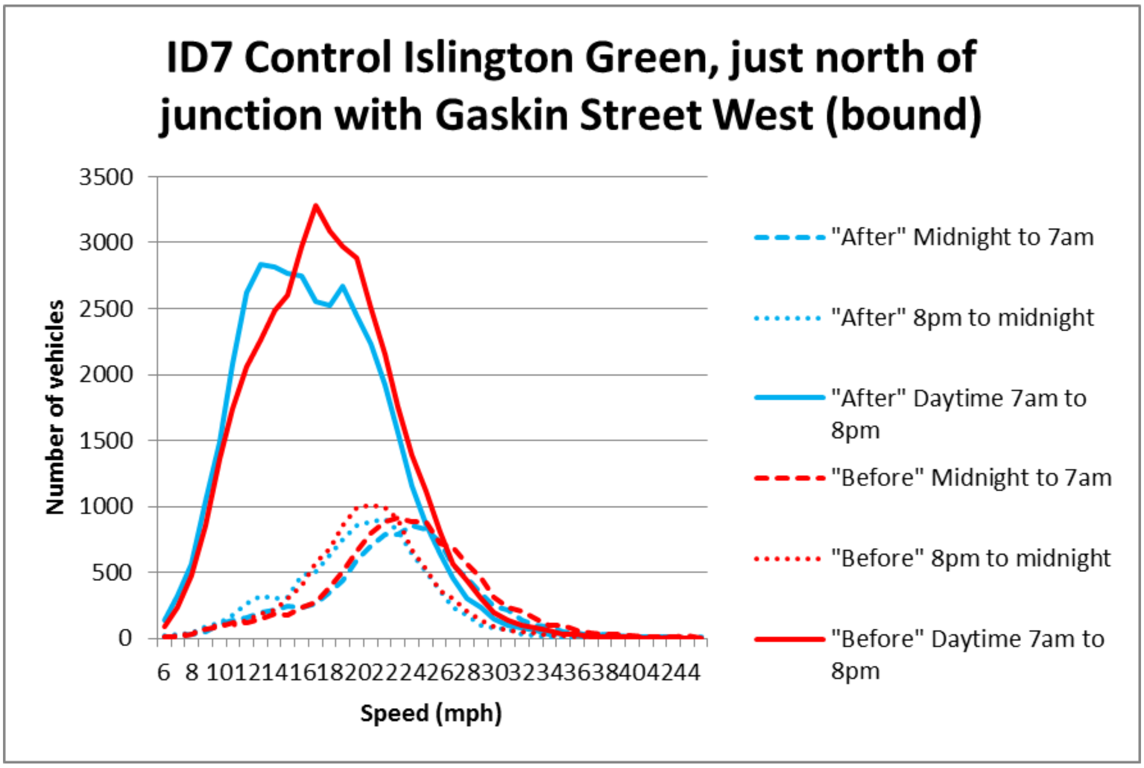
ID5 Highbury Grove at Aberdeen Lane North (bound)
3000
2500
2000
1500
1000
500
0
Number of vehicles
6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
Speed (mph)
"After" Midnight to 7am
"After" 8pm to midnight
"After" Daytime 7am to 8pm
"Before" Midnight to 7am
"Before" 8pm to midnight
"Before" Daytime 7am to 8pm


ID5 Highbury Grove at Aberdeen Lane South (bound)
Number of vehicles
4000
3500
3000
2500
2000
1500
1000
500
0
6 8 101214161820222426283032343638404244
Speed (mph)
"After" Midnight to 7am
"After" 8pm to midnight
"After" Daytime 7am to 8pm
"Before" Midnight to 7am
"Before" 8pm to midnight
"Before" Daytime 7am to 8pm


ID6 Control Cliveden Place tube to between Sedding St and Bourne St East (bound)
Number of vehicles
7000
6000
5000
4000
3000
2000
1000
0
6 8 101214161820222426283032343638404244
Speed (mph)
"After" Midnight to 7am
"After" 8pm to midnight
"After" Daytime 7am to 8pm
"Before" Midnight to 7am
"Before" 8pm to midnight
"Before" Daytime 7am to 8pm


ID6 Control Cliveden Place tube to between Sedding St and Bourne St West (bound)
4000
3500
3000
2500
2000
1500
1000
500
0
Number of vehicles
6 8 101214161820222426283032343638404244
Speed (mph)
"After" Midnight to 7am
"After" 8pm to midnight
"After" Daytime 7am to 8pm
"Before" Midnight to 7am
"Before" 8pm to midnight
"Before" Daytime 7am to 8pm


ID7 Control Islington Green, just north of junction with Gaskin Street East (bound)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Number of vehicles
6 8 101214161820222426283032343638404244
Speed (mph)
"After" Midnight to 7am
"After" 8pm to midnight
"After" Daytime 7am to 8pm
"Before" Midnight to 7am
"Before" 8pm to midnight
"Before" Daytime 7am to 8pm



ID7 Control Islington Green, just north of junction with Gaskin Street West (bound)
3500
3000
2500
2000
1500
1000
500
0
Number of vehicles
6 8 101214161820222426283032343638404244
Speed (mph)
"After" Midnight to 7am
"After" 8pm to midnight
"After" Daytime 7am to 8pm
"Before" Midnight to 7am
"Before" 8pm to midnight
"Before" Daytime 7am to 8pm

Appendix C 2CV report 1

Background

- TfL are running a trial of Intelligent Speed Assistance (ISA) technology on 48 London Buses. The technology brings together internal information on the vehicle speed with external information on the speed limit, and actively controls the speed of the vehicle to stay within the speed limit.

- ISA has been trialled across Europe and research in Sweden shows a positive impact of the technology both in terms of improving road safety and acceptance from drivers. A recent report from the European Commission recommended mandating ISA in all commercial vehicles. TfL therefore need to ensure London is fully prepared for any future legislation and has an understanding of any potential impact of the technology.

- This trial is also part of TfL's Pedestrian Safety Action Plan and Cycle Safety Action Plan, and aims to recognise the potential role this technology could play in promoting adherence to speed limits across the road network.

- 2CV has conducted research to explore the likely impact of this new technology, were it to be fitted on TfL buses. 2CV's qualitative research focussed on understanding the experiences and perceptions of the bus drivers using the new systems. Additional research has been carried out simultaneously by another partner agency to quantitatively test the accuracy and impact of the technology.

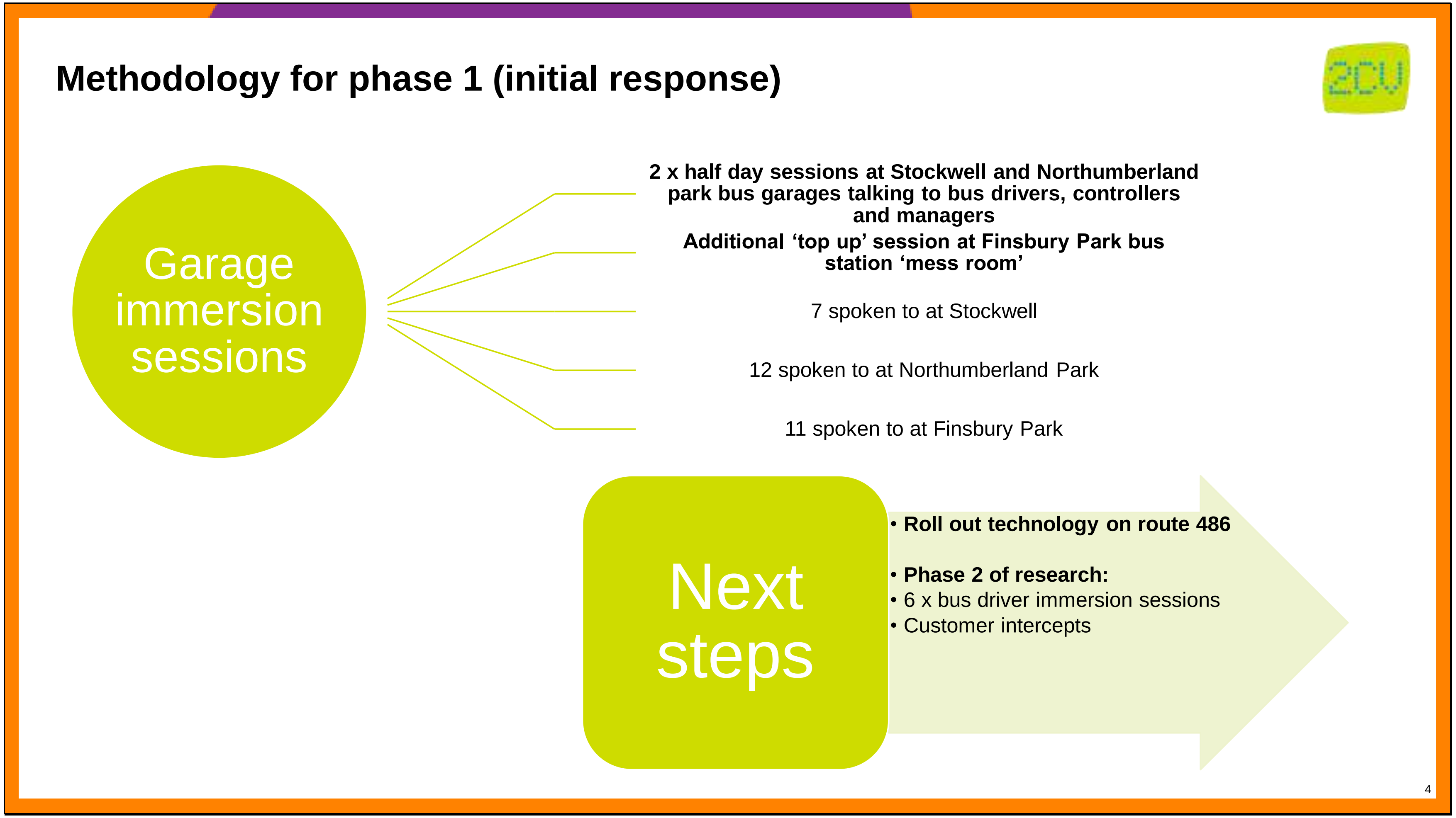
2

Research objectives

To understand in depth the operators' and bus drivers' perceptions of having the ISA technology on buses

To establish how the ISA technology on buses impacts the drivers' and customers' experiences

3


Methodology for phase 1 (initial response)
Garage immersion sessions
2 x half day sessions at Stockwell and Northumberland park bus garages talking to bus drivers, controllers and managers
Additional 'top up' session at Finsbury Park bus station 'mess room'
7 spoken to at Stockwell
12 spoken to at Northumberland Park
11 spoken to at Finsbury Park
Next steps
• Roll out technology on route 486
• Phase 2 of research:
• 6 x bus driver immersion sessions
• Customer intercepts
4

Key findings

- **While drivers appreciate the intent of ISA technology (ie safer roads) they are sceptical of its future**
  - Their negative experiences are making them feel unsafe and uncomfortable
- **There is an overall resistance to the tech**; this is in part due to **negative** and sometimes **dangerous** experiences
  - Additionally, many drivers feel like they have had their control of the vehicle taken away and that they are not trusted to do their job
- **Speed capping at 20mph is causing frustration**, particularly when accelerating and trying to overtake cyclists
  - Real issues with maintaining 20mph as 'the throttle' cuts out and reduces down to 16-18mph; some have even experienced a sudden reduction down to 5mph - the movement of this speed capping is jerky and makes customers and themselves uncomfortable
- **Problems with the speed control is impacting on other road users and passengers**
  - Passengers and other road users are getting frustrated with the bus drivers as the bus is not keeping up with the traffic
  - There is lots of confusion with many road users thinking the bus is giving way when in fact they are struggling to accelerate out of bus stops

5

Key findings

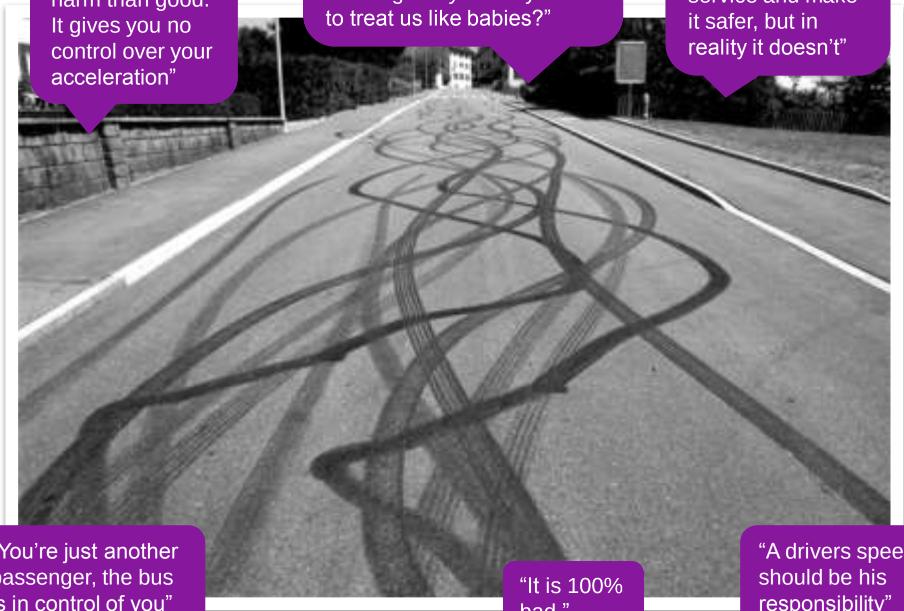
- **Bus drivers feel unsafe when they cannot control the bus in a way they think is suited to the environment**
  - Many feel that 'the computer' cannot see the road, therefore it cannot adapt to emergency or risky situations
  - Experiences between different buses vary and drivers sense that it is very unpredictable across the fleet
- **It is affecting reliability with bus drivers struggling to finish their route on time**
  - Being 15-20 minutes late is 'standard' and easily done, even without traffic
  - This is creating confusion for the controllers and drivers are really feeling the pressure for something that is out of their hands
- **Ultimately, bus drivers feel that the technology is more of a hindrance than a help and it is making their job harder and more stressful**
  - Some can see its potential if it were to run smoothly, but <u>everyone</u> must be educated, particularly through signs on the back of the bus to inform other road users that *'This bus is automatically restricted to each speed limit zone'*
  - They also see potential for buses to 'lead the way' and have a positive influence on other road users, but this cannot be achieved without **communication** and **awareness**

6

There is an overall resistance to the technology

- They sense that their **responsibility is being reduced** and that they are **not in full control of their bus**
  - This is **frustrating** and drivers can feel **unsafe** and **less confident**
  - They feel **very limited by the ISA technology** and that they **cannot do their job properly**
  - They are left wondering **‘who is the boss’?**

- Bus drivers are also concerned about **being the only ones on the road who are limited**
  - They **don’t feel** it is an **even playing field** if only buses have ISA
  - ‘Why us?’ is a question often asked when they feel there are other road users who are in more need (eg HGV drivers)



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Primary concerns centre around safety of bus drivers, other road users and passengers

Bus driver

- Speed capping makes pulling out from stops and junctions / roundabouts slow and risky
- Bus drivers can feel in danger when they cannot pull out into the traffic and keep up the pace
- More risks are taken, especially at roundabouts
- Feel their concentration is removed from the road when the ISA isn't working properly

Other road users

- Sudden reduction in speed after reaching 20mph can surprise road users and force them to brake
- 'Unpredictable' nature of speed assistance means the driver cannot adapt to the environment instinctively – putting other roads users at risk

Passengers

- Jerky nature of speed capping is uncomfortable and can cause falls / stumbles

"My main concern is the safety of my passengers, at one point I felt the bus was putting them at risk, as one of jolts at 20mph caused a lady to fall while going up the stairs. From that point, I refused to drive the bus"

Bus drivers are expecting an accident to happen and are nervous about it happening on their bus

8

When things go wrong, bus drivers are feeling an immense pressure from other road users, passengers and controllers

- When the speed capping is faulty and reduces speeds too severely, it is assumed that the driver is at fault
- As a result, they are experiencing:

Aggression and impatience from other road users for appearing erratic / incapable

"They swear at me, beep their horns, bang on my window and there is nothing I can do, I look like a bad driver"

"I had a cyclist shout out to me (as I couldn't overtake them because of the computer') and tell me to stop f**king around and drive properly, that I would kill someone driving like that.. There was absolutely nothing I could do, the gas had cut out completely and I had to pump it like mad"

Aggression and frustration from passengers for not keeping up with traffic and appearing to deliberately drive slow and jerky

"Passengers are always muttering under their breaths 'stupid driver' They think I am choosing to drive this way"

"Sometimes they come to the cab and ask me what the hell I'm doing, it's a clear road ahead and I'm driving at 12 mph… it's embarrassing"

Pressure and blame from controllers for being late

"The controllers are always like.. What are you doing? Why are you so late? They don't understand that the technology is holding us back"

"It looks bad on me if I am late because the bus won't drive fast enough, it drives dangerously slow at times and naturally the controllers are freaking out like 'get on with it, why are you so slow, headway headway!'"

They don't like being perceived as 'bad drivers' and are concerned about the impact on their reputation – especially as there is limited knowledge about the technology across other drivers, managers, reps and controllers

9

Speed capping at 20mph is causing frustration, particularly when accelerating and trying to overtake cyclists

- Real issues with maintaining 20mph as ‘the throttle’ cuts out and reduces down to 16-18mph, some have even experienced a sudden reduction down to 5mph

- Trying to overtake cyclists can be impossible, this can be dangerous

- Drivers feel it is having a detrimental effect in the ‘health’ of the vehicle eg overheating gear box / high temperature of transmission fluid (112 degrees in one instance)

“My job used to be frustrating. Now it is even more frustrating. It serves no purpose and just makes our drive more difficult”

“I understand capping it, but it should not decrease. At least if you could hold 20mph but not go any faster that would be fine, but the way it slows you down makes it horrible to drive”

“Cyclists overtake you, it’s ridiculous”

“You feel your exhausting it at just 19mph”

“You go to overtake a cyclist but it slows you down when your halfway past so then the cyclist re-overtakes you. It is not safe for cyclists because the bus is acting unpredictably, they don’t understand what we’re doing”

“The 30mph zone is better but when you move zones it drops you down to 15.”

10

They feel unsafe when they cannot control the bus in a way they think is suited to the environment

- They feel that ‘the computer’ cannot see the road, therefore it cannot adapt to emergency or risky situations
- Experiences between different buses vary and drivers sense that it is very unpredictable across the fleet (depending on the bus driven eg hybrid or diesel)
- It is an uncomfortable experience as a driver

“I hate that you can’t always respond how you think is safest. If you need to be driving faster, you just can’t do it”

“It is compromising the safety of everyone on and around the bus”

“I get that the speed limit is 20, but you need to have some emergency power.”

“It jolts and jerks so much it hurts my back. And my knees bang on the steering wheel because I’m tall”

“It’s not safe because you don’t know what to expect. Losing control of the speed of your vehicle is a scary thing”

“The tech is not reading the road, it doesn’t know what is going on and how other road users are behaving, I do, I have eyes, I have the experience”

11

It is affecting reliability with bus drivers struggling to finish their route on time

- Being 15-20 minutes late is ‘standard’ and easily done, even without traffic
- This is creating confusion for the controllers and drivers are really feeling the pressure for something that is out of their hands
- Managers are concerned about the impact on EWT as have noticed the impact on reliability

“It’s affecting EWT, it really is creating problems and there s nothing to be done unless they get rid of it. I understand now that it is not the drivers fault. It’s just not good enough”

“You can be 15-20 minutes late easy peasy, nothing eventful has to happen, you are just trying to get from A-B and it’s not reliable”

“I was 50 minutes late the other day. It.was.a.nightmare. I’ve never known anything like it. It’s a joke”

12

At present, bus drivers feel that ISA is more of a hindrance than a help

- It is making their job **harder** and more **stressful** and they do not want it on the buses they drive
    - Their experiences are **not consistent enough for them to feel that it is one less thing for them to worry about**
- Some can see it's potential if it were to run smoothly
    - But all drivers must be **educated**, as well as other road users
    - Particularly **through signs on the back of the bus** to inform other road users that *'This bus is automatically restricted to each speed limit zone'*
- They also see **potential for buses to 'lead the way'** and have a **positive influence** on other road users, but this **cannot be achieved without communication and awareness**

"If a car flashes to let you go, you want to move quickly to show appreciation but you can't, you have to crawl and it infuriates other road users"

"I am a mentor – I actually teach drivers how to drive. And I'm telling you – it is not safe. I would not want to teach a new driver in this bus"

"All road users would need to know about it. They all need to understand the deal or we are going to still feel like idiots. They have to educate everyone"

13

There is potential, but it needs to be drastically improved

All drivers think the **cap should be set higher by a few mph**, to allow them to stay at 20, and allow them some pulling power

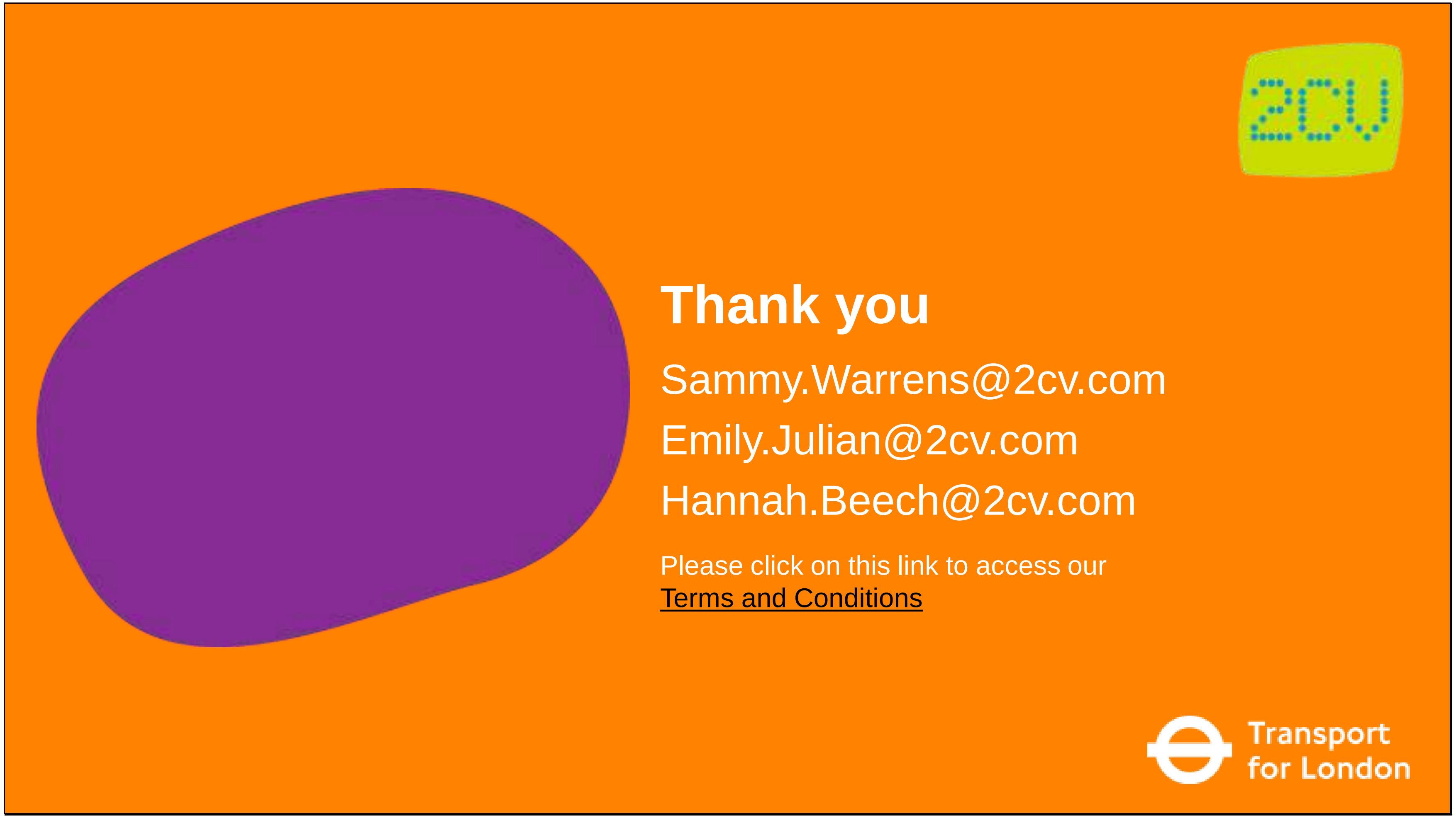
They want the 20mph experience to be akin to the 30mph experience

At this stage, **drivers want full control of the vehicle back**. Especially while other road users are **not aware of / do not have ISA**

“If they set it at 25, then we could slow ourselves down”

“If the cap was higher than the speed limit then you could smoothly change between speeds and the driver would have more control”

14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Appendix D 2CV report 2

Background

- TfL is running a trial of Intelligent Speed Assistance (ISA) technology on the 19 bus route. The technology brings together internal information on the vehicle speed with external information on the speed limit, and actively controls the speed of the vehicle to stay within the speed limit.
- ISA has been trialled across Europe and research in Sweden shows a positive impact of the technology both in terms of improving road safety and acceptance from drivers. A recent report from the European Commission recommended mandating ISA in all commercial vehicles. TfL therefore need to ensure London is fully prepared for any future legislation and has an understanding of any potential impact of the technology.
- This trial is also part of TfL's Pedestrian Safety Action Plan and Cycle Safety Action Plan, and aims to recognise the potential role this technology could play in promoting adherence to speed limits across the road network.
- 2CV has conducted research to explore the likely impact of this new technology, were it to be fitted on TfL buses. 2CV's qualitative research focussed on understanding the experiences and perceptions of the bus drivers using the new systems. Additional research has been carried out simultaneously by another partner agency to quantitatively test the accuracy and impact of the technology.

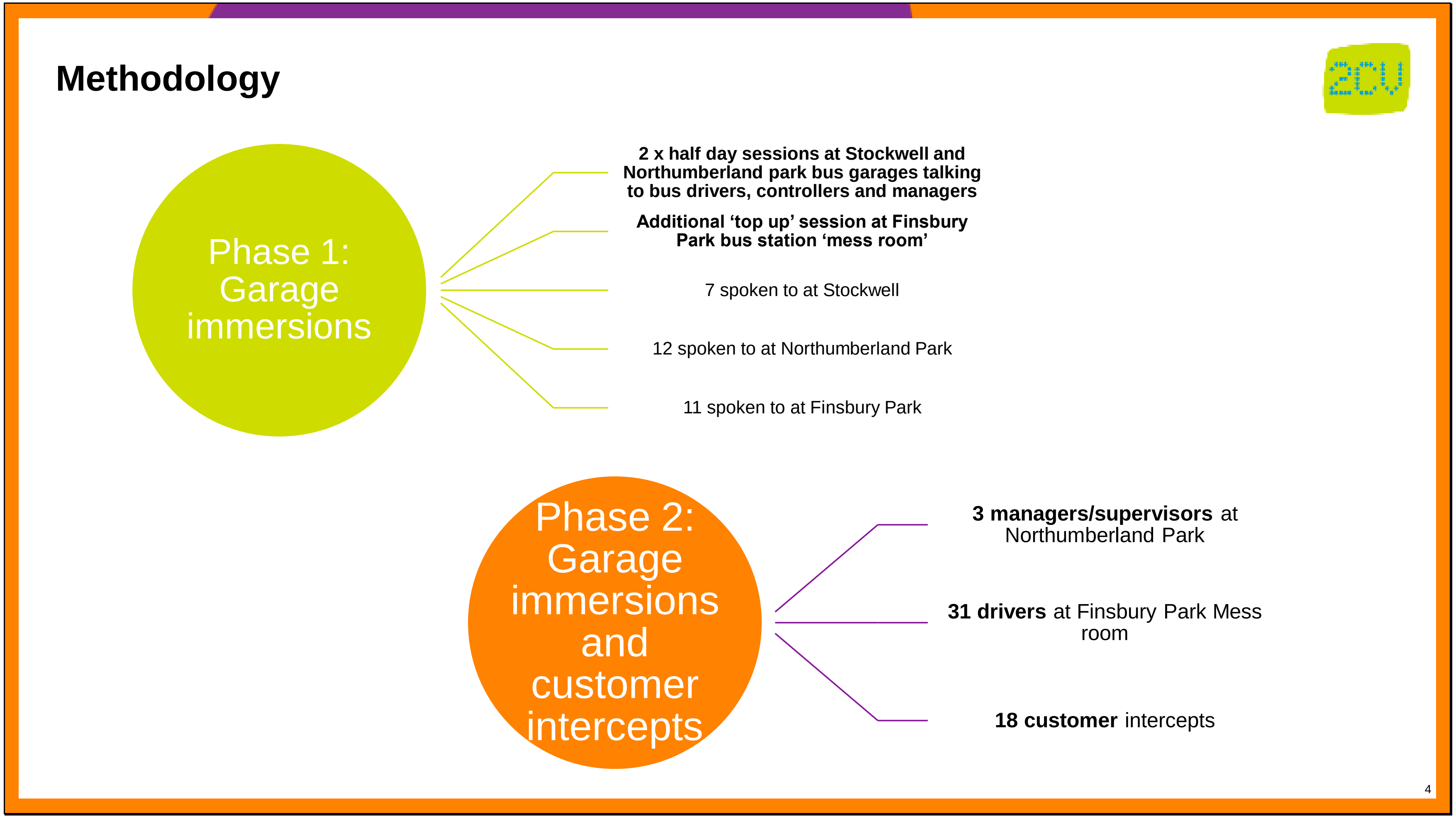
2

Research objectives

To understand in depth the operators' and bus drivers' perceptions of having the ISA technology on buses

To establish how the ISA technology on buses impacts the drivers' and customers' experiences

3


Methodology
Phase 1: Garage immersions
2 x half day sessions at Stockwell and Northumberland park bus garages talking to bus drivers, controllers and managers
Additional 'top up' session at Finsbury Park bus station 'mess room'
7 spoken to at Stockwell
12 spoken to at Northumberland Park
11 spoken to at Finsbury Park
Phase 2: Garage immersions and customer intercepts
3 managers/supervisors at Northumberland Park
31 drivers at Finsbury Park Mess room
18 customer intercepts
4

Key findings from Phase 1 (Oct 2015)

At first, there was overall resistance to the tech; this is in part due to **negative** and sometimes **dangerous** experiences, which left drivers feeling out of control and unsafe

The key issue was with maintaining 20mph as the speed would sometimes drop down to as little as 5mph

The problems with speed control was **confusing other road users which caused tension and risky behaviours**

Bus drivers struggled to finish their route on time

Ultimately, bus drivers felt that ISA was more of a hindrance than a help

5

In response to the issues faced, TfL paused the trial ahead of Phase 2 to fix the issues with the 20mph speed cap

Phase 2 started on December 10th 2015, with the final day of fieldwork on January 6th 2015

6

Key findings from Phase 2 (January 2015)

Since the problems have been fixed, **drivers are much more open to the technology as it is working more as intended,** with fewer pinch points

However, **the behaviour of other road users remains the same during off peak shifts,** where no. 19 buses are sticking to the speed limit **other road users (incl. buses) continue to speed and overtake** – sometimes in quite risky ways

Customers were not aware of the technology and feel that the **19 is no different to other buses** they get on, but they feel very positively toward ISA technology

Education for all road users will be essential if the technology is rolled out so that everyone is informed about its purpose

Effectiveness of the ISA will need to be **monitored** and **maintained accordingly**

7

Supervisors / managers are not hearing any complaints about the ISA technology from drivers

- Drivers are no longer coming to them with the issues they were complaining about in Phase 1
- They are pleased that the technology is being trialled and think it is a good idea to improve safety in this way

"There has been complete silence from the 19 drivers in the past month or so, so to me that is a very good sign"
Supervisor

"I think it's a brilliant idea and gives drivers more capacity to pay attention to other things"
Accident prevention manager

8

Issues can occur during off–peak shifts, where roads are clearer and other road users become more impatient

- Drivers do not notice the technology during peak times as they rarely get the opportunity to reach full speed
- The issues start to appear during off-peak shifts, where the roads are clearer and the ISA can put them at a disadvantage against other road users (this largely comes down to a lack of education about ISA on buses):

Hard to overtake cyclists on hills at 20mph limit	Other roads users still speed on an open road and lose their temper at bus drivers for staying at the limit	Harder to pull out into traffic that is speeding – other drivers are impatient and speed up despite giving way	Some customers ask why the bus is going so slowly, putting pressure on the driver
"Because the cyclist doesn't know why I'm not going faster to overtake them, you can find yourself in a bit of a stand off with them. I've seen many a middle finger when this happens!"	*"Other cars or buses see an open road and that I am holding them up because my bus is sticking to the limit, they honk, they swear and can even overtake when it really isn't safe"*	*"If a car gives way, I think they expect me to pick up speed quicker, and when I can't they get really annoyed and beep or drive too closely to the bus"*	*"If passengers can see a clear road ahead they think that I am driving too slowly even though it's a 20mph zone, I've had a couple approach me and ask me why I'm going slow"*

10

Customers are unaware of the technology but very open to it

- Customers feel that the **19 is no different to other buses** they get on
- **Only one customer** we spoke to has **complained to a driver about why they were driving so slowly**, but she would have been happy with an explanation of what ISA was
- Overall, **customers think it is a good idea** and that it will make for:
  - **More comfortable** journeys as it will **prevent drivers** from driving **too fast** and **erratically**
  - **Safer roads,** particularly for **pedestrians** and **cyclists**

"I think some buses are newer than others but that's about it…"

"It's a great idea, I definitely think some bus drivers go way to fast, especially at night"

"It's good for safety I guess, it won't impact upon my journey but may make the roads safer for cyclists in some way"

"The bus doesn't go fast enough through central London for me to notice it!"

11

Recommendations for the future of ISA on buses

- Educate all road users about ISA with the aim to normalise
  - Communications strategy and press coverage
  - Put a sticker on the back of the bus
- Monitor key frustrations:
  - Maintaining 20mph
  - Ability to overtake cyclists
  - Pulling out from bus stops
  - Impact on gearbox

"Everyone needs to be educated on this, it needs to be on the news, in the metro so they understand why we drive the way we do!"

"I think other road users would get a lot less frustrated if they knew that the speed was not in the hands of the driver, it is a computer!"

"I think we need to make sure all the buses work in the same way with the ISA, we can't go back to the speed dropping to 5mph, the quality of ISA needs to be monitored and maintained"

"The gearboxes need to be kept an eye on. We don't know what this technology is doing to them. I am seeing the engine light come on more since ISA was introduced"

12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Appendix E ISA manufacturer's information

Intelligent Speed Adaptation

Zeta Automotive have developed EconoSpeed Connect, the patented and award winning, acceleration and speed limiting device.

EconoSpeed Connect is connected between the accelerator pedal and the Engine Control Unit (ECU). It constantly monitors acceleration demand from the driver with the throttle pedal, as well as monitoring the engine and road speed of the vehicle via a Controller Area Network (CAN).

When the vehicle speed is less than the set maximum level, EconoSpeed allows as much throttle output to the ECU as the driver requests. However, if EconoSpeed Connect detects that the vehicle speed has reached the set maximum speed, it restricts acceleration too maintain the maximum speed.

The hardware inside the EconoSpeed Connect is able to read and replicate all commonly used throttle pedals in use today. Mechanical relays provide a hardware fail-safe pass-through, should power fail or valid signals are lost. Speed inputs are read via the vehicle's CAN bus, which is set as 'listen only', so as not to interfere with other systems on the vehicle. EconoSpeed Connect only restricts signals coming from the accelerator.

The ISA feature of the unit allows the unit to detect which road the vehicle is travelling along using GPS technology and therefore set the maximum vehicle speed to the current road speed limit.

The EconoSpeed Connect uses a GSM connection to allow speed limit changes to be updated remotely without the need to physically make contact with the unit.

Intelligent Speed Assistance on London Buses

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ISSN

ISBN

CPR2332