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Effectiveness of Speed Indicator Devices on reducing vehicle speeds in London

L K Walter and J Knowles

Transport Research Laboratory

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by LK Walter and J Knowles (TRL)

Prepared for: Project Record: **Effectiveness of Speed Indicator Devices on reducing vehicle speeds in London**

Client: **Transport for London, London Road Safety Unit (Peter Sadler)**

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Contents

List of Figures

List of Tables

Executive summary

Speed Indicator Devices (SIDs) are temporary vehicle activated signs which detect and display real-time vehicle speeds. SIDs are a relatively cheap method of speed management which aim to change drivers' speed behaviour in different driving environments. They are increasingly being installed at sites across London with the aim of reducing vehicle speeds, but there has been little research in Great Britain or in urban contexts to measure their effectiveness. This report presents the results of a study of their effectiveness in reducing vehicle speeds in London that was carried out in 2007 by TRL on behalf of Transport for London.

The Department for Transport's (DfT) Vehicle Activated Signs Traffic Advisory leaflet (DfT, 2003) contains general information on the conditions in which a Vehicle Activated Sign (VAS) should be used. As long as speed limit or road traffic signs are not attached to the same lamp column as the SID and the SID is not used for enforcement, no authorisation from DfT is required for its installation.

The Royal Borough of Kingston-upon-Thames (RBK) has been using SIDs since 2003, and their strategy for selecting sites and installing SIDs has developed with experience and research. RBK currently owns 13 temporary SIDs which are rotated around approximately 90 sites, remaining at any one site for three weeks. Thus a SID returns to each site approximately every 15 weeks. In addition to the rotation sites, 15 sites in RBK have a fixed SID or VAS. The experience and recommendations of RBK are presented in this report as a case study for good practice, and were used in the study design and site selection for this research.

The main conclusions from the experience of SIDs in RBK are:

- SIDs should preferably be mains powered, especially if they are permanent or return regularly to the same sites,
- RBK has a specific policy which governs where SIDs can be placed. In general they are placed: at or near sites where the speed limit changes, particularly at the beginning of 20mph zones; at sites with a high collision rate; at sites on relatively straight roads, not obscured by vegetation and away from junctions and pedestrian crossings; and at sites with a known speeding problem or public concern over vehicle speeds exists.
- The SID should detect vehicle speeds at around 100m before the vehicle reaches the sign. This gives the driver sufficient time to react to the sign, but is short enough to be obvious to the driver that they are the one who has activated the sign.
- A study of five sites in RBK found that SIDs had a 'novelty' effect. In the initial period of operation, all drivers reduce their speeds, whether they are driving above or within the speed limit. As drivers become accustomed to the sign, only those driving above the speed limit tend to reduce their speed (Poulter and McKenna, 2005). The 'novelty' effect was found to last about a week and then speeds slowly increased in the second week of observation. Currently, SIDs in RBK remain in place for no longer than three weeks and are then moved to another site.
- Vehicle speed data are collected periodically at fixed and temporary locations in RBK and are analysed to inform their speed management strategy. They have found that radar vehicle classifiers record speed data more reliably than automated traffic counters (ATC): data from ATCs have sometimes been unreliable or missing due to mechanical failure of the ATC or vandalism.

The specific aims of this new study were to assess the effectiveness of SIDs over time and distance at several locations in London. SIDs were installed at eleven sites in South East London for one, two or three weeks. Vehicle speeds were recorded at each site from one week before the SID was installed until two weeks after it was removed.

The sites were selected from a list of potential sites comprising locations where borough staff were aware of a speed problem, also single carriageway roads where one fatal or serious collision or at least two injury collisions (any severity) occurred in 2005 with "exceeding the speed limit" as a contributory factor. All proposed sites were visited to ensure that the environment was suitable for a SID installation and for the speed data collection method (i.e. a long stretch of road was needed for three or four loops 200m apart). The final 11 sites were then selected so that they were all 30mph sections of two-way single carriageway roads with no traffic calming, speed cameras, red light cameras, major junctions, sharp bends and no or few pedestrian crossings (any of these may influence drivers' speed choice). Sites that were un-congested for the majority of the day were chosen in order to observe as much free-flowing traffic as possible, so sites close to schools were rejected. Another selection criterion was that no road works should be planned for the duration of the study and no SIDs were located on signed diversionary routes for the Grand Depart of the Tour de France.

The following research questions were investigated:

Q_1: Do SIDs have an effect on vehicle speeds in free-flowing conditions?

Q_2: How long does the effect last: 1, 2 or 3 weeks?

Q_3: Is the SID effective when in place but not in operation?

Q_4: How far beyond the SID does the speed reduction last?

Q_5: Does the effect continue after the SID is removed, and for how long?

Q_6: How does the effectiveness of SIDs vary between locations and where are they most effective?

Q_7: Under what conditions are SIDs most effective?

Effects were calculated by measuring the difference between the mean speeds of vehicles at the SID before and during the SID operation. Any underlying vehicle speed changes were controlled for using data collected from a point 200m before the SID position.

The main conclusions were as follows:

- An overall speed reduction of 1.4mph was detected across all sites whilst the SIDs were operational. The reduction varied between sites from 0.6mph to 2.6mph.
- The proportions of drivers exceeding 30mph and 36mph (ACPO guidelines) were significantly reduced at all sites except one whilst the SID was in operation, showing that speeding drivers are affected by SIDs.
- There was evidence of a 'novelty' effect at some sites, with the SID being most effective in the first week of operation and significantly less effective during week 2. The study was unable to conclude whether speeds were reduced when the SID operated for a third week. The SID operated for three weeks at only two sites: there was no change in mean speed between week 2 and 3 at one site, while the effect tailed off towards the end of the three-week period at the other.

- At four sites, the SID's battery failed for a period of three or more days, and drivers were not informed of their speed during these periods. At all but one site, vehicle speeds were observed to be higher when the SID was not operating. As the SID batteries were found to be unreliable, it is suggested that SIDs should be mains operated, taking power from the lamp column upon which they are placed, according to the RBK policy, or use solar panels.
- At most sites the effect downstream of the SID was dramatically reduced – the speed reduction after 200m was less than a quarter of the reduction at the SID site, and even less after a further 200m - or an increase in some cases. This implies that any effect after 400m is likely to be negligible.
- In general, there was no continuing speed reduction after the SID was removed, although there was a small continuing effect at sites which had had the biggest reductions whilst the SID was in place
- It was found that the SID operating at sites classified as residential was significantly more effective at reducing speeds than at sites where there was a combination of commercial and residential land. A larger reduction in mean speeds was also observed at sites without parking and at sites with relatively low traffic flows (fewer than 7,000 vehicles per day).
- It is estimated that the overall reduction in speed would lead to a 5.6% reduction in collisions occurring in the area whilst a SID was operational.

In conclusion, SIDs have been found to be effective at reducing vehicle speeds on 30mph roads in London when deployed for a short time. The effectiveness of SIDs lasts only a short distance beyond the sign and varies depending on site characteristics. The study's findings can inform the design and operation of a SID speed management strategy. It is suggested that SIDs should remain at each site for at least two weeks and no longer than three weeks. There is little or no residual effect on vehicle speeds after the SID is removed, so it should be reinstalled regularly. The case study shows that there should be a reasonable period before the SID is returned to a particular site so that drivers will have forgotten about the previous installation. Each site is different, and so expert judgement should inform how regularly signs are replaced.

1 Introduction

Speed management is a key theme in London's Road Safety Plan 2001 (Transport for London, 2001). In 2006, a third of killed or seriously injured (KSI) casualties in London were caused by collisions where excessive or inappropriate speeds were recorded as contributing to the collision. Reducing vehicle speeds in London is therefore an important issue in road safety that could reduce the number of road casualties in London. In addition, reducing vehicle speeds would lessen the level of intimidation vulnerable road users may feel when using London's roads. Methods of reducing vehicle speeds in London include safety cameras, traffic calming, 20mph speed limits and 'Home Zones'. Speed Indicator Devices (SIDs) have the potential for being an additional method for reducing excessive speeds.

This report describes the results of analyses to determine the overall effectiveness of SIDs for reducing speeds at 11 sites in London. In addition, this study was designed to investigate the characteristics of SIDs, such as their effectiveness over time and distance downstream of the SID site as well as the types of locations where they were least effective.

The research questions that are examined in the report are:

Q_1: Do SIDs have an effect on vehicle speeds in free-flowing conditions?

Q_2: How long does the effect last: 1, 2 or 3 weeks?

Q_3: Is the SID effective when in place but not in operation?

Q_4: How far beyond the SID does the speed reduction last?

Q_5: Does the effect continue after the SID is removed, and for how long?

Q_6: How does the effectiveness of SIDs vary between locations and where are they most effective?

Q_7: Under what conditions are SIDs most effective?

The appendices to this report are included in a separate report: Effectiveness of Speed Indicator Devices on reducing vehicle speeds in London – Technical appendices.

2 Use of SIDs in Great Britain and London

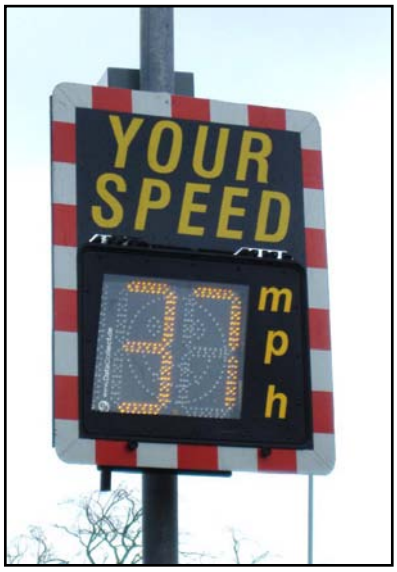

Figure 2.1: SID sign

SIDs detect and display real-time vehicle speeds. There are many different types and manufacturers of SIDs. In addition to displaying vehicle speeds, some SIDs also display smiley or sad faces or a "slow down" message to vehicles obeying or exceeding the speed limit. SIDs are usually temporary signs and can be portable or fixed. They provide a highway authority with a relatively low cost speed management option which is aimed at changing drivers' behaviours towards speed choice within varying road environments. They require a relatively straight road so that the radar used to detect the vehicles is not interrupted, and an electricity supply which can be a battery or, more commonly, taken directly from a lamppost or solar panels. In order to give the driver time to react before passing the sign, the SID LED display flashes speed and pictures when the vehicle is approximately 100m in front of the sign. Each SID has a maximum speed above which the SID does not display the speed of the approaching vehicle. Generally this speed is either 15mph above the speed limit or follows the Association of Chief Police Officers (ACPO)[1] guidelines on enforcement (above 10%+2mph). This discourages irresponsible drivers seeing the signs as a challenge to exceed the speed limit by a large amount.

As well as showing information these signs can also store speed and flow data for up to 60,000 vehicles, which can then be downloaded remotely. Previous experience in the Royal Borough of Kingston-upon-Thames has shown that these data are not always reliable.

The Department for Transport's (DfT) Vehicle Activated Signs Traffic Advisory leaflet (TAL) (DfT, 2003) contains general information on the conditions in which a Vehicle Activated Sign (VAS) should be used. This advocates the use of these signs in conjunction with conventional road signing. It should be noted that this advice applies generally to VAS and not specifically to SIDs. These are, of course, vehicle activated, although have some important differences: for example, SIDs are generally used for a short period of time (one or two weeks) and then removed and SIDs have dynamic displays whereas VAS have a fixed display.

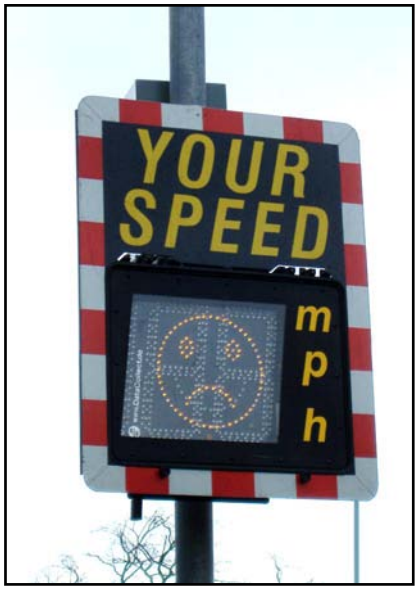

Figure 2.1: SID sign in safety mode

The DfT's position specific to SIDs is detailed in a letter dated January 2004 from the Road Safety Division (see Appendix A). This states that as long as speed limit or road traffic signs are not attached to the SID and that they are not used for enforcement, then no authorisation from DfT is required for their installation.

[1] Association of Chief Police Officers Speed Enforcement Guidelines, 2002. http://www.acpo.police.uk/asp/policies/Data/speed_enforcement_guidelines_web_v7_foi.doc

Some Local Highway Authorities have their own additional rules for allocating SIDs, for example Milton Keynes (Milton Keynes Council, 2005) and the Royal Borough of Kingston-upon-Thames (see Section 4) which detail location restrictions and technical details.

3 Previous research

Despite the widespread use of SIDs across the UK, there have been very few studies to determine their effectiveness. Studies in the USA have shown a significant reduction in mean speeds. Three studies are discussed below.

The most recent research (and most relevant to London) involved a study at five sites in the Royal Borough of Kingston-upon-Thames on a 30mph road using a four-week model (Poulter and McKenna, 2005). During the first week of the study, 'before' data were collected for week-days only, the SID was then installed and data were collected for two weeks. A week of follow-up 'after' data was collected once the SID was removed.

The results using this model found some fluctuation within the five weekdays, but the main findings showed that there was a 'novelty' effect which lasted for about a week (an overall reduction in mean speed of 1.3mph) and then speeds slowly increased in the second week of observation (mean reduction of 1.2mph). The after period showed a small but statistically significant decrease in mean speed (0.2mph) from the before data.

This study applies similar methods, with some refinements. In addition to an overall assessment of the effectiveness of SIDs, this study investigates the effectiveness of SIDs further down the road and after the SID is removed. In addition SIDs were installed for varying periods of time in order to assess the 'novelty' effect. Data were collected at 11 different locations, the SID was installed for between 1 and 3 weeks at the different sites and data were collected at the SID site before and after the SID implementation. These refinements allowed a more detailed analysis than was possible in the study by Poulter and McKenna.

The Texas Transportation Institute (Rose & Ullman, 2003) conducted a study using Dynamic Speed Display Signs (DSDS) by installing them at roadway situations where excessive speeds could be a significant safety or operational problem. DSDS are a particular make of SID. They collected data before the installation of the DSDS, one week after installation and four months after. The size of effect on drivers' speeds varied with the type of site as did the time the effect lasted. The research concluded that those drivers travelling faster than the posted speed limit were influenced most by the DSDS, and that there was an initial 'novelty' effect.

A large scale evaluation of vehicle activated signs (VAS) conducted by TRL (Winnett & Wheeler, 2002) considered speed roundels and warning-of-bend and intersection VAS. The signs were triggered by vehicles travelling in excess of a pre-determined 'safe' or 'appropriate' speed. Unlike SIDs, the signs did not display the speed of a vehicle. 60 sites were used, in four English counties. The evaluation looked at speed reduction due to the installation of the sign, as well as comparing collisions before and after installation. The study found large and statistically significant decreases in speeds after the installation of a speed roundel VAS, ranging between 1mph and 7mph on a range of roads with speed limits varying from 20mph to 50mph.

4 Case study for good practice: Royal Borough of Kingston-upon-Thames SID rotation programme

4.1 Royal Borough of Kingston-Upon-Thames

Located on the River Thames in South West London, the Royal Borough of Kingston-upon-Thames (RBK) is the second smallest London borough (after the City of London). The borough covers 3,748Ha and has a population of 147,273 (2001 Census).

One of the casualty reduction targets for London is for a 50% reduction by 2010 in the number of people killed or seriously injured (KSI) in road collisions, compared to the average for 1994-98. In 2006, there were 77 KSI casualties from road collisions in RBK, 38% less than the 1994-98 KSI baseline (TfL, 2007).

4.2 RBK Road Safety plan

RBK is committed to the management of vehicle speeds in the borough. A large range of engineering, enforcement and educational measures are used including, since 2003, interactive signs. Interactive signs include VAS, variable message signs, warning signs and SIDs. RBK's Road Safety plan, (RBK Local Implementation Plan, 2006) states that the use of SIDs is an integral part of RBK's strategy to reduce vehicle speeds in the borough.

4.3 SIDs in RBK

RBK has accrued a wealth of experience and knowledge built up since it first used SIDs in 2003. The evidence and data led approach to managing speed on RBK Highway Authority roads has led to the development of the RBK SID rotation programme. Information from the borough influenced the study design, especially in the selection criteria used for sites for inclusion in the study.

The borough currently operates 13 temporary SIDs which are rotated around approximately 90 sites, remaining at any one site for three weeks. In addition to the rotation sites there are 15 sites in RBK which have a fixed SID or VAS. Several types of SID from different manufacturers are used. The 13 mobile SIDs are manufactured by Data Collect and distributed by Traffic Technology. In addition RBK has 12 VariText signs and three 3M signs.

The RBK SIDs have different displays, some display the speed alternating with a happy or sad face dependent on the speed and others have the speed flashed up repeatedly. The most common SID used in RBK is a temporary sign measuring 604 x 776 x 200mm and weighing 8.5kg. The 3M signs can be accessed through telemetry - turned on / off and have their settings changed remotely and vehicle speed and volume data can also be downloaded. The VariText and Data Collect signs can also store vehicle speed and volume but RBK tend not to use this facility on all these signs for two reasons.

1. The authority has a good arrangement of 54 permanent loop sites on its strategic road network which is being added to each year.
2. Tests and onsite inspection confirm that forward facing radars cannot determine 'volume' very accurately; particularly on busy urban roads.

All SIDs used in RBK are mains powered as batteries are not recommended because of their limited battery life in heavy traffic and the additional time and cost

necessary to replace and recharge them. The use of solar power has also been considered in RBK but these do not function so well at night and the assemblies are more difficult to remove and install, plus they are considered unsightly.

SIDs are activated by radar detecting oncoming vehicles. From RBK experience in operating SIDs it is felt that the speed of an oncoming vehicle should be detected approximately 100m before the sign location. The activated sign will then give the driver sufficient time to react to the message, and is a short enough distance to be obvious which vehicle is triggering the SID.

4.4 RBK SID site selection process and criteria

RBK has a specific policy for the use of interactive signs which governs where the signs can be placed and the possible road environments for which they are suitable. Each proposed site is surveyed by a Neighbourhood Traffic Engineer for its appropriateness. SIDs are mostly placed at or near speed limit changes, particularly at the beginning of 20mph zones or at sites where a high collision rate (of all severities) exists. Sites near junctions and pedestrian crossings are normally avoided, as vehicle speeds are generally reduced in these areas and drivers should not be distracted unnecessarily.

One or more of the following criteria suggest that a temporary SID should be deployed if required and if resources allow:

- The criteria for a permanent VAS are not met;
- A history of a high number of collisions at the site (of all severities);
- A clear sight length for the device to operate fully away from junctions and pedestrian crossings;
- A known speeding problem is evidenced; or
- Public concern over vehicle speed exists and is supported by a Neighbourhood Traffic Engineer site visit.

4.5 SID positioning

SIDs should be installed in accordance with existing criteria and guidelines to ensure their use is as effective as possible in terms of reducing collisions. All SIDs in RBK are mains powered through lamp columns or lit signs at the site of the SID. If the SID cannot be positioned on the lamp column, for example if there are other signs attached to the column, or the column is too old, weak or about to be renewed, then the SID can be mounted on a dedicated post near the lamp column. This requires a power feed (embedded in the footway) from the lamp column and increases initial costs by around £120.

SIDs should be mounted high enough to be out of reach of vandals and be lightweight so that they can be mounted and removed safely and quickly. A column must not be too near the kerb (a minimum of 0.6m away) to ensure a gap between the edge of the sign and passing vehicles. In RBK, SIDs are fixed to the column by being mounted on a pre-fixed backing board, and are locked to this board to prevent theft.

All SID sites are subject to a Risk Assessment, and the personnel installing the SID are trained in erecting, operating, installing and uninstalling the SIDs in terms of health and safety requirements, e.g. working on the highway, high visibility clothing, working with ladders, electrical safety etc. Two people wearing high visibility

clothing are involved in carrying out the work, in daylight and using the appropriate ladder, tools and fixings. No traffic management is required as all work is undertaken on the footway.

The sight line of the SID must be taken into consideration as the radar will normally detect vehicles approximately 100m before the sign. In order for the SID to detect vehicles reliably and for drivers to see the sign clearly, it should be positioned on a relatively straight road and not obscured by vegetation. Therefore based on the curvature of the road at a particular site a SID may have to be installed on the opposite footway or in the middle of the carriageway if a large central island and lighting column is available.

4.6 SID rotation

Research (see Section 4.7) has shown that the effect of SIDs on vehicle speeds reduces as the 'novelty' effect wears off. Therefore, in RBK currently, the mobile (temporary) SIDs remain in place for a three-week period and are then moved to another site. There are nearly 90 established rota sites in RBK where SIDs can be installed, and the regular rotation scheme allows a SID to be installed at each site approximately every 15 weeks. In RBK 13 SIDs are uninstalled, moved and re-installed every three weeks. The rotation programme has tolerances for the unavailability of equipment and holiday periods built in which means that in practice SIDs are moved 14 times a year. The movement of 13 SIDs takes two people with a van about six hours (effectively one working day). The SID rotation programme also allows for the regular maintenance of SIDs to replace burnt out LEDs. This maintenance is undertaken by the UK agents of the signs.

4.7 SID evaluation and monitoring

When RBK obtained its first SID in 2003 its effectiveness in reducing vehicle speeds was evaluated using temporary tube type Automatic Traffic Counters (ATC), which recorded traffic speed and volume before, during and after the installation of the sign. The sign proved effective in reducing speeds by up to 2 mph for a limited period. This success coupled with positive public feedback led RBK to identify additional sites and purchase further signs.

A larger scale evaluation of the effectiveness of SIDs in reducing vehicle speeds was undertaken using five sites. This study found that in the initial period of SID installation, all drivers reduce their speed, whether driving above or within the speed limit (Poulter and McKenna, 2005). As drivers become accustomed to the sign, only those driving above the limit tend to reduce their speed. A 'novelty' effect was observed in this data and speeds can be seen to return to normal i.e. increase gradually after the SID was removed. This research fed into the rotation policy of RBK.

As mentioned above, continued periodic speed data are collected by RBK at various sites to monitor speeds in the borough. Generally these speed, volume and classification surveys use ATCs coupled to tubes to carry out this work, but RBK is tending to move over to radar traffic classifiers (for example the Datacollect model www.datacollect.de) rather than tubes. This is due to experiences of unreliability of survey data caused by vandalism, reduced costs of not requiring traffic management, no disruption to traffic, but more importantly personal safety issues as using the radar type device does not require work on the carriageway. When ATC 'tubes' are used on busy roads to survey traffic RBK will only extend the tubes to the

centreline of the road in order to reduce errors in the data caused by two vehicles crossing in different directions simultaneously.

4.8 Public perception of SIDs

In RBK, SIDs have been well received by the public, including the younger population who respond positively to the smiley faces when installed near schools. This has been demonstrated by the number of requests received by the RBK from members of the public for the installation of these signs.

Members of the public can and regularly do request a SID on a road which they perceive to have a speeding problem. However, this site will not be inserted into the rota until a Neighbourhood Traffic Engineer has verified this claim with data obtained from a speed survey to ensure that the SID site selection criteria have been met.

4.9 Lessons learnt

Since SIDs were first used in RBK in 2003, the strategy for selecting sites and installing SIDs has developed with experience and research. Overall, the main lessons have been:-

- SIDs should preferably be mains powered, especially if they are permanent or return regularly to the same sites;
- SIDs have a 'novelty' effect and should remain for a short period (around two to three weeks) in order to maximise the effect;
- The radar within the SID should be set to detect and display vehicle speeds at around 100m beyond the sign;
- Radar vehicle classifiers record speed data more reliably than ATCs which can be targeted by vandals and therefore fail to record data. In addition, radar classifiers are cheaper and safer to install: but beware of battery life which is shorter than a tube type ATC;
- A constant watch should be maintained on permanent SID/VAS signs as a poorly operating sign can have a detrimental effect on drivers. Depending on the malfunction, (e.g. corrupt image/incorrect speed displayed) a faulty sign will only irritate drivers as they pass this same sign day after day. It is best to switch the sign off; but even then, this can generate criticism on the lines of 'wasted funds' if the sign is left for too long a period. The best option of all is to arrange for the sign to be fixed or removed.

4.10 Current and future developments

As more sites are identified that would benefit from periodic SID installation more SIDs are required. Clearly if the number of SIDs remains the same and the number of sites increases then each site will be visited less regularly. RBK is considering the effectiveness of using different display images on drivers familiar with SIDs. RBK are also considering the benefits of SIDs that display the vehicle's registration mark. However, the cost of these devices is still prohibitive at present.

5 Study Design

In order to evaluate the effectiveness of SIDs on vehicle speeds, 11 study sites were selected in South East London. Vehicles' speeds were recorded at three or four points on the road near the position of the SID before, during and after the SIDs were operational. A pilot study was carried out at one site to ensure that all areas of the study were compatible.

5.1 Site selection

Sites were selected on borough roads in the London Boroughs of Sutton, Croydon, Bromley, Bexley, Lewisham and Greenwich. The initial list of potential sites was a combination of locations suggested by the boroughs where a speed problem was known to exist. In addition, single carriageway roads in South East London were included in the potential list if either a fatal or serious collision occurred or at least two collisions of any severity occurred on the same road in 2005. At least one vehicle involved in the collision had to have the contributory factor[2] "exceeding the speed limit" attributed to it. Authorisation from the boroughs was sought and received and a site visit was then conducted at all proposed sites to ensure that the environment was suitable for a SID and for the speed data collection method. Video footage was taken of each proposed site during this site visit in order to record characteristics of the sites. This process caused some sites to be rejected due to alternative speed management or unsuitable characteristics being present.

The final selection of sites was restricted by a number of factors so that variation in the data was controlled and the interpretations could be as consistent as possible. The chosen sites were all 30mph sections of two-way single carriageway roads with no traffic calming, speed cameras, red light cameras, major junctions, sharp bends and no or few pedestrian crossings, all of which may influence speed choice. A long stretch of road was required in order to get sufficient space for three or four loops 200m apart, and additional length at either end to ensure that traffic speed was not affected by approaching junctions – approximately 1km of road was required for a three loop site and 1.2km for a four loop site between junctions. Routes that remained un-congested for the majority of the day were chosen in order to observe as much free-flowing traffic as possible, so routes close to schools were rejected. No on-road parking was preferable; however, this was not possible at some sites because of the other restrictions on site selection. There was on-road parking at three sites. There were no road works planned on the selected routes for the entire duration of the study and no SIDs were located on signed diversionary routes for the Grand Depart of the Tour de France.

In order to assess the effect of a SID under different site characteristics, a number of factors were measured and/or recorded for each site. The sites are shown in Table 5.2 along with their site characteristics. The location and layout of each study site is shown in Appendix B.

5.2 Study timetable

For every site the SID was installed for a period of 1, 2 or 3 weeks. In the main study, the SID was installed for one week at three sites, for two weeks at four sites and the remaining three non-pilot sites had a SID installed for three weeks. The

[2] Contributory factors are subjective assessments, reported by the Police, of how and why a collision occurred. These factors provide additional information on the key actions and failures attributed to each driver that led to the collision.

study was designed such that SIDs were installed on a range of days from Monday to Friday. On each day SIDs were installed at a randomly selected pair of sites: one with higher traffic flow and a site with lower traffic flow. These were situated in geographically close pairs in order to minimise the time between SID pairs being installed, and these pairs were randomly assigned to the design as shown in Table 5.1.

A balanced design was necessary to reduce the possible effect of external factors (for example, day of week or flow) on the results. For example, it is unknown whether a SID is more effective if it is put in on a Monday or any other day, so a balance of installation days (day when the SID was installed) was required to control for this factor. It was not possible to implement a completely balanced design as there were three lengths of SID period and ten main study sites. The exact dates of SIDs installations are detailed in Appendix C.

Table 5.1: Study plan for SID installation

Site	Day of week	SID period (weeks)
A – Foxley Lane (pilot)	Mon	2
B – King Henry's Drive	Mon	3
C – Manor Road	Tues	3
D – Welling Way	Weds	3
E – Bromley Hill	Mon	2
F – Parkhill Road	Tues	2
G – Malden Road	Thurs	2
H – Kings Hall Road	Fri	2
I – Shooters Hill Road	Weds	1
J – Beddington Lane	Thurs	1
K – Brownhill Road	Fri	1

Table 5.2: Site locations and characteristics

Site	Location	Borough	Direction	Hatching	Footway	Cycle lane	Parking[3]	Bus Stop at loop	Flow[4]	Road environment
A	Foxley Lane	Croydon	WB	Y	Y	Y	N	1	Low	Residential
B	King Henry's Drive	Croydon	EB	Y	Y	N	N		Low	Residential
C	Manor Road	Sutton	SB	N	Y	N	N	2	High	Commercial/ Residential mix
D	Welling Way	Bexley	WB	Y	Y	N	Y		High	Residential
E	Bromley Hill	Bromley	SB	N	Y	N	N	1 & 3	High	Residential
F	Parkhill Road	Croydon	SB	N	Y	Y	N		Low	Residential
G	Malden Road	Sutton	SB	N	Y	N	Y		High	Residential
H	Kings Hall Road	Bromley	EB	Y	Y	N	Y		Low	Residential
I	Shooters Hill Road	Greenwich	EB	Y	Y	N	N	1 & 3	High	Commercial/ Residential mix
J	Beddington Lane	Sutton	SB	N	N	N	N		Low	Industrial
K	Brownhill Road	Lewisham	EB	N	Y	N	N		Low	Commercial/ Residential mix

[3] No on-road parking is defined as when parking is not permitted (i.e. double yellow lines, red route etc).
[4] High or low flow is defined as above or below an average of 7,000 vehicles per day.

5.3 Speed Indicator Devices

For this study, ten SIDs manufactured by Traffic Technology[5] were deployed. All SIDs were of the same make and were set in safety mode (see Figure 2.2) showing alternating vehicle speed and a happy or sad face, as appropriate.

5.4 Data collection method

Speed and flow data were collected by Automatic Traffic Counters (ATCs) placed across the roads at the site of the SID (loop2), 200m before the SID (loop1), 200m after the SID (loop3) and, in six cases, 400m after the SID (loop4). Each ATC collected speed, flow, headway, direction of travel and vehicle type data for each individual vehicle 24 hours a day for the specified periods.

The MetroCount 5600 Series Vehicle Classifier System were used for this study as these enable all the above mentioned data to be recorded and logged by individual vehicle.

Collision data were not collected as part of this study. There are well established relationships between speed reductions and collisions however, and these are used in Section 11 to estimate the reduction in collisions that can be expected from the speed reduction recorded.

Figure 5.1: MetroCount 5600 Series Vehicle Classifier System

[5] www.traffictechnology.co.uk

6 Method

6.1 Data collection

At each site, data were collected continuously from one week before the SID was installed, during the SID operation until two weeks after the SID was removed. Within the report, data collection periods are defined as:

- 'Before' refers to the week before the SID was installed;
- 'During' refers to the weeks the SID was in operation (1, 2 or 3 weeks labelled as during1, during2, during3 as appropriate);
- 'After' refers to the two week period after the SID was removed (2 weeks labelled after1 and after2).

Speed and headway were collected for each vehicle at three or four points on the road near where the SID was located. For each site ATCs were placed:

- 200m before SID (loop1);
- at or close to SID (loop2);
- 200m after SID (loop3);
- 400m after SID (loop4), the fourth ATC was positioned at the pilot site and at five of the sites in the main study.

6.2 Data preparation

The following steps were taken to ensure that the analysis was performed using a data set that met a high standard of quality and that conclusions were based on reliable data.

For each site the speed data were examined in detail by day, hour and loop investigating anomalies, missing data and outliers (e.g. particularly high/low speeds). Data were excluded if deemed unreliable, for example for a period of time at site K, many speeds were recorded as above 100mph for two days in the after period. This resulted in these days being excluded. In addition the headway data were examined and vehicles were removed if headway = 0; this anomaly occurs when two vehicles travelling in different directions cross the loop at the same time resulting in unreliable speed estimates. Daily traffic flow data were also examined and checked for consistency and missing data flows at each loop. Finally, results from the analysis and subsequent conclusions were checked for consistency with other studies and any unusual results were investigated further.

6.3 Statistical Analysis

6.3.1 Free-flowing conditions

All analyses are based on free-flowing conditions using the complete data set (i.e. weekdays and weekends, all times of day). The conditions for free-flowing traffic were defined by examining plots of average flow, speed and headway (the distance between two vehicles measured in seconds) to identify distinct patterns and to define a threshold for when traffic would be considered to be in free-flowing conditions. A sensitivity analysis on the results using these thresholds was conducted. It was decided that all vehicles travelling more than 20mph with

headway greater than 2 seconds should be included in the complete dataset (a complete description is contained in Appendix D).

6.3.2 Summary statistics

An initial analysis of each of the 10 sites (the pilot site A is reported in Section 7) was undertaken providing summary statistics. The summary statistics for each site are presented in Section 9 and Appendix E and include tables of missing data and mean speeds for all loops in each period as well as 85th percentile speeds and daily mean speeds with confidence intervals. In addition, the proportions of vehicles at loop 2 driving at or exceeding the following speed levels are presented:

- 30mph: speed limit
- 36mph: the level at which the Association of Chief Police Officers suggest enforcing speed limit violations
- 45mph: one and a half times the speed limit

6.3.3 Research questions

The research questions which were investigated were:

Q_1: Do SIDs have an effect on vehicle speeds in free-flowing conditions?

Q_2: How long does the effect last: 1, 2 or 3 weeks?

Q_3: Is the SID effective when in place but not in operation?

Q_4: How far beyond the SID does the speed reduction last?

Q_5: Does the effect continue after the SID is removed, and for how long?

Q_6: How does the effectiveness of SIDs vary between locations and where are they most effective?

Q_7: Under what conditions are SIDs most effective?

Each of the research questions were investigated for all sites combined in order to gain an overall understanding of the effectiveness of SIDs. The data within a site were adjusted by the mean speed in the before period at loop1. In this way the variability between sites can be controlled for and differences between speeds can be meaningfully compared across all sites in a combined-site analysis. It should be noted that due to the way that the contrast is calculated, the combined contrast is not in any way an average of the individual contrasts and the combined sites results will not necessarily provide the same conclusions as the individual sites analysis. Due to missing data, described in Section 8, these estimates are not equally representative of each site, so, as well as the overall combined result, an alternative measure of effectiveness was calculated for each question using a weighted (for missing data) mean for weekdays. Data, by week and loop, were weighted to allow for missing data during that week. For example, if five days of data were available for a week (Monday to Friday) then each data point was given a weight of one, if only 3 days of data were available then each data point was weighted by 5/3 in order to imitate a weeks worth of data.

In addition, for research questions Q_1 to Q_5 and analysis on each individual site is reported. This shows the variability of conclusions between sites.

To understand where and under which conditions SIDs are most effective, the effectiveness of SIDs were compared across a range of road characteristics and conditions in Q_6 and Q_7.

The 1st group of factors describe the road environment (Q_6):

- Road environment: residential or commercial and residential mix
- Hatching: does hatching exist in the middle of the road at loop2?
- Parking: is there on-road parking at the SID site at loop2?
- Flow: high or low flow defined by above or below an average of 7,000 vehicles per day.

The 2nd set of factors varies within the site (Q_7):

- Light level: 5am to 8pm defined as light[6]
- Day: weekend or weekday
- Vehicle type: Motorcycle, car and other (including buses, LGVs and HGVs)

Two methods of analysis were considered, the contrast method and the ANPR method described in Sections 6.3.4 and 6.3.5.

6.3.4 Contrast method

All research questions were investigated by comparing the mean speeds before the SID was in place with the speeds of interest while controlling for the baseline speeds at loop1. Baseline speeds were defined as those observed at loop1, i.e. 200m before the SID site. It was necessary to control for baseline speeds at loop1 as this reduced the chance of a speed difference being due to an external random effect other than the SID. In all cases one-way ANOVAs (analysis of variance) with contrasts have been used to calculate this effect whilst controlling for baseline speeds. A one-way ANOVA tests whether several means (mean speed in this case) for different groups or conditions are equal. A worked example of the ANOVA analysis is given in Appendix F. The contrasts are essentially a 'difference of speed differences'. That is, the detectable effect of a SID is calculated as the difference in mean speed between the 'before' SID and 'during' SID periods at loop2, minus the difference in mean speed between the 'before' and 'during periods' at loop1 (which is assumed not to be influenced by the SID and thus controlling for any underlying speed change). The detectable effect equation is detailed below:

$$\text{Effect} = (\text{mean speed}_{\text{time}}(\text{loop x}) - \text{mean speed}_{\text{before}}(\text{loop x})) - (\text{mean speed}_{\text{time}}(\text{loop 1}) - \text{mean speed}_{\text{before}}(\text{loop 1})) \quad \text{(A)}$$

Each question uses a subset of the complete database which is appropriate to the question being investigated. Questions Q_1, Q_2 and Q_3 involved comparing mean speeds in the 'before' period with the 'during' period at the SID site (loop2) controlling for the baseline speed before the SID site (loop1), that is time='during' and x=2 in equation (A) above. Q_4 was answered by testing the difference between the 'before' and 'during' periods at loop3 and at loop4 (taking into account the differences at loop1 in both cases). Q_5 was answered by testing the difference between the 'before' and 'after1' period at loop2 (taking into account the differences at loop1) and testing the difference between the 'before' and 'after2' period at loop2 (taking into account the differences at loop1). Q_6 and Q_7 apply the same equation

[6] based on London one hour within dawn and dusk times in June (http://www.gaisma.com/en/location/london.html)

as questions Q_1, Q_2 and Q_3 but for different road characteristics (for example on-road parking) and conditions (for example daylight and dark).

These effects are conservative estimates of the effect of the SIDs as they assume that the drivers were not affected by the SID whilst at loop1. This may not always be the case as the driver may well have seen the SID being activated by a vehicle in front and reacted by slowing down. In addition the filtering process may also contribute to a conservative effect. For example, all speeds less than 20mph were eliminated, this may lead to more cases being filtered in the 'during' SID operating phase if vehicles travelling at slow speeds are also affected by the SID (i.e. they travel even slower and as a result are filtered out).

6.3.5 ANPR method

An alternative analysis used a matching technique similar to that which would have been used if Automatic Number Plate Recognition (ANPR) data had been collected. ANPR data consists of speed and headway of individual vehicles as before, as well as the vehicle registration mark (VRM) of each individual vehicle. The VRM acts as a matching variable across the loops and enables a vehicle's speed at each loop to be tracked and compared. Individual vehicle differences of speed between loop1 and loop2 could then be calculated. However, as ANPR was not collected, a proxy for this detailed matching analysis was investigated on the pilot data. The mean speed for all (free-flowing) vehicles was calculated for every set of contiguous five minutes of every day. A contrast was calculated for each five minutes, where loop1 and loop2 before SID implementation and the first week of during SID data were available.

This method was tested and compared to the contrast method for the pilot data (discussed in Section 7.3).

6.3.6 Method conclusion

Both methods have disadvantages. Firstly, the contrast method does not match sessions and thus, in theory, if a large chunk of data is missing then, for example, Wednesday and Thursday before the SID was operational might be compared with Saturday and Sunday during the SID active period if these were the only data available. This would result in daily variation in speed being confused with the effect of the SID.

The ANPR method necessarily requires data to be available at both loop1 and loop2, before and during SID activation, in order for the contrast in that five minute session to be calculated. Valid data are excluded when, in a five minute session, there are missing data at loop1 or loop2, before or during the SID. This could result in large amounts of data being unused.

As the ANPR method could potentially exclude a large amount of data, and calculations are based on grouped data rather than individual vehicles, the contrast method has been used for the main study. To reduce the chance of confusing daily variation with SID effect, where there are more than two days of missing data in a week, the data have been examined closely and a comment has been made in the report to explain the possible misinterpretation, i.e. the data have been selected because they can be considered representative of the site. In some cases this has led to the exclusion of a whole site in the combined site analyses in Section 10.

7 Pilot Study

7.1 Site selection for pilot

A pilot trial was arranged to test the project method by implementing loops and a SID as well as managing and analysing the data. It was important that the pilot site chosen complied with all the inclusion and exclusion criteria placed on SID sites for the main trial. A single carriageway road in South East London without other speed management in the area was required that was sufficiently long (1.2km) to include four loops between junctions.

The site chosen for the pilot trial was Foxley Lane in the London Borough of Croydon. This section of road was suggested by Croydon Council as a road where a speeding problem was evident.

The SID was situated at the junction with Woodcote Drive, facing westbound traffic. This site had both hatching and a cycle lane at the site of the SID. A map and photo of the SID site are displayed in Figure 7.1 and Figure 7.2.

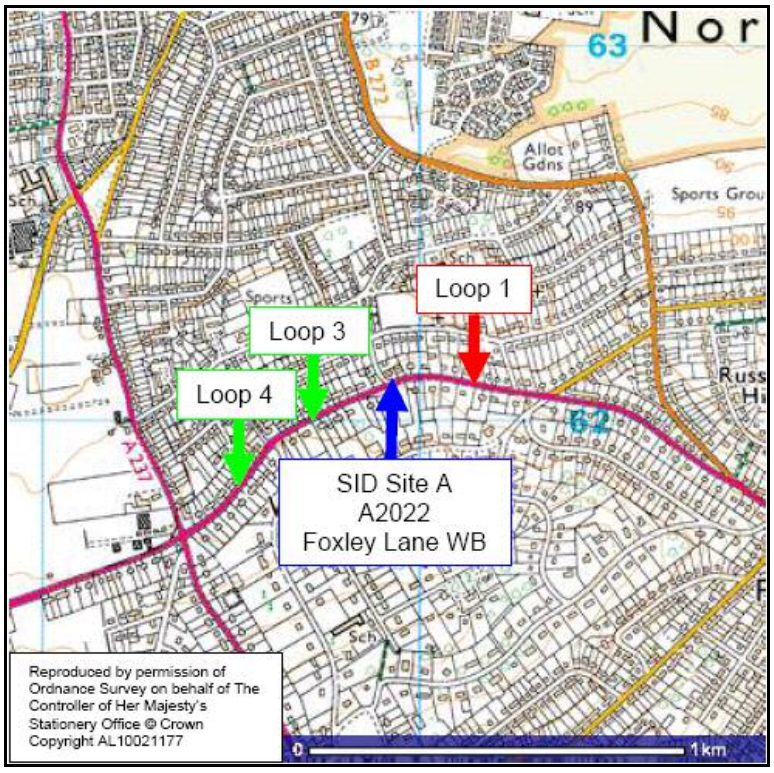

Figure 7.1: Pilot site (Foxley Lane) location and layout map

7.2 Pilot site data collection

Due to a technical difficulty, the SID was not positioned until three weeks after the planned date and removed after nine days instead of the intended 15. In addition, there was no information on whether the SID was operational for the full nine days, and thus it was not possible to assess the SID battery life during the pilot. The loops were mainly reliable throughout, with only two days of missing data at loop4 at the beginning of the trial.

Figure 7.2: Photo of pilot site

Improvements of the timetable for SID and loop implementation dates were made as a result of the pilot study, and additional information on the operation of the SID was requested for the main study.

7.3 Pilot site data analysis

Two different analyses were completed on the pilot trial data to assess the effect of the SID (essentially Q_1 in Section 6.3). These analyses used free-flowing data as discussed in Appendix D.

The first analysis calculated the effect of the SID using the contrast method described in Section 6.3.4 – i.e. the overall mean speed at loop2 (adjacent to the SID) whilst the SID was operational minus the mean speed at this loop before the SID was implemented (adjusted for the baseline difference). The analysis concluded that whilst the SID was installed at the site a 0.16mph statistically significant mean speed increase was recorded.

An alternative method of analysis was tested with the pilot data, discussed in Section 6.3.5 which compares five minute intervals. This contrast was the effect of the SID in each matched daily five minute session for the first full week of SID operation (Monday – Sunday). The mean of these contrasts was -0.12mph.

A small difference was observed (less than 0.3mph) between the results from the two analyses due to the way that missing data are managed, i.e. the data sets consisted of slightly different observations. The fact that different conclusions are reached is of concern and is due to the results being quite close to zero. However, if the mean speed change is further from zero then it is expected that the two different methods would produce equivalent conclusions.

8 Missing data

8.1 ATC missing data

The aim, as described in Section 6.1, was to collect speed data continuously from one week before the SID was operational, during the SID operation until two weeks after the SID was removed. These data were collected at three or four points at each site. In practice the method for collecting the speed data (ATCs described in Section 5.4) was not always reliable and around 10% of the data were missing or unreliable due to mechanical failure of the ATC.

Table 8.1 shows the amount of speed data missing or unusable due to inconsistencies. Each box represents a week, and the colour represents the amount of speed data available for that week. About half of the weeks have complete data (light blue). Due to incomplete data concerning the exact time of SID installations, the morning period on the day of installation (during1) and the day of removal (after1) have been excluded. In most cases, during1 and after1 had a full week of speed data available (light blue) but a small part was excluded due to uncertainty of SID installation time (making it mid blue). Tables in Appendix E specify exactly how many days of speed data were available for each site whilst the SID was operational (Table 8.1 shows all reliable speed data available, whether or not the SID was operational whilst installed).

In some cases very little or no data were available for a whole week (darker and darkest blue respectively). In some cases this meant that it was impossible to assess the effectiveness of the SID at certain sites for particular research questions and led to the exclusion of sites or weeks in the combined site analysis. The extent of missing data for each site is listed below.

Site B: Very little data were missing. All research questions were answered reliably.

Site C: Some data were missing at loop3 in during weeks. However, this was reasonably distributed across times of day and day of week. All research questions were answered although the SID was not operational for a period of time (see Section 10.3). Footnotes have been added to tables when the data were not fully available and thus the results may not be representative.

Site D: The SID was not fully operational in the first two weeks of operation (during1 and during2). Footnotes appear in tables where the data were not fully complete. Data were unreliable or missing at loop1 and loop3 from the during3 period until the end of the study. It was not possible to assess the effectiveness of the SID for the during3 period or once the SID was removed. All during3 data (including loop2) were excluded from the combined analysis.

Site E: Around 25% of data were missing in the during periods. This was reasonably distributed across times of day and day of week, and the analyses were relatively reliable. The SID was not fully operational at the same time the ATC was not reliably collecting data. Therefore, it was not possible to assess the effectiveness of the SID when it was not operational (Q_3: is the SID effective when in place but not operational?).

Site F: No data missing

Site G: No data missing (except 1.5 days in the last week)

Site H: No data missing although the SID was not working for a period (see Section 8.2).

Table 8.1: Availability of speed data by period, loop and site

Period	Before				During1				During2				During3				After1				After2			
Loop	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
B - King Henry's Drive																								
C - Manor Road																								
D - Welling Way																								
E - Bromley Hill																								
F - Parkhill Road																								
G - Malden Road																								
H - Kings Hall Road																								
I - Shooters Hill Road																								
J - Beddington Lane																								
K - Brownhill Road																								

Data availability key:

7 days (out of a possible 7)
6-7 days (out of a possible 7)
Fewer than 6 days (out of a possible 7)
No days (out of a possible 7)
Not applicable (i.e not part of the study design)

Site I: Only 1.5 days of data were available at loop1 in the during period which is not representative of a full week. Also, data were unreliable at loop1 in the after2 period. As a result, this site was not included in the combined analysis. Effects were calculated for the individual site analyses and a footnote describes the missing data where appropriate.

Site J: Very little after data were available at this site and the before data at loop1 was restricted to 1.5 days. Individual site analyses are shown but site J was excluded from the combined analysis due to unrepresentative data.

Site K: There was no data at loop1 for the first week of before data. As this forms the basis for all the research questions, it was impossible to assess the effectiveness of the SID. This site was also excluded from the combined analysis.

These missing data have led to the combined site analysis not including sites I, J and K, and during3 for site D. As described in Section 6.3.3, data were weighted to allow for missing data. The weights were formed using the proportions of data missing in a week shown in Table 8.1.

8.2 SID operational time

As the SIDs used in this study were temporary and not part of a rotation scheme the cost of adapting a lamp column to power the SID could not be justified. Therefore, the SIDs were powered by battery. The battery life was tested before the study commenced to determine how regularly batteries would need to be replaced. As a result of this test, SIDs were revisited 10 days after installation to replace the batteries. A further visit was made at sites B, C and D 5, 6 and 7 days later respectively to replace the batteries.

Due to SID batteries not being totally reliable, four sites had periods where the SID was installed but not operational. During these times, drivers may have seen the SID but no speeds would have been displayed. The days where SIDs were defined as not operational (not displaying speeds) are detailed in Table 8.2.

Table 8.2: Number of SID non-operational days relative to operational period

Site	Number of non-operational days	Number of SID operational days before battery failure
C - Manor Road	6	4
D - Welling Way	4	4
E - Bromley Hill	4	6
F - Parkhill Road	3	12

Data collected during these times were excluded from all research questions except Q_3 (is the SID effective when in place but not operational?). In practice it was impossible to tell exactly when a SID stopped displaying speeds and so the days displayed above are approximate, and some periods where the SID was working may be included in these days (and vice versa).

9 Overall Summary Statistics

This section presents overall summary statistics collected at the site of the SID (loop2) for the individual sites. Detailed summary statistics collected at all loops for each site are presented in Appendix E. Throughout this section 'before' refers to the week before the SID was installed, 'during' refers to the weeks the SID was in operation and 'after' refers to the two week period after the SID was removed.

Table 9.1 presents the average daily traffic flow for each site before, during and after the SID operation. Site I had the highest average daily flow of around 11,600 vehicles and site H had the lowest at around 3,100 vehicles per day. The average daily flow did not change significantly between the three time periods, varying between 2% and 7%.

Table 9.1: Average daily traffic flow before, during and after SID operation at loop2

	Average daily flow (vehicles per day)[7]		
Site	**Before**	**During**	**After**
B – King Henry's Drive	4,719	5,019	4,774
C – Manor Road	7,708	7,327	7,337
D – Welling Way	7,961	7,418	7,473
E – Bromley Hill	9,872	9,513	9,717
F – Parkhill Road	5,333	5,234	5,252
G – Malden Road	9,312	9,093	9,059
H – Kings Hall Road	3,300	3,103	3,068
I – Shooters Hill Road	11,850	11,502	11,416
J – Beddington Lane	5,451	5,584	Missing data
K – Brownhill Road	9,986	9,278	9,311

Table 9.2 presents the mean traffic speed at each site before, during and after the SID operation. In all cases, except site K, the overall mean traffic speed is reduced during the SID operation at loop2. This effect is investigated in detail in Section 10.1. The sites with the lowest mean traffic speeds, sites C and I also had the highest levels of congestion (see Table D.4).

Table 9.3 gives the average 85th percentile speeds for each site. As with mean speed, in all cases, except site K, the overall average 85th percentile speed is reduced during the SID operation at loop2.

[7] Based on complete days

Table 9.2: Mean traffic speed before, during and after SID operation at loop2

	Mean speed (mph)		
Site	**Before**	**During**	**After**
B – King Henry's Drive	35.4	32.5	34.9
C – Manor Road	28.4	26.9	28.3
D – Welling Way	34.9	32.5	34.8
E – Bromley Hill	31.7	29.6	31.6
F – Parkhill Road	32.3	30.0	32.1
G – Malden Road	30.7	29.3	30.8
H – Kings Hall Road	33.2	32.5	33.6
I – Shooters Hill Road	28.6	27.8	28.7
J – Beddington Lane	31.9	31.3	Missing data
K – Brownhill Road	30.4	30.5	30.7

Table 9.3: 85th percentile speed before, during and after SID operation at loop2

	85th percentile speed (mph)		
Site	**Before**	**During**	**After**
B – King Henry's Drive	41.6	38.1	40.5
C – Manor Road	33.5	31.0	33.4
D – Welling Way	39.6	37.1	39.3
E – Bromley Hill	36.6	33.7	36.2
F – Parkhill Road	37.2	34.4	36.8
G – Malden Road	35.2	33.6	35.3
H – Kings Hall Road	38.3	37.4	38.8
I – Shooters Hill Road	33.4	32.2	33.4
J – Beddington Lane	37.1	36.5	Missing data
K – Brownhill Road	35.8	35.9	36.0

10 Results

This section presents the results from the combined analysis of all sites and the analysis of each of the 10 individual sites answering the research questions stated in Section 6.3. Details of the ANOVA analysis can be found in Appendix F. As in previous sections, 'before' refers to the week before the SID was installed, 'during' refers to the weeks the SID was in operation and 'after' refers to the two week period after the SID was removed. Loop1 refers to the traffic data collected 200m before the SID, loop2 refers to the SID position and loop3 and loop4 refer to the traffic data 200 and 400m downstream from the SID.

10.1 Q_1: Do SIDs have an effect on vehicle speeds in free-flowing conditions?

The first research question is to determine whether SIDs reduce vehicle speeds and if so by how much. This question was answered by testing the difference between mean speeds in the 'before' period with the 'during' period at the SID site (loop2) taking into account the difference between the 'before' and 'during' period at loop1 (200m before the SID site). That is:

$$\text{Effect} = (\text{mean speed}_{\text{during}}(\text{loop2}) - \text{mean speed}_{\text{before}}(\text{loop2})) - (\text{mean speed}_{\text{during}}(\text{loop1}) - \text{mean speed}_{\text{before}}(\text{loop1}))$$

Table 10.1 shows the overall effect of a SID on mean vehicle speeds at loop2 for each site. Over all sites (excluding site I, J and K and during3 of site D), SIDs were observed to reduce mean speeds by 1.4mph whilst in operation. The effect using weekday data weighted to take account of missing data resulted in a greater speed reduction of 1.8 mph. The effect was negative for each individual site indicating that the conclusion is consistent across sites. The size of the effect varied between sites, with the largest reduction of 2.6mph for site B followed by site F and site E and only slight reductions for sites H, I and J. All reductions are significantly different from 0.

Too many data were missing for site K to calculate a result. In some cases (sites C, D, E and H) the SID was in place but was not in operation for several days, and speed data collected during these periods were not included in the analysis. The effects were calculated using data for all days and times including only free-flowing data. A separate investigation of the effects of the SIDs at weekends compared to weekdays, at night compared to day and at different times of the day was also carried out and is presented in Section 10.7.

The proportion of vehicles exceeding certain speed levels before, during and after the SID was installed at the SID site (loop2) were compared.

- 30mph: speed limit
- 36mph: the level at which the Association of Chief Police Officers suggest enforcing speed
- 45mph: one and a half times the speed limit.

Table 10.1: Overall effect of SID on mean speed at loop2 during SID operation

Site	Effect (mph)[8]	Confidence interval (95%)
All sites[9]	-1.4 *	(-1.46, -1.39)
All sites weekdays (weighted)[10]	-1.8 *	(-1.87, -1.79)
B - King Henry's Drive	-2.6 *	(-2.67, -2.46)
C - Manor Road[11]	-1.2 *	(-1.28, -1.14)
D - Welling Way[11,12]	-1.9 *	(-2.01, -1.83)
E - Bromley Hill[11]	-2.0 *	(-2.10, -1.95)
F - Parkhill Road	-2.1 *	(-2.14, -1.98)
G - Malden Road	-1.3 *	(-1.40, -1.26)
H - Kings Hall Road[11]	-0.6 *	(-0.73, -0.49)
I - Shooters Hill Road[13]	-0.6 *	(-0.66, -0.47)
J - Beddington Lane[14]	-0.7 *	(-0.83, -0.64)
K - Brownhill Road	Insufficient data to draw any conclusions	

* Indicates a statistically significant effect (i.e. the probability of no effect is <5%)

For all sites except K the proportion at or exceeding 30mph and 36mph and at all sites except J and K the proportion at or exceeding 45mph were significantly lower when the SID was in operation. Once the SID was removed the proportion of vehicles at or exceeding the speed limits increased to levels slightly lower than 'before' the SID was installed for four sites (B, C, E and F) and slightly higher than 'before' levels or the same as the 'before' levels for five sites (D, G, H, I and K). This suggests that the SIDs have an effect on the speeding driver population.

[8] A value <0 indicates a reduction in speed whilst SID is operational
[9] All sites does not include sites I, J, K and during3 of site D
[10] Data are weighted to take account of missing ATC data (see Section 8.1)
[11] SID was in place but not working for a period of time. Data during this time have been excluded
[12] Due to missing data result was calculated excluding 'during3'
[13] Result is based on 1.5days of during data for loop2; restricting loop1 to these days gives effect of -1.67 with CI (-1.81, -1.52)
[14] Due to missing data result is based on 1 before day (instead of the usual 7)

Table 10.2: Proportion of vehicles exceeding speed levels at loop2 by time period and site

Site	Period	Proportion at or exceeding: 30mph		36mph		45mph	
All sites	Before	56.5%		18.8%		2.0%	
	During	45.4%	*	13.1%	*	1.5%	*
	After	56.0%	*	17.7%	*	1.8%	*
B - King Henry's Drive	Before	80.4%		45.2%		5.9%	
	During	61.8%	*	23.5%	*	2.1%	*
	After	79.7%	*	41.5%	*	3.9%	*
C - Manor Road	Before	32.3%		9.1%		1.3%	
	During	19.6%	*	5.2%	*	0.8%	*
	After	31.6%	*	8.6%	*	1.2%	*
D - Welling Way	Before	85.9%		36.5%		3.9%	
	During	65.4%	*	20.2%	*	2.3%	*
	After	85.6%	*	34.6%	*	3.6%	*
E - Bromley Hill	Before	63.0%		17.2%		1.7%	
	During	38.5%	*	8.3%	*	1.0%	*
	After	62.4%	*	16.3%	*	1.5%	*
F - Parkhill Road	Before	69.0%		21.3%		1.3%	
	During	45.5%	*	9.3%	*	0.7%	*
	After	67.5%	*	19.4%	*	1.2%	*
G - Malden Road	Before	52.2%		12.1%		1.1%	
	During	36.8%	*	8.1%	*	0.8%	*
	After	53.5%	*	12.5%		1.1%	
H - Kings Hall Road	Before	72.1%		26.0%		2.8%	
	During	65.7%	*	21.6%	*	2.6%	*
	After	74.8%	*	28.9%	*	3.5%	*
I - Shooters Hill Road	Before	33.9%		7.8%		0.8%	
	During	27.2%	*	6.0%	*	0.6%	*
	After	34.8%	*	7.9%		0.9%	
J - Beddington Lane	Before	63.2%		19.5%		2.1%	
	During	55.8%	*	17.2%	*	1.9%	
	After	Missing		Missing		Missing	
K - Brownhill Road	Before	47.7%		14.5%		2.2%	
	During	48.8%	*	14.9%	*	2.4%	*
	After	50.1%	*	15.9%	*	2.5%	*

*indicates the proportion is statistically significant (95%) from the 'before' period (i.e. the probability of no effect is <5%)

10.2 Q_2: How long does the effect last: 1, 2 or 3 weeks?

Previous research showed that an initial 'novelty' effect of a SID lasted for about a week, then speeds slowly increased to previous levels (Poulter and McKenna, 2005).

ANOVA analyses were run with up to three separate contrasts, testing the differences between the mean speeds 'before' and 'during1', 'before' and 'during2' and 'before' and 'during3' at loop2, taking into account any differences at loop1. The analysis was run for the sites where the SID was in place for two and three weeks (taking into account any periods when the SID was in place but not operational).

$$\text{Effect} = (\text{mean speed}_{\text{during } x}(\text{loop2}) - \text{mean speed}_{\text{before}}(\text{loop2})) - (\text{mean speed}_{\text{during } x}(\text{loop1}) - \text{mean speed}_{\text{before}}(\text{loop1}))$$

where x=1, 2 or 3.

Table 10.3 shows the change in mean speed by week for the sites where the SID was installed for two and three weeks. The result for all seven sites combined showed the same mean speed reduction of 1.5mph for week 1 and week 2 (i.e. no 'novelty' effect was detected). However, in this calculation no allowance was made for missing data; some sites were missing weekend data (e.g. site C) while others were missing weekday data (e.g. site D). In a later investigation (Section 10.7), it was found that the SID had a different effect during weekends and weekdays. Therefore, weekday data was considered separately and weighed to allow for the missing data. When this was done, the mean speed reduction in the first week of SID operation (-1.9mph) was significantly greater than the second week (-1.6mph), showing evidence of SIDs having more effect on speeds in the first week compared to the second week - a 'novelty' effect.

Table 10.3 also presents the results for the individual sites. The SID was in place for three weeks for sites B, C and D. Site B showed the SID to be effective in reducing the mean speed for all three weeks. The largest reduction was seen at site B in week 1 (-3.0mph), after which the effect reduced in week 2 (to -2.5mph) and remained at the same level for week 3 (no significant difference between week 2 and 3 $p>0.10$). Site C showed the SID to be most effective in week 2 (effect of -1.6mph) with a significant reduction in effectiveness during week 3 ($p<0.01$). The change in mean speed for week 1 was lower than expected at -1.1mph. This unexpected result was investigated further by performing ANOVA analysis for weekdays and weekends separately, because the SID was not in operation for a weekend. The extra analysis found that the SID was twice as effective at the weekend compared to a weekday (weekend effect at site C -1.9mph compared to weekday effect -1.0mph). It was difficult to draw any conclusions from site D due to incomplete and unreliable speed data. In this case, extra ANOVA analysis treating weekdays and weekends separately found the SID to be most effective in the week (-2.1mph) compared to weekends (-1.5mph). This would explain the low result for during week 1 as the SID was not in operation for two weekdays. The data was too unreliable for site D to assess the speed reduction in week 3.

The SID was in place for two weeks for sites E, F, G and H. An initial 'novelty' effect was observed during the first week of SID operation for sites F, G and H (effect of -2.2mph, -1.9mph and -0.8mph respectively) with a significant reduction in effectiveness during week 2 ($p<0.01$ in all cases). No 'novelty' effect was observed for site E; the SID was as effective in week 1 as in week 2 ($p>0.10$).

Table 10.3: Overall effect of SID operation on mean speed at loop2 by week

	Change in mean speed during week 1		Change in mean speed during week 2		Change in mean speed during week 3	
Site	**Effect (mph)**	**Confidence interval**	**Effect (mph)**	**Confidence interval**	**Effect (mph)**	**Confidence interval**
All sites[15]	-1.5*	(-1.54, -1.46)	-1.5*	(-1.55, -1.47)	Data unreliable/not collected	
All sites weekdays[16]	-1.9*	(-1.92, -1.82)	-1.6*	(-1.67, -1.58)	Data unreliable/not collected	
B – King Henry's Drive	-3.0*	(-3.10, -2.86)	-2.5*	(-2.58, -2.34)	-2.5*	(-2.64, -2.40)
C[17] – Manor Road	-1.1*	(-1.23, -1.03)	-1.6*	(-1.72, -1.52)	-1.0*	(-1.12, -0.96)
D[17] – Welling Way	-1.6*	(-1.66, -1.44)	-2.2*	(-2.24, -2.05)	Data were unreliable	
E[17] – Bromley Hill	-2.0*	(-2.10, -1.93)	-2.0*	(-2.12, -1.95)	Week3 was not collected	
F – Parkhill Road	-2.2*	(-2.26, -2.08)	-1.9*	(-2.04, -1.85)	Week3 was not collected	
G – Malden Road	-1.9*	(-1.93, -1.77)	-0.8*	(-0.92, -0.77)	Week3 was not collected	
H[17] – Kings Hall Road	-0.8*	(-0.92, -0.66)	-0.4*	(-0.52, -0.22)	Week3 was not collected	

* indicates a statistically significant result at 95% (i.e. the probability of no effect is <5%)

10.3 Q_3: Is the SID effective when in place but not in operation?

At four sites (sites C, D, E and H) the SID stopped working due to battery failure for between three and six days while the loops continued to collect speed data. ANOVA analyses were carried out testing the difference between the mean speeds 'before' and 'during the period of the SID not working' at loop2, taking into account any differences at loop1.

$$\text{Effect} = (\text{mean speed}_{\text{not working}}(\text{loop2}) - \text{mean speed}_{\text{before}}(\text{loop2})) - (\text{mean speed}_{\text{not working}}(\text{loop1}) - \text{mean speed}_{\text{before}}(\text{loop1}))$$

Table 10.4 shows the change in mean speed when the SID was in place but not working during the study period. Overall, it was possible to detect a slight reduction of 0.5mph in mean speeds at the site of the SID in the 'not working period' compared to the before period, controlling for loop1 differences. In both individual site cases (C and D) the SID battery failed after four days of successful operation and for the days whilst the SID was not working the reduction in speed was significantly lower than when the SID was working (site C: -0.6mph compared with -1.1mph; site D: -0.4mph compared with -1.6mph). For site H, the SID battery failed for the last three days of the study period. When the SID was in operation the overall speed reduction was slight at -0.6mph but when the SID was in place and not working the speeds were slightly higher than before the SID was installed (0.6mph). This slight increase in speeds was also seen in the two weeks following the removal of the SID (see Table 10.6). The speed data were missing for site E, and so an analysis was not possible.

[15] All sites does not include sites I, J, K and during3 of site D
[16] Data are weighted to take account of missing ATC data (see Section 8.1)
[17] The SID was in place but not working for a period. Data during this period have been excluded.

Table 10.4: Overall effect of SID when installed but not working on mean speed at loop2

Site	Number of days the SID was not working	Effect during period when SID was in place but not working	
		Effect (mph)	Confidence interval
All sites[18]	13	-0.5*	(-0.56, -0.43)
C – Manor Road	6	-0.6*	(-0.69, -0.51)
D – Welling Way	4	-0.4*	(-0.46, -0.24)
E – Bromley Hill	3	Loop not working during this period	
H – Kings Hall Road	3	0.6*	(0.37, 0.88)

* indicates a statistically significant result (i.e. the probability of no effect is <5%)

10.4 Q_4: How far beyond the SID does the speed reduction last?

The previous questions looked at the effect of the SID at the SID site (loop2), controlling for differences at loop1. This question is concerned with the potential speed reduction 200m after the SID site (loop3) and 400m after the SID site (loop4). ANOVA analyses were used to test the differences between the mean speeds 'before' and 'during' the period of the SID at loop3 and loop4, taking into account any differences at loop1.

$$\text{Effect} = (\text{mean speed}_{\text{during}}(\text{loop}x) - \text{mean speed}_{\text{before}}(\text{loop}x)) - (\text{mean speed}_{\text{during}}(\text{loop1}) - \text{mean speed}_{\text{before}}(\text{loop1}))$$

where x = 3 or 4.

Table 10.5 shows the effect of the SID on mean vehicle speeds after the vehicle has passed the SID site; that is 200m after the SID (loop3) and 400m after the SID (loop4). Overall (all sites), a small reduction in mean speed was recorded at loop3 (0.2mph) and an overall speed increase was observed at loop4 (0.6mph). During the week (Monday to Friday) and taking into account the missing data, a speed reduction of 0.7mph was recorded at loop3 and an increase of 0.7mph was recorded at loop4.

Considering the sites individually, a decrease in mean vehicle speeds at loop3 was observed at seven of the sites when the SID was in place, albeit only slight and significantly lower than the effect observed at the SID site (loop2). For sites I and J no significant reduction in speed was observed at loop3, although there was a substantial amount of missing data for these sites. In general, the mean speed reduction at loop4 was less than at loop3 and was close to the before mean speed.

[18] All sites includes sites C, D and H.

Table 10.5: Effect of SID on mean speed at 200m (loop3) and 400m (loop4) after the SID site

Site	Loop3			Loop4		
	Effect (mph)		Confidence interval	Effect (mph)		Confidence interval
All sites[19]	-0.2	*	(-0.24, -0.17)	0.6	*	(0.60, 0.70)
All sites weekday[20]	-0.7	*	(-0.72, -0.64)	0.7	*	(0.08, 0.21)
B – King Henry's Drive	-0.6	*	(-0.66, -0.45)	-0.2	*	(-0.27, -0.05)
C – Manor Road	-0.2	*	(-0.33, -0.16)	No loop4		
D – Welling Way	-0.2	*	(-0.33, -0.16)	No loop4		
E – Bromley Hill	-0.3	*	(-0.33, -0.17)	-0.1	*	(-0.01, -0.18)
F – Parkhill Road	-0.5	*	(-0.57, -0.40)	No loop4		
G – Malden Road	-0.3	*	(-0.35, -0.21)	No loop4		
H – King's Hall Road	-0.4	*	(-0.46, -0.26)	<0.1		(-0.10, 0.11)
I – Shooters Hill Road[21]	-0.1		(-0.20, 0.02)	No loop4		
J – Beddington Lane[22]	-0.1		(-0.25, 0.14)	-0.4	*	(-0.57, -0.18)
K – Brownhill Road	Insufficient data to draw conclusions			Insufficient data to draw conclusions		

* indicates a statistically significant result (i.e. the probability of no effect is <5%)

10.5 Q_5: Does the effect continue after the SID is removed, and for how long?

Previous analyses compared the differences in speed between the 'before' and 'during' time periods. This question assesses whether the speed reduction continues after the SID has been removed, and if so for how long up to a period of two weeks. ANOVA analyses were run with two separate contrasts, testing the differences between the mean speeds 'before' and 'after1' and 'before' and 'after2' at loop2, taking into account any differences at loop1.

$$\text{Effect} = (\text{mean speed}_{\text{after}x}(\text{loop2}) - \text{mean speed}_{\text{before}}(\text{loop2})) - (\text{mean speed}_{\text{after}x}(\text{loop1}) - \text{mean speed}_{\text{before}}(\text{loop1}))$$

where x=1 or 2.

Table 10.6 shows the effect on mean vehicle speeds after the SID had been removed. Speeds immediately returned to higher levels similar to the before period once the SID was removed for all sites combined. This was also true when the missing data was taken into account (i.e. using weighted weekday data).

In general for individual sites, once the SID was removed reductions in vehicle speed were no longer observed. The mean vehicle speeds at site B and F were slightly lower for both weeks after the SID was removed, although the reduction was

[19] All sites excludes sites I, J and K and during3 or site D
[20] Data are weighted to take account of missing ATC data (see Section 8.1)
[21] Result is based on 1.5 days of during data for loop1
[22] Due to missing data result is based on 1 before day (instead of the usual 7).

significantly lower than observed when the SID was in place (-2.6mph and -2.1mph respectively, Table 10.1). The average speed returned to the levels observed 'before' the SID was in place for sites C and E and average speeds were slightly higher than the 'before' levels for sites G, H and I. The speed data for the 'after' period were missing for sites D, J and K so an analysis was not possible.

Table 10.6: Effect mean speed once the SID is removed

Site	After 1 week			After 2 weeks		
	Effect (mph)		Confidence interval	Effect (mph)		Confidence interval
All sites[23]	0.0	[24]	(-0.07, 0.01)	0.1	*	(0.04, 0.12)
All sites weekday[25]	0.0	[24]	(-0.06, 0.04)	0.2	*	(0.10, 0.21)
B – King Henry's Drive	-0.5	*	(-0.66, -0.42)	-0.5	*	(-0.64, -0.35)
C – Manor Road	-0.1		(-0.16, 0.02)	-0.1		(-0.16, 0.02)
D – Welling Way	Loop1 after data not reliable			Loop1 after data not reliable		
E – Bromley Hill	0.0	[26]	(-0.06, 0.10)	0.2	*	(0.11, 0.27)
F – Parkhill Road	-0.1	*	(-0.22, -0.03)	-0.1		(-0.15, 0.04)
G – Malden Road	0.2	*	(0.07, 0.23)	0.2	*	(0.14, 0.30)
H – King's Hall Road	0.6	*	(0.51, 0.78)	0.6	*	(0.49, 0.75)
I – Shooters Hill Road	0.5	*	(0.39, 0.56)	Loop1 after2 data not reliable		
J – Beddington Lane	Loop1 and loop2 after data not available			Loop1 and loop2 after data not available		
K – Brownhill Road	Loop1 and loop2 after data not reliable			Loop1 and loop2 after data not reliable		

*indicates a statistically significant result (i.e. the probability of no effect is <5%)

10.6 Q_6: How does the effectiveness of SIDs vary between locations and where are they most effective?

The effect of the SID was calculated for each characteristic and is shown in Table 10.7 and Table 10.8. For example, for the parking factor, the effect of the SID was calculated for sites where there was on-road parking and sites where there was no on-road parking. The difference between the two values, that is the effect of on-road parking, can then be measured and compared. Table 10.7 shows the results from the combined sites with no adjustments for missing data and Table 10.8 shows the results from the combined sites for weekdays only weighted to allow for missing data (referred to as weighted weekday results). The results of significance tests from the comparisons between each pair of characteristics are presented in the final columns of Table 10.7 and Table 10.8.

Initially the data were grouped by the road environment – whether the location was mostly residential or a mixture of residential and commercial land. Overall, the un-

[23] All sites analysis excludes sites D, I, J and K
[24] These values were between -0.1 and 0.0
[25] Data are weighted to take account of missing ATC data (see Section 8.1)
[26] This value was between 0.0 and 0.1.

weighted data and weighted weekday data show that the effect of the SID was significantly higher in the residential areas than the mixed areas. A less consistent picture was observed at sites with and without hatching. The un-weighted data, Table 10.7 suggests that at sites where there was no hatching, vehicle speeds reduced more than at sites where hatching existed. In comparison, Table 10.8 shows that during weekdays, and allowing for missing data, vehicle speeds reduced more at sites with hatching than without.

At sites with parked vehicles the SID had less effect on the mean vehicle speed than at sites with no parking, and at sites where a low flow was recorded (<7000 vehicles per day) vehicles were more affected by the SID than those at higher flow sites (>7000 vehicles per day).

These results are dependent on the sites included in the analysis and conclusions are not consistent when sites are removed or added. The study was not designed to measure these factors in a balanced way, so it cannot be guaranteed that the effects shown in Table 10.7 and Table 10.8 are due to the factors described.

Table 10.7: Effect of SIDs at sites[27] with different road characteristics, un-weighted

Factor	Road characteristic	Effect (mph)	Standard error	Sample size (million)	Significance of difference between characteristics
Road environment	Residential	-1.5	0.02	1.35	p<0.01
	Commercial/ residential mix[28]	-1.2	0.04	0.42	
Hatching	No	-1.6	0.02	1.05	p<0.01
	Yes	-1.2	0.03	0.60	
Parking	No	-1.7	0.02	1.00	p<0.01
	Yes	-0.9	0.03	0.65	
Flow	Low	-2.1	0.03	0.53	p<0.01
	High	-1.2	0.02	1.11	

[27] All sites analysis excludes sites I, J and K and during3 of site D
[28] This result based on one site

Table 10.8: Effect of SIDs at sites[29] with different road characteristics, weighted[30] weekdays

Factor	Road characteristic	Effect (mph)	Standard error	Sample size (million)	Significance of difference between characteristics
Road environment	Residential	-1.7	0.02	0.95	p<0.01
	Commercial/ residential mix	-1.0	0.05	0.22	
Hatching	No	-1.7	0.03	0.77	p<0.05
	Yes	-2.0	0.04	0.40	
Parking	No	-1.8	0.03	0.74	p<0.05
	Yes	-1.5	0.03	0.43	
Flow	Low	-2.0	0.05	0.40	p<0.05
	High	-1.8	0.03	0.77	

10.7 Q_7: Under what conditions are SIDs most effective?

Similarly to Section 10.6, a selection of factors associated with light level, day of week and vehicle type were identified in order to test the effect of the SID under different conditions. Within each factor, the effect of the SID was calculated for each condition (see Table 10.9) and the effects were then compared between conditions, as shown in Table 10.10. These effects were calculated using all sites combined (un-weighted for missing data) and all sites combined for weekdays, weighted for missing data.

Comparing weekday effect (-1.4mph) with the effect of the SIDs at the weekend (-1.5mph) across all sites found a marginally (yet significant) greater reduction in speed during weekends. Each day in the sample was split into day and night with 'day' defined as 5am to 8pm according to dawn and dusk times in June. No significant difference was detected between the effects of the SIDs in day and night conditions in the weighted weekday data, but speeds were reduced more in the day than the night according to all the data combined. There may be an interaction between the factors Day and Light level – for example, the effect of a SID may be different during a weekend night compared to a weekday night. In order to test this, the two factors were combined to form 'Day and Light level' and these four conditions were compared. Some significant differences were found between these four conditions: the biggest SID effect occurring during the day at weekends and the smallest SID effect occurring at night at the weekend (-1.2mph).

[29] All sites analysis excludes sites I, J and K and during3 of site D
[30] Data are weighted to take account of missing ATC data.

Table 10.9: Effect of SIDs in different conditions

		All sites			Weekday weighted		
Factor	**Condition**	**Effect (mph)**	**Standard error**	**Sample size (million)**	**Effect (mph)**	**Standard error**	**Sample size (million)**
Day	Weekday	-1.4	0.02	1.23	-1.8	0.02	1.17
	Weekend	-1.5	0.04	0.42			
Light level	Day	-1.4	0.02	1.42	-1.8	0.02	1.02
	Night	-1.3	0.06	0.23	-1.9	0.07	0.15
Day and light level	Day & weekday	-1.4	0.02	1.08	-1.8	0.02	1.02
	Day & weekend	-1.6	0.04	0.34			
	Night & weekday	-1.3	0.07	0.16	-1.9	0.07	0.15
	Night & weekend	-1.2	0.11	0.07			
Vehicle type	Motorcycle	1.2	0.28	0.02	-1.9	0.31	0.03
	Car	-1.5	0.02	1.46	-1.9	0.02	1.03
	Other	-0.9	0.06	0.17	-1.6	0.06	0.13

The factor ‘vehicle type’ tests the relative effect of SIDs on different vehicles. Overall the speed reduction was largest for cars. For the un-weighted data a speed increase was recorded for motorbikes. There were relatively few motorcyclists recorded travelling on the routes during the study, so estimates are subject to variation. There was a reduction in speeds for motorcyclists at loop2 in the during period, but a slightly bigger reduction was observed in the during period at loop1, hence the implied increase in vehicle speeds. Indeed the effect on speed for the weighted weekday data suggests a decrease in vehicle speeds compared to loop1 and the before period.

Similarly to Section 10.6, these results are dependent on the sites included in the analysis and conclusions are not consistent when sites are removed or added.

Table 10.10: Comparing effect of SIDs in different conditions

	All sites			Weekday weighted		
Comparing	**Difference of effect (mph)**	**Pooled standard error**	**Significance of difference**	**Difference of effect (mph)**	**Pooled standard error**	**Significance of difference**
Weekday – weekend	0.2	0.04	p<0.01			
Day – night	-0.2	0.06	p<0.01	0.1	0.07	ns
Day and weekday – day and weekend	0.2	0.04	p<0.01			
Day and weekday – night and weekday	-0.1	0.07	ns	0.1	0.07	ns
Day and weekday – night and weekend	-0.2	0.11	p<0.05			
Day and weekend – night and weekday	-0.3	0.08	p<0.01			
Day and weekend – night and weekend	-0.5	0.11	p<0.01			
Night and weekday – night and weekend	-0.2	0.13	p<0.05			
Motorcycle – car	2.7	0.28	p<0.01	<0.1	0.31	ns
Motorcycle – other	2.1	0.29	p<0.01	-0.3	0.32	ns
Car – other	-0.6	0.06	p<0.01	-0.2	0.07	p<0.01

'ns' represent a difference that is not significant i.e. the probability of there being a difference is <5%

11 Estimated collision reductions

There has been much research into the link between vehicle speed and the frequency of injury collisions (e.g. Taylor et al 2000, Taylor et al 2002) which broadly concludes, across all road types, that a 1mph decrease in mean speed would reduce the number of collisions by 5%. Quite clearly the number of collisions is also affected by many other road and traffic conditions as well as speed, however it is generally accepted that higher speeds lead to a higher number of collisions, and that this increase is more rapid at higher speeds. Speed is also important in the severity of a collision.

The results from Taylor et al (2000) have been used to estimate the collision reduction that might be expected from installing SIDs in London using the approach adopted in this study. Taylor et al concluded that the reduction in collisions per 1mph speed reduction on urban medium speed (mean speed 25-35mph) roads is 4%. It is assumed that this reduction is equally distributed across all severities of collisions.

The overall speed reduction achieved by an active SID was shown in to be 1.4mph, although this reduction applied only over a relatively short stretch of road and for two weeks after installation. Based on the finding that a 1mph reduction in speed will reduce the number of collisions by 4%, this suggests that a 5.6% reduction in collisions might be expected on the section of road where the SID is influencing drivers' speed choice.

The estimated casualty saving is not large. However, using SIDs is one of the many speed management measures available and should be used in combination with other speed management strategies, not replace them. The use of SIDs may be the best, most appropriate or cost effective solution in some areas for a short period of time.

12 Discussion

As with most data intensive studies, difficulties arose during the analysis due to missing and inconsistent speed data and SIDs not working for periods. A series of processes have been applied in order to draw valid conclusions.

For a speed intervention such as a SID to affect drivers' speed choice, drivers must be in a position to choose their speed. Drivers in congested traffic are restricted in their speed choice and therefore the effect of the intervention cannot be measured in congested traffic. Vehicle speeds analysed in this study were therefore required to be in 'free-flowing' traffic. The sites for this study were chosen according to a series of requirements including choosing routes that remained 'free-flowing' for the majority of the day. Even though sites were chosen to have little or no congested traffic, inevitably some congested traffic remained and had to be excluded from the analysis.

The criteria for excluding data were derived in a systematic way from patterns in a series of factors: headway (distance between two vehicles), speeds and flow. Several possible thresholds were subjected to sensitivity analysis which allowed the consistency of results and conclusions to be compared. The final threshold was defined as vehicles travelling less than 20mph and with a headway of less than 2 seconds. Data below this threshold were removed consistently across all sites, loops and time periods. The disadvantage of this threshold being based on speed is that more data are excluded when speeds reduce (due to the SID), leading to a conservative estimate of the effectiveness of the SID.

Vehicle speeds were recorded from the week before the SID was installed to two weeks after it was removed. A simple comparison of mean speeds before the SID was installed and during operation would not allow for underlying speed distribution changes due to external factors. Even if a SID had not been installed, the vehicle speeds and flows would not have been exactly the same on each day. A simple comparison of before and during may find a significant difference in speeds, but it is not possible to determine whether this is just natural or random variation in vehicle speeds due to external factors or an effect of the SID. Therefore a baseline is required in order to distinguish between an underlying speed change due to external factors and the effect of the SID.

This baseline has been defined as the difference between before and during at loop1 (200m before the SID). It is assumed that vehicles at loop1 are travelling at speeds within the underlying speed distribution (affected by external factors) but have not observed or been affected by the SID at loop2. If this is true then the difference between speeds before and during at loop1 is the underlying speed difference due to random variation or external factors and any additional difference in speeds at loop2 are due to the SID. If the assumption is not true and drivers have observed the SID being activated by a vehicle in front and modified their speed accordingly, then the estimate of the effectiveness of the SID is, again, conservative.

During the study, SIDs were powered by battery due to the expense of adapting lamp columns to provide mains power. The battery was tested before a SID was deployed, but the batteries were not reliable and at four sites the SID was installed but not operational for part of the study. The vehicle speeds recorded during these times were excluded from the data for all but Q_3 (Is the SID effective when in place but not in operation?), which caused the data from some sites to be incomplete.

In addition to incomplete data at four sites caused by the SID not being operational, approximately 10% of the speed data expected were missing or unreliable. Unreliable speed data were defined during standard quality control procedures

checking for inconsistent or exceptionally high speeds. Data were removed as a result of these procedures.

The fact that certain data are missing means, in most cases, that the real effect can only be estimated from the data that are available. This estimate is likely to be fairly reliable if the missing data are spread evenly across dates and times: for example, if the proportions of weekend and weekday data missing are equivalent. In many cases this is true or at least approximately true and estimates can be made successfully.

Wherever an estimate in a table has been based on incomplete data, this has been documented in a table footnote; where an estimate is believed to be particularly unreliable, however, it has been omitted. For example, no data are available in the before period at loop1 at site K, so it is not possible to establish a baseline for this site and no estimates could be made. A large number of sites and a large number of vehicles recorded at each site mean that data with a small amount of missing data form valid and representative estimates of the effectiveness of SIDS.

For an overall estimate of SID effectiveness, data from the whole study have been combined. In order to remove the random variations in speeds between sites, all speeds have been adjusted within site relative to the mean 'before at loop1' speed. Sites with excessive gaps in the data have been consistently removed from the combined analysis: sites I, J and K (missing data) and during3 of site D (unreliable and missing data). This has left seven sites, some with missing data and periods where the SIDs were not operational. Overall effects have been calculated using the seven sites combined, noting but not adjusting for missing data. As some sites have more missing data than others, this combined site estimate is not representative across all sites – sites with no missing data will make up more of the estimate than sites with missing data. To account for this, estimates are also made of the effectiveness of SIDs for weekdays weighting up data to take account of missing data and thus making each week at every site equally represented in the overall estimate.

These two different ways of estimating the effectiveness of SIDs do not provide exactly the same answers and this is due to differences in weekday and weekend effect and to how the missing data are treated. These differences are especially noticeable in Q_6 and Q_7. For example, different conclusions are reached when comparing sites with and without hatching in Section 10.6 and comparing day and night effects in Section 10.7, using the two methods of combining all sites. This is again due to the different ways the missing data are dealt with, but also the fact that the study was not designed to take the road characteristic factors into account in a balanced way. This also leads to changes in results as sites are added and removed suggesting that some of the comparisons in Sections 10.6 and 10.7 are not stable results and should be used with care.

Overall however, inconsistent and missing data have been treated consistently throughout and the assumptions that have been necessary mean that the effect size will be underestimated. The conclusions are consistent – SIDs are effective at reducing speeds however missing data are treated.

13 Conclusions

13.1 Research questions

Q_1: Do SIDs have an effect on vehicle speeds in free flowing conditions?

An overall speed reduction of 1.4mph was detected across all sites whilst the SIDs were activated. This is a similar to the reduction of 1.3mph found in the University of Reading report (Poulter & McKenna, 2005). The speed reduction at all sites was significantly better than no effect. The effect varied across sites from 2.6mph at site B where the SID was installed for three weeks to 0.6mph at site I where the SID was only implemented for one week.

The proportions of drivers exceeding 30mph and 36mph (ACPO guidelines) were significantly reduced at all sites (except K) whilst the SID was in operation, showing that speeding drivers are affected by SIDs. The Texas Transportation Institute report (Rose & Ullman, 2003) suggested that SIDs are more effective on speeding drivers. Overall the proportion of drivers exceeding 36mph in the during period was 13.1% compared to the 18.8% exceeding 36mph in the before period.

The overall reduction of 1.4mph has been used to estimate that a 5.6% reduction in collisions could occur at sites whilst a SID was operational for a short period of time.

Q_2: How long does the effect last: 1, 2 or 3 weeks?

The SID was in operation for at least two weeks at seven sites (sites B to H). There is evidence to suggest that there may be a 'novelty' effect of the SID in week 1 at site B, F, G and H, and overall at all sites combined at weekdays (allowing for missing data by weighting). At all four sites the SID was the most effective in the first week of operation with a significant reduction in effectiveness during week 2. The SIDs at sites B, C and D were in operation for a third week. There was no observed change in mean speed between week 2 and 3 for site B, while the effect tailed off towards the end of the three-week period for site C. Royal Borough of Kingston-upon-Thames have a policy of removing the SIDs after three weeks, and this report presents some evidence to suggest that the effect of the SID does diminish soon after installation.

Q_3: Is the SID effective when in place but not in operation?

At four sites the SID's battery failed for a period of three days or more which means that drivers were not informed of their speed. There was no consistent picture on the effect of the mean speeds, except that overall and at all but one site vehicle speeds were higher than when the SID was operational (0.5mph reduction compared to the 1.4mph reduction when the SID was operational at all sites). As the SID batteries were found to be unreliable and maintenance costly, it is suggested that SIDs are mains operated, taking power from the lamp column that they are placed on as the Royal Borough of Kingston-upon-Thames policy requires (Section 4) or use solar panels.

Q_4: How far beyond the SID does the speed reduction last?

At most sites and overall there was a statistically significant small reduction in mean speeds at 200m downstream from the SID (a reduction of 0.2mph in the during period compared to the before period). This effect was less than a quarter of the effect recorded at the SID (loop2) at most sites. An even smaller effect or an opposite effect (increase in speeds of 0.6mph) was observed 400m downstream implying that any effect after 400m is likely to be negligible.

Q_5: Does the effect continue after the SID is removed, and for how long?

In general, there was no lasting effect after the SID was removed. A small reduction in speeds remained at those sites where the SID had most effect when in place.

Q_6: How does the effectiveness of SIDs vary between locations and where are they most effective?

The evaluation of Vehicle Activated Signs (Winnett et al, 2002) suggested that the size of effect and how long the effect lasts depends on the type of site. Section 10.6 showed that at sites classified as residential, the SID was significantly more effective at reducing speeds than at sites where there was a combination of commercial and residential land. A larger effect was also observed at sites without parking and at sites with a lower traffic flow (fewer than 7,000 vehicles per day).

These conclusions were not consistent when adding or removing sites. However, it can be concluded that for every category within each road environment factor tested, vehicle speeds were reduced whilst the SID was operational.

Q_7: Under what conditions are SIDs most effective?

Overall, the SIDs were most effective at reducing mean vehicle speeds during the day at weekends and least effective during the day during weekdays. There was no significant difference in their effectiveness between light conditions in the weekday weighted data, but speeds were reduced more in the day than at night according to all the data combined. The largest speed reductions were seen for cars.

As with Q_6, these results depend on the sites included in the analysis and conclusions are not consistent when sites are removed or added.

13.2 Good practice

For detailed practical recommendations, the reader is referred to Section 4, where the Royal Borough of Kingston-upon-Thames SID programme is described. Royal Borough of Kingston-upon-Thames currently own 13 temporary SIDs which are deployed on roads around Royal Borough of Kingston-upon-Thames in a rotation programme. As SIDs are primarily temporary signs, a SID visits each SID site for three weeks approximately every 15 weeks.

In general, a SID should be positioned on a lamp column or a separate post near a lamp column in order that mains power can be supplied to the SID. Experience in the Royal Borough of Kingston-upon-Thames and during this study has shown that battery powered SIDs are not reliable, and when the SID is not working the effect on speed reduction is, of course, much less. The SID needs to be situated on a relatively straight road for it to register vehicles at an appropriate distance and for drivers to observe the sign early enough to adapt their driving behaviour. Vandals, private property and wide vehicles should be taken into account when positioning a SID. In Royal Borough of Kingston-upon-Thames SID sites are near speed limit changes or sites with high collision rates. SIDs should not be situated near junctions or pedestrian crossings.

13.3 Recommendations

The number of sites in any area that form a rotation programme for SIDs depends on speed behaviour, site characteristics and resources. The number of SIDs required to fulfil a rotation scheme in that area also depends on the length of time the SID is installed and the time between removing and reinstalling the SID at any

site. It is suggested from the results of Q_2 that SIDs should remain at each site for at least two weeks and no longer than three weeks. Once the SID is removed there is little or no residual effect on vehicle speeds according to Q_5 and so they should be replaced regularly with a reasonable gap in order that drivers forget about the previous installation. Each site is different, as demonstrated in Q_6, and so expert judgement should inform how regularly signs are rotated. In the Royal Borough of Kingston-upon-Thames's rotation programme, SIDs are reinstalled at the same site every 15 weeks and in the absence of any scientific evidence this should be used as a guide.

It would be informative to assess the effect on a route of a regularly recurring SID, and compare the differences in effectiveness of different types of SID display in reducing vehicle speeds.

In conclusion, SIDs have been found to be effective at reducing vehicle speeds on 30mph roads in London and the effectiveness varies depending on site characteristics.

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Abstract

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The specific aims of this study were to assess the effectiveness of SIDs over time and distance at several locations in London. SIDs were installed at eleven sites in South East London for one, two or three weeks. Vehicle speeds were recorded at each site from one week before the SID was installed until two weeks after it was removed. SIDs were found to be effective at reducing vehicle speeds on 30mph roads in London when deployed for a short time.

Effectiveness of Speed Indicator Devices on reducing vehicle speeds in London

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The specific aims of this study were to assess the effectiveness of SIDs over time and distance at several locations in London. SIDs were installed at eleven sites in South East London for one, two or three weeks. Vehicle speeds were recorded at each site from one week before the SID was installed until two weeks after it was removed. SIDs were found to be effective at reducing vehicle speeds on 30mph roads in London when deployed for a short time.

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