Department for Transport

Ealing
www.ealing.gov.uk

Active management of urban road network air quality ‘hot spots’

Exhaust emissions from queuing road vehicles at traffic signals

DfT Local Transport Air Quality Challenge Innovation Grant Competition October 2015
Final Report

Project timeframe:	December 15th 2015 to March 21st 2016
Report date:	April 15th 2016 (version 1.1)
Author:	Dr Glyn Rhys-Tyler
Version	**Public document for dissemination**

Executive Summary

The “Active management of urban road network air quality ‘hot spots’” project seeks to establish a proof of concept for managing urban road network air quality ‘hot spots’ in real time. ‘Hot spots’ in this context are defined as short sections of highway network where high concentrations of vehicle related exhaust emissions are generated due to issues such as queuing and congestion, with consequent severe negative impacts on local air quality.

Utilising three illustrative case study locations in the London Borough of Ealing, light vehicle stopping events and durations have been quantified (based on instrumented vehicle surveys). NO_x exhaust emission rates from light vehicles during idle events have been estimated with reference to pre-existing emissions datasets combined with reasonable estimates of idle fuel consumption. The study indicates that significant reductions in local exhaust emissions may be possible in ‘hot spot’ locations that comply with relevant criteria.

A recent development in light vehicle technology has been the introduction of automated stop/start systems. A survey of vehicle manufacturers was carried out as part of the study to quantify, for the first time, the degree of market penetration of such technologies into the UK vehicle fleet. The adoption and use of such technologies has the potential to become increasingly significant in future local air quality management.

Disclaimer

The views expressed in this research report are those of the author, and do not necessarily reflect the policy or position of the Department for Transport, the London Borough of Ealing, or Transport for London.

The analysis described in this research report was carried out under a Department for Transport Local Air Quality Challenge Innovation Grant and is furnished "as is". Whilst reasonable efforts have been made to ensure accuracy, no warranty is provided whatsoever. The author will not be held responsible for any loss, damage or inconvenience caused as a result of any inaccuracy or error.

Copyright notice

Table of Contents

List of Figures

List of Tables

List of Annexes

List of Acronyms

Term	Meaning
CO_2	Carbon Dioxide
DEFRA	Department for Environment, Food & Rural Affairs
EPA	Environmental Protection Agency (US)
MOVA	Microprocessor Optimised Vehicle Actuation
NEDC	New European Drive Cycle
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen (expressed as NO_2 equivalent values by mass unless otherwise stated)
PEMS	Portable Emissions Monitoring System
RSD	Remote Sensing Detector
SCOOT	Split Cycle Offset Optimisation Technique
SMMT	Society of Motor Manufacturers and Traders
TfL	Transport for London
TRL	Technology Readiness Level
UTC	Urban Traffic Control
UTMC	Urban Traffic Management & Control
VMS	Variable Message Sign

1. Aims and objectives of the study

The aim of the project is to undertake a study into the feasibility (at TRL level 3) of aspects of potential active management of air quality 'hot spots' on the urban road network in Ealing in real time. The findings of such a study would be potentially transferable to other urban locations in the UK. 'Hot spots' in this context are defined as short sections (perhaps 100 - 200m) of highway network where high concentrations of vehicle related exhaust emissions are generated due to issues such as queuing and congestion, with consequent negative impacts on local air quality.

Evidence for such localised problems in Ealing has been produced in recent Defra funded work carried out by the author in 2014, and reported in the project report "Scenario development to inform air quality action planning in the London Borough of Ealing" (Rhys-Tyler, 2014). On urban roads in Ealing with known air quality problems, up to 35% of vehicle journey time is spent stationary, typically waiting at traffic lights (up to 26% spent stationary for periods of 10 seconds or more). It is hypothesised that if all (or a significant proportion of) vehicle engines were consistently switched off during these stationary episodes, there would be a significant reduction in the absolute emissions of exhaust pollution into the local atmosphere at these emission 'hot spots'.

The project seeks to explore the feasibility of actively managing these situations by providing the driver with real time information on the likely length of delays (typically queuing at traffic signals). This would ideally be facilitated by real time links between urban traffic control systems and variable message signing, perhaps supported by complementary traffic management measures such as static signing.

The project has direct links with the following three DfT priority areas:

- Characterising with greater spatial, temporal and source resolved detail the air pollutant emissions from the transport fleet, and the effect of mitigation measures in real-time or near real-time;
- Using smart traffic management systems to reduce air pollution emissions, and;
- Modifying driving style to reduce air pollution emissions.

The beneficiaries of such active management would include all population impacted by poor air quality in such 'near road' locations, including residential, retail, education, and employment land uses, which across the UK will amount to many hundreds of thousands of people. It is considered that interventions could be explored in the study that would have very short implementation lead times (< 1 year), and which have the potential for significant localised benefits in locations where road transport related air quality problems are at their most severe.

The project commenced on December 15th 2015, and reported on March 21st 2016, providing a practical project delivery duration of just under three months. Such a short duration study has practical limitations in terms of what is achievable within such a timescale, but useful and constructive insights were gleaned which will be helpful in informing future policy and practice.

This report provides a description of the study approach and methodology, and presents study results, conclusions, and recommendations for further work and next steps.

2. Outline of the concept

2.1 Concept outline

Recent work in Ealing has highlighted the significant proportion of overall vehicle journey time spent stationary, and the significant NO_x emissions associated with this aspect of vehicle operation. Previous work addressed this issue at TRL level 1 by quantifying the potential air quality benefits of systematically switching off light vehicle engines during ‘long duration’ stops (Rhys-Tyler, 2014).

It is hypothesised that if all (or a significant proportion of) vehicle engines were consistently switched off during these stationary episodes, there would be a significant reduction in the absolute emissions of NO_2 and NO_x into the local atmosphere at these emission ‘hot spots’ (in addition to reductions in other pollutants and greenhouse gases).

Idling reduction policies as applied to, for example, taxi waiting areas are relatively common in the UK. However, idling reduction interventions targeting queuing traffic for the purpose of air quality improvement have not received much (if any) attention in the UK. In the USA, the Environmental Protection Agency promotes policies of turning engines off if drivers expect to be stationary for more than 10 seconds (EPA, 2012), but these tend to be associated with specific sensitive land uses such as schools.

There is a need to assess the technological feasibility of adapting existing traffic management and control systems to communicate delay information to the vehicle / driver in real time, in an appropriate manner in ‘hot spot’ locations. There is also a need to assess the behavioural feasibility of safely communicating delay information to the vehicle / driver, in such a manner as to obtain the desired changes in behaviour (reduction in NO_x / NO_2 emissions) without introducing undesirable changes in behaviour (safety) in ‘hot spot’ locations.

'Count down' systems have been used in some parts of the world, but in the UK this has mainly been focused on pedestrian behaviour. There are potential advantages and disadvantages of providing such information to drivers. In the context of active air quality management in pollution ‘hot spots’, a 'count down' would not necessarily be appropriate; a simple VMS message such as “Idling pollutes our air – Switch off engine” could be used, and only displayed when the delay was above a defined time threshold. Indeed, since the commencement of (and independent of) this study, a scheme has been implemented at Tower Bridge in London which does this when the bridge is raised. This study investigates some aspects of these issues, with a view to identifying pragmatic and workable solutions applicable to the wider urban highway network.

Vehicle manufacturers have in recent years begun to introduce ‘stop/start’ technologies in certain vehicle types, primarily to improve CO_2 emissions performance over type approval drive cycles. However, there is no published data on the current, or likely future, market penetration of such technologies into the UK passenger car, commercial vehicle, or bus fleets. Also, it is not known what proportions of drivers systematically switch off their engines using such technologies. Aspects of these areas of uncertainty will be addressed during the study.

Drivers of vehicles not fitted with such automated systems (currently the majority) can always manually switch off their engines. However, one of the major challenges is that, when arriving at a red traffic signal, the driver does not know how long the delay will be. This highlights the importance of integrating such a proposed air quality ‘hot spot’ management system into the existing UTC / UTMC systems (obtaining real time delay information from, for example, SCOOT).

3. Study methodology

Given the constrained timescale of the project, a pragmatic approach has been adopted to provide maximum benefit from the study resources, within the available time. The project included consultations and stakeholder engagement, site surveys and data acquisition, a postal survey of light vehicle manufacturers, analysis of new and existing data sources, and production of refined exhaust emissions estimates within a sub-set of illustrative ‘hot spot’ locations.

3.1 Consultations and stakeholder engagement

Officers at the London Borough of Ealing (Regulatory Services) were consulted regarding the study scope and objectives at project inception. Officers at the London Borough of Ealing were also consulted regarding the selection of representative and illustrative case study locations within the Borough. Transportation officers at Ealing were consulted regarding the practicality, cost and efficacy of utilising variable message signing to influence driver behaviour.

Officers at Transport for London were contacted regarding two primary issues. Firstly, the Area Performance Manager (West) was consulted regarding the practicality of linking variable message signing to the UTC systems, in particular the SCOOT traffic control system. Secondly, research officers at TfL were consulted regarding relevant past research carried out in London, in particular lessons learned from the TfL ‘No idling’ campaign implemented in 2012.

A representative VMS industry supplier was also contacted to obtain information regarding state-of-the-art system capabilities, particularly with respect to VMS system interfaces with UK UTC and UTMC systems.

3.2 Site visits and data acquisition

Multiple site visits were carried out at case study locations within the London Borough of Ealing in order to assess their suitability for active management of idling behaviour, including aspects such as physical spatial constraints, queuing behaviour, and prevailing traffic signal timings. This included making sample measurements of traffic signal timings on site.

Data on vehicle stops and delays, derived from instrumented vehicle surveys implemented in Ealing in October 2013 (Rhys-Tyler, 2014), were re-analysed to quantify stops and delays in defined ‘hot spot’ locations within the selected case study areas.

3.3 Postal survey of vehicle manufacturers

A postal survey was sent out to 22 vehicle manufacturers and importers (representing over 95% of total new car and van sales in the UK), requesting information on the market penetration of stop/start technologies in new car and van sales in the UK since 2010 (by fuel type), and requesting information on estimates of market penetration of such technologies in their product portfolios to 2020.

3.4 Refinement of vehicle exhaust emissions assumptions

Vehicle exhaust emission estimates in Ealing have previously been based on remote sensing surveys carried out in 2012, combined with estimates of average urban fuel consumption from official published NEDC test results. It was recognised that the use of average urban fuel consumption values (averaged across different aspects of vehicle dynamics) might tend to over-estimate calculated exhaust emissions at idle, because fuel consumption at idle would be expected to be lower. For this reason, historical fuel consumption data obtained from previous Portable Emissions Monitoring System (PEMS) surveys were re-analysed to derive absolute estimates of fuel consumption during idle conditions, and in particular the ratio of fuel consumption rates at idle to average urban drive cycle fuel consumption rates. These ratio results were used to refine estimates of absolute NO_x emissions in a subset of the case study locations.

4. Outcome of the project / findings:

4.1 Selection of case study locations

Discussions with officers at the London Borough of Ealing identified a number of potential case study locations, based on criteria including poor air quality, vehicle queuing behaviour, traffic flow, and systematic delays due to traffic signal timings. Locations of interest identified included:

- Junction of the Broadway and Uxbridge Road (Ealing Broadway Station);
- A40 Western Avenue (junction at Savoy Circus);
- A40 Western Avenue (junction at Horn Lane / Wales Farm Road);
- Beaconsfield Road / South Road junction in Southall, and;
- Level crossing at Bollo Lane.

All these potential case study locations were visited, and data collected including physical site constraints and sample traffic signal timings. Data on vehicle flows were obtained (where available) from past surveys. Data on vehicle stops and delays (from instrumented vehicle surveys implemented in Ealing in 2013 were only available for three of these five locations (Ealing Broadway, and the A40 Western Avenue junctions). Given constraints on project resources and data availability, a pragmatic decision was made to select three junction approaches as case study locations for further analysis. These were:

- Horn Lane northbound approach to the A40 Western Avenue;
- Wales Farm Road southbound approach to the A40 Western Avenue, and;
- Ealing Broadway southbound approach to Uxbridge Road.

The two approaches to the A40 (which are more strategic in nature) provide an interesting comparison with the Ealing Broadway location (which is more local in character).

Figure 1: Horn Lane northbound approach to the A40 Western Avenue

Figure 2: Wales Farm Road southbound approach to the A40 Western Avenue

Figure 3: Ealing Broadway southbound approach to Uxbridge Road

4.2 Observed signal timings

The traffic signal timings at the A40 locations and at Ealing Broadway are all under SCOOT control, and signal timings (red/green splits, and cycle offsets) therefore vary with changes in traffic demand across the local network. Sample measurements of traffic signal timings were made at different times of day to quantify 'typical' values. Timings were made using a hand stopwatch, and are reasonably accurate to ±1 second. Signal timings do not automatically translate into vehicle stops and delays; stops and delays will also be a function of arrival timing and arrival profiles (which will be influenced by factors such as distance from upstream signals, upstream signal timings, and platooning effects between junctions).

It can be seen from Figure 4 that the daytime cycle time at the Horn Lane northbound approach is 120 seconds, and that despite the variability inherent in the SCOOT system, the red time per cycle is generally around 100 seconds. Figure 4 presents four different periods of observation on two different dates, with multiple cycles observed (in the range 12 to 20 minutes per observation period).

Figure 5 presents a similar picture for the Wales Farm Road southbound approach (as is perhaps to be expected as it is the opposite minor arm of the same junction at Gypsy Corner). Observed red time per cycle is observed to be typically in the range 90 – 100 seconds.

The situation at Ealing Broadway (Figure 6) is somewhat different. Generally, the cycle time was observed to be approximately 60 seconds, with red time per cycle more variable (in the range 33 to 47 seconds). It would appear from the observed data that the SCOOT algorithm is implementing a greater degree of variation in signal timings (in particular splits) at this location, than at Horn Lane or Wales Farm Road.

Figure 4: Horn Lane northbound – Observed traffic signal timings

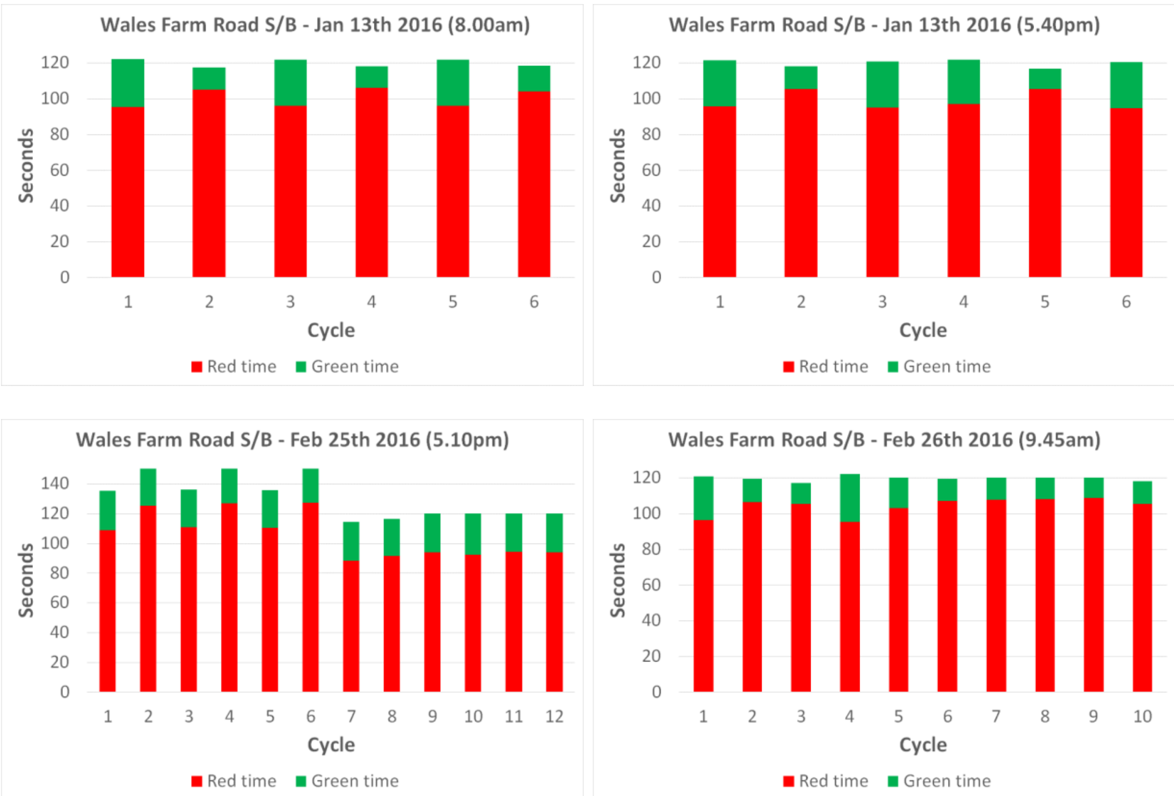

Figure 5: Wales Farm Road southbound – Observed traffic signal timings

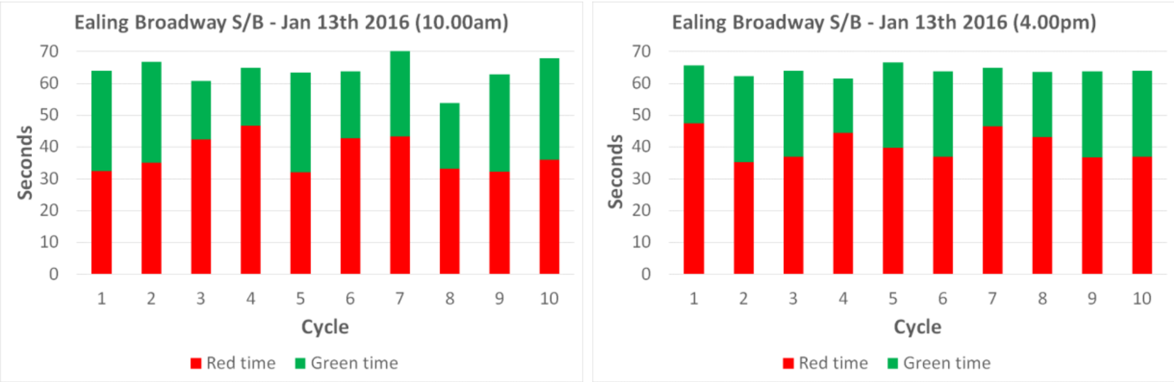

Figure 6: Ealing Broadway southbound – Observed traffic signal timings

4.3 Observed vehicle delays / stop times

Data on vehicle stops and delays in the case study areas were derived from instrumented vehicle surveys implemented in Ealing in October 2013 (Rhys-Tyler, 2014). These data were collected from multiple runs (circa 30 runs per route and direction, measured at a time resolution of 10Hz) during weekdays, within the time period 9.00am to 6.00pm. They are considered broadly representative of daytime weekday conditions. For purposes of analysis and reporting, each case study location was divided into two 100 metre sections on the approach to the stop line (0 – 100 m from the stop line, and 100 – 200 m from the stop line). These 100 metre sections are labelled ‘A’ and ‘B’ respectively in Figure 7.

Figure 7: Spatial definition of 100 metre ‘hot spots’ within case study locations

The vehicle stop and delay information for the Horn Lane northbound approach to the A40 at Gypsy Corner is presented in Figure 8. In section ‘A’, the 100 metre section immediately approaching the stop line, it can be seen that 70% of journey time spent within this section was spent stationary. Only 30% of journey time in section ‘A’ is spent moving. Notably, of the 70% of journey time spent stationary, more than half is spent stationary for 60 seconds or more. As is perhaps to be expected, the observed vehicle dynamics in section ‘B’ (further away from the stop line) are different, with only 31% of journey time spent stationary, and

69% of journey time spent moving. In section ‘B’, less than half of the time spent stationary is spent in stops of 60 seconds duration or more.

There is a similar picture observed at the southbound approach to the A40 on Wales Farm Road (Figure 9). At this location, on the immediate approach to the stop line (section ‘A’), 72% of total journey time within the section is observed to be spent stationary, and 28% of total journey time spent moving. Stop durations within section ‘A’ on the Wales Farm Road southbound approach to the A40 are observed to be generally longer than on the Horn Lane northbound approach, with a significant proportion of total stop time (51%) being of 60 seconds duration or more. In section ‘B’ (100 – 200 metres from the stop line), the proportion of journey time spent stationary reduces to 33%.

The situation observed on the Ealing Broadway approach to Uxbridge Road (Figure 10) is somewhat different, perhaps influenced by the fact that the junction was operating on a cycle time of around 60 seconds during the observations. On the immediate approach to the stop line (section ‘A’), only 44% of journey time was observed to be spent stationary, with 56% spent moving. Combined with the shorter cycle time, this resulted in shorter stop durations, with the majority of stop durations being less than 20 seconds. In section ‘B’ on Ealing Broadway, only 8% of journey time was observed to be spent stationary, with 92% spent moving.

The factors generally influencing stop and delay time and durations in these case study locations are observed to be junction cycle time, available green time on the approach of interest, and traffic demand (volume).

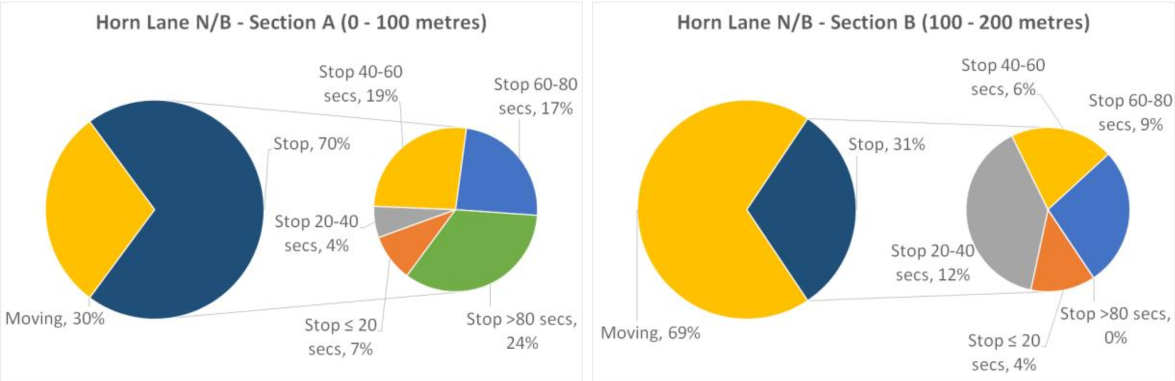

Figure 8: Horn Lane northbound – Vehicle dynamics and stopping metrics

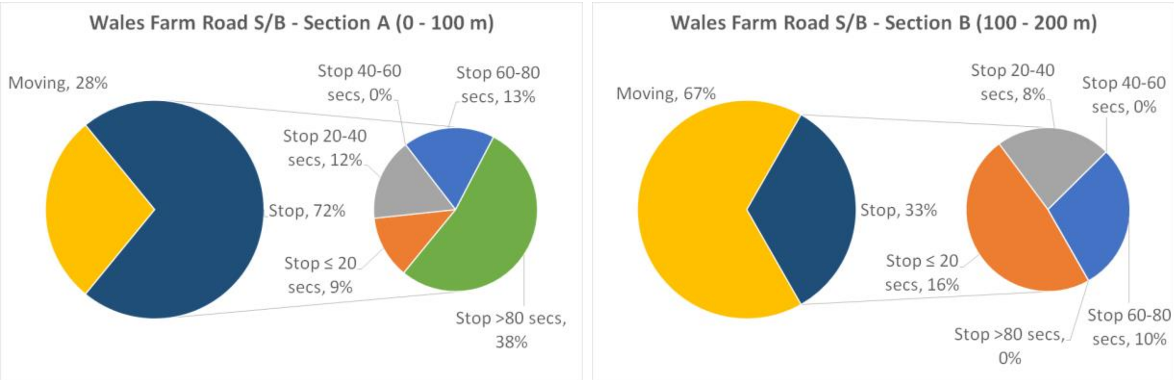

Figure 9: Wales Farm Road southbound – Vehicle dynamics and stopping metrics

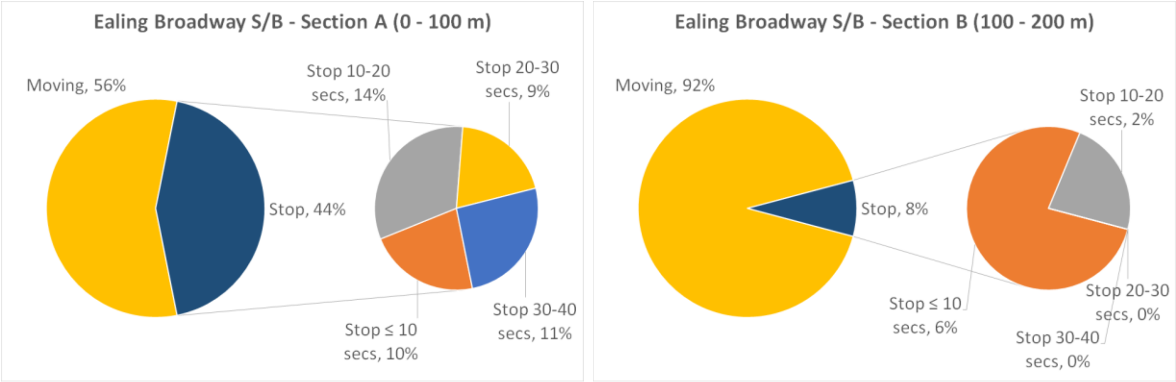

Figure 10: Ealing Broadway southbound – Vehicle dynamics and stopping metrics

4.4 Consultation feedback

4.4.1 Transport for London

Transport for London were consulted regarding their knowledge of driver behaviour and idling, particularly in the context of their past experience with the TfL 'No idling' campaign implemented in 2012. TfL stated that:

"Encouraging drivers to reduce engine idling is challenging because it is a low conscious behaviour and the experience of driving on London's roads is already hectic and complex. It will take more than a campaign to encourage drivers to change but from our campaign development we established that to have greatest impact on behaviour, it is important to provide specific instructions to drivers: explaining what idling is and how and when not to idle (as well as why they should not idle). However, although awareness of the advertising relating to "turning off your engine" increased following the campaign, the campaign seems to have had little effect on claimed "idling" behaviour."

TfL research related to the 2012 campaign included a range of relevant observations.

"Most private drivers know that engine idling means leaving their engine running, but they do not know what behaviour constitutes this - the length of time engine running, occasions, etc. They are aware that fumes cause air pollution, but without knowing an exact definition of what engine idling is, it's hard for them to know what the direct impact to air pollution is, and when they are doing something they shouldn't." (TfL, 2011).

Drivers often revert to habitual behaviours when driving, and are typically in a state of 'auto-pilot' – especially when the route is familiar

Therefore, cues to prompt no-idling behaviour in 'idling hotspots' (taxi ranks, at traffic lights etc.) are needed.

Making the behaviour of no-idling easy and convenient is essential to encourage behaviour change

A barrier to no-idling is unpredictable wait times; mechanisms to help drivers to predict wait times could help to overcome this (e.g. systems at traffic lights to show green-red change times)

TfL 2016

Traffic engineering staff at TfL were also consulted, in particular regarding the possibility of implementing linkages between the UTC system and a variable message signing system.

TfL had no difficulty with the idea of a pilot trial of such a system in principle; however some practical challenges were identified. In the original proposal concept, it is envisaged that the timing of operation of any VMS signage would be related to the timing of the end of the 'red' signal aspect (to help drivers predict wait times, as highlighted in TfL 2016 above). However, the adaptive nature of the SCOOT traffic control system (and indeed other adaptive systems such as MOVA), means that nobody knows in reality when a 'red' signal aspect is going to change to 'red/amber' until between 1 and 4 seconds before it happens (the typical lead time of the SCOOT split and offset optimisers). TfL engineering staff suggested as an alternative having VMS signs operating (illuminated) constantly, or alternatively linking variable message signs to real time air quality monitors giving specific information to drivers on local air quality levels and/or thresholds.

However, as can be seen in report section 4.2 above, it is observed in practice that 'red' signal timings at SCOOT junctions on a minor arm (such as at Horn Lane northbound or Wales Farm Road southbound) can be quite stable in congested conditions (because SCOOT is allocating most green time to the major traffic demand, in this case the A40). Given this system characteristic, there may be practical (pragmatic) methods of estimating when the traffic signal aspect is going to change, sufficient to provide drivers with some indication of the probable wait time (for example, based on a calculation of a moving average of signal timings in cycles immediately preceding).

An alternative compromise might be to have VMS signs 'on' only when there is a red aspect displayed, but this would not provide drivers with 'useful' information on likely wait times, and so would fall short of the aspired ideal.

The issue of uncertainty in traffic signal timings is of course only an issue for adaptive systems. Traffic signals operating using 'fixed time' plans would not have this problem.

TfL engineering staff emphasised the need for 'clarity of message' in any VMS deployment i.e. what would the public see, and how would they respond?

4.4.2 London Borough of Ealing

Transportation officers at the London Borough of Ealing were consulted on the project proposals. They stated that, based on past experience, VMS signage can tend to lose their impact on driver behaviour after a few weeks or months, after an initial positive impact. However, they were of the view that VMS signs have a role to play in conjunction with a more extensive behaviour change publicity programme to inform and educate drivers on the effects of engine idling. This approach using multiple media channels was used for the Olympics and for the recent Southall Broadway works which both involved road closures and diversions.

Transportation officers at Ealing also stated that it would be useful to have the expected costs and benefits of any scheme quantified, including any ongoing maintenance costs.

4.4.3 VMS industry supplier

A VMS commercial supplier was contacted to obtain information regarding the current 'state-of-the-art' in VMS technology, in particular with respect to control and communication linkages with current UK UTC and UTMC systems. The supplier confirmed that systems have already been developed (such as the Siemens Stratos system) to facilitate linkage of mobile VMS signs with the TfL UTMC system. Communications between the VMS signs and the UTMC system would be wireless, without the need for cabling or ducting. The supplier suggested that VMS signs could simply be hired and would not in principle require any additional integration work. This would exclude development of any additional system logic which might be required to calculate and provide delay information to drivers.

Quoted prices for the supply of mobile VMS signs ranged from £345 to £425 per week, plus delivery and collection costs.

4.5 Penetration of stop/start technology into the light vehicle fleet

A significant technological development in recent years which is of relevance to this study is the introduction of automatic stop/start technology into passenger cars, and to a much lesser extent into other vehicle categories. Vehicle manufacturers have implemented these technologies primarily as one of the mechanisms for reducing fuel consumption and CO_2 emissions in the context of European carbon reduction legislation. However, it is also potentially an important consideration in the context of vehicle emissions and local air quality.

A postal survey was sent out to 22 light vehicle manufacturers and importers (representing over 95% of total new car and van sales in the UK), requesting information on the market penetration of stop/start technologies in new car and van sales in the UK since 2010 (by fuel type), and requesting information on estimates of market penetration of such technologies in their product portfolios to 2020. Full or partial responses were received from 14 manufacturers, representing approximately 40% of annual passenger car sales in the UK.

Figure 11: UK market penetration of automatic stop/start systems in passenger cars

Figure 11 presents the UK market penetration of automatic stop/start systems in passenger cars, based on the survey returns from vehicle manufacturers. Table 1 presents the percentage of diesel passenger car sales with automatic stop/start systems, by manufacturer (constrained by survey responses).

It can be seen from the figures that penetration of stop/start systems has been occurring more quickly in diesel engine cars than in petrol engine cars. In 2012, 50% of diesel cars sales had automatic stop/start systems, and this has increased to 74% in 2015. In contrast, in 2012, 18% of petrol cars sales had automatic stop/start systems, increasing to 48% in 2015. There appears to be a clear trend amongst most of the manufacturers surveyed. Survey responses (where volunteered) estimating future sales of stop/start equipped passenger cars are presented in Table 2. Based on the prevailing fleet composition in Ealing, it is estimated that the overall passenger car fleet at 2017 will comprise approximately 14% diesel cars with automatic stop/start, 31% diesel cars without automatic stop/start, 7% petrol cars with automatic stop/start, and 48% petrol cars without automatic stop/start.

Table 1: UK % sales of diesel passenger cars with automatic stop/start systems

Manufacturer	2010	2011	2012	2013	2014	2015
A		75%	92%	94%	96%	99%
B	0%	10%	20%	28%	50%	43%
C	0%	40%	74%	72%	82%	86%
D	4%	33%	64%	71%	74%	77%
E	0%	0%	46%	79%	88%	94%
F	1%	17%	45%	64%	62%	71%
G	0%	0%	22%	86%	97%	97%
H	27%	29%	9%	23%	27%	27%
I	0%	11%	24%	31%	47%	68%
J	93%	100%	100%	100%	100%	100%
K	4%	9%	13%	8%	9%	42%
L	0%	0%	0%	28%	77%	98%
M	0%	0%	1%	13%	31%	41%
N	15%	15%	52%	69%	73%	84%
Total	**4%**	**30%**	**50%**	**60%**	**66%**	**74%**

Table 2: Estimated future passenger car sales with automatic stop/start technology

Manufacturer	Fuel	2016	2017	2018	2019	2020
A	Diesel	100%	100%	100%	100%	100%
E	Diesel	100%	100%	100%	100%	100%
G	Diesel	100%	100%	100%	100%	100%
I	Diesel	75%	80%	85%	90%	95%
J	Diesel	100%	100%	100%	100%	100%
K	Diesel	98%	100%	100%	100%	100%
L	Diesel	100%	100%	100%	100%	100%
N	Diesel	100%	100%	100%	100%	100%
A	Petrol	100%	100%	100%	100%	100%
E	Petrol	100%	100%	100%	100%	100%
G	Petrol	91%	87%	89%	91%	96%
I	Petrol	18%	25%	35%	47%	60%
J	Petrol	97%	97%	97%	97%	95%
K	Petrol	99%	100%	100%	100%	100%
L	Petrol	24%	48%	62%	62%	62%
N	Petrol	100%	100%	100%	100%	100%

4.6 Vehicle exhaust emission calculations

Vehicle exhaust emission estimates in Ealing have previously been based on remote sensing surveys carried out in 2012, combined with estimates of average urban fuel consumption from official published NEDC test results. It was recognised that the use of average urban fuel consumption values (averaged across all aspects of vehicles dynamics) might tend to over-estimate calculated exhaust emissions at idle, because fuel consumption at idle would be expected to be lower. For this reason, historical fuel consumption data obtained from previous Portable Emissions Monitoring System (PEMS) surveys were re-analysed to derive absolute estimates of fuel consumption during idle conditions, and in particular the ratio of fuel consumption rates at idle to average urban drive cycle fuel consumption rates. These ratio results were used to refine estimates of absolute NO_x emissions in the case study locations.

These revised fuel consumption assumptions were utilised to produce revised estimates of emissions of NO, NO_2, and NO_x from light vehicles (cars, taxis and vans) in the case study locations.

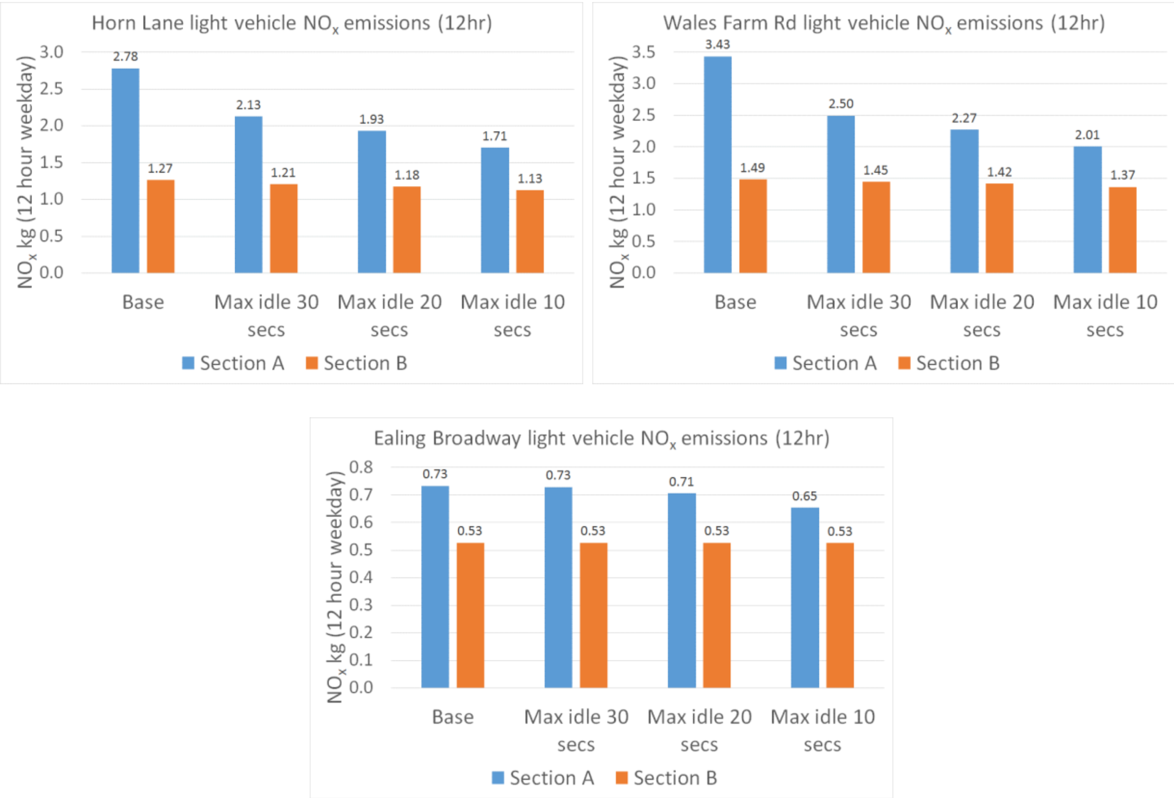

Figure 12: Light vehicle NO_x emissions by case study location

Figure 12 presents the calculated light vehicle NO_x emissions (NO_2 equivalent values) in mass units of kilograms, for an average weekday 12 hour period (0700-1900). Results are presented for each case study location, by spatial section ('A' and 'B'). Four sets of results for each case study location are presented. Data labelled 'Base' are emissions from light vehicles (moving and stationary) assuming that engines are never switched off, and are allowed to idle when the vehicle is not moving.

Max idle 30 secs – Assumes that if a stop is of duration 30 seconds or more, the engine is switched off for the element of the stop duration in excess of 30 seconds;

Max idle 20 secs – Assumes that if a stop is of duration 20 seconds or more, the engine is switched off for the element of the stop duration in excess of 20 seconds;

Max idle 10 secs – Assumes that if a stop is of duration 10 seconds or more, the engine is switched off for the element of the stop duration in excess of 10 seconds.

The detailed breakdown of the exhaust emission results for each case study location is presented in data tables in Annex 3. It is assumed in this analysis that bus and HGV engines are not switched off, primarily because detailed information on bus and HGV vehicle dynamics was not available to the study. Bus and HGV emission rates in Annex 3 are calculated using a simplified approach based on average fuel consumption per unit distance, and distance travelled within the case study area (Rhys-Tyler, 2014). Such assumptions can be revisited in future work if additional data becomes available.

The calculated reduction in emissions are particularly notable in section 'A' at Horn Lane and section 'A' at Wales Farm Road. Significant stop numbers and durations were observed at these locations in the instrumented vehicle surveys, and therefore there is the potential for significant reductions in emissions at these locations if engines are switched off. Light vehicle NO_x emissions in section 'A' at Horn Lane are calculated to reduce by 24% (max idle 30 seconds), 31% (max idle 20 seconds), and 39% (max idle 10 seconds). If sections 'A' and 'B' at Horn Lane are combined, the overall reductions become 18%, 23%, and 30% respectively.

Light vehicle NO_x emissions in section 'A' at Wales Farm Road are calculated to reduce by 27% (max idle 30 seconds), 34% (max idle 20 seconds), and 42% (max idle 10 seconds). If sections 'A' and 'B' at Wales Farm Road are combined, the overall reductions become 20%, 25%, and 31% respectively.

The observed stop numbers and durations at Ealing Broadway were relatively lower, due to a combination of reduced cycle time, increased proportion of available green time, and relatively lower traffic flows. Light vehicle NO_x emissions in section 'A' at Ealing Broadway are calculated to reduce by 1% (max idle 30 seconds), 4% (max idle 20 seconds), and 11% (max idle 10 seconds). If sections 'A' and 'B' at Ealing Broadway are combined, the overall reductions become approximately 0%, 2%, and 6% respectively.

From this simple analysis it can be seen that potentially significant emissions reductions are achievable from active management of vehicle idling at 'hot spot' locations which meet the criteria of high cycle time, low relative green time, and large traffic demand (queuing). As previously stated, it is estimated that at 2017 the overall passenger car fleet will include approximately 14% diesel cars with automatic stop/start. Therefore, it can be argued that not all of the stated benefits will be realised because some drivers will already be using automated stop/start systems. However, this analysis serves to quantify the difference between not switching engines off at idle, and all drivers behaving according to an idealised set of rules pertaining to idling behaviour

5. Technical Feasibility

5.1 Traffic control systems

The project concept envisages a system where the timing of operation of any VMS signage (whether mobile or fixed) would be related to the timing of the end of the 'red' signal aspect. As stated by TfL above, "*A barrier to no-idling is unpredictable wait times; mechanisms to help drivers to predict wait times could help to overcome this (e.g. systems at traffic lights to show green-red change times)*". (TfL 2016).

A vehicle countdown system is not proposed, as this would have potential challenges with respect to driver behaviour and safety (for example, drivers focusing on the countdown, rather than on the wider highway environment, pedestrians on crossings etc.). Nevertheless, some mechanism would be desirable to provide drivers with an indication of whether a stop is going to be of ‘long duration’, or ‘short duration’. One means of achieving this would be to terminate the operation of the VMS sign a nominal (short) duration before the traffic signal aspect changes from ‘red’ to ‘red/amber’, as illustrated in Figure 13 below. In this example, the VMS sign is switched off 10 seconds before the traffic lights change, providing the drivers with a visual indication that the remaining stop duration will be short, without the need for a countdown facility. Drivers who regularly travel through the site will become accustomed to the significance of the change, and the duration of time lag between the VMS sign switching off, and the traffic lights changing, could be adjusted depending on local driver behaviour.

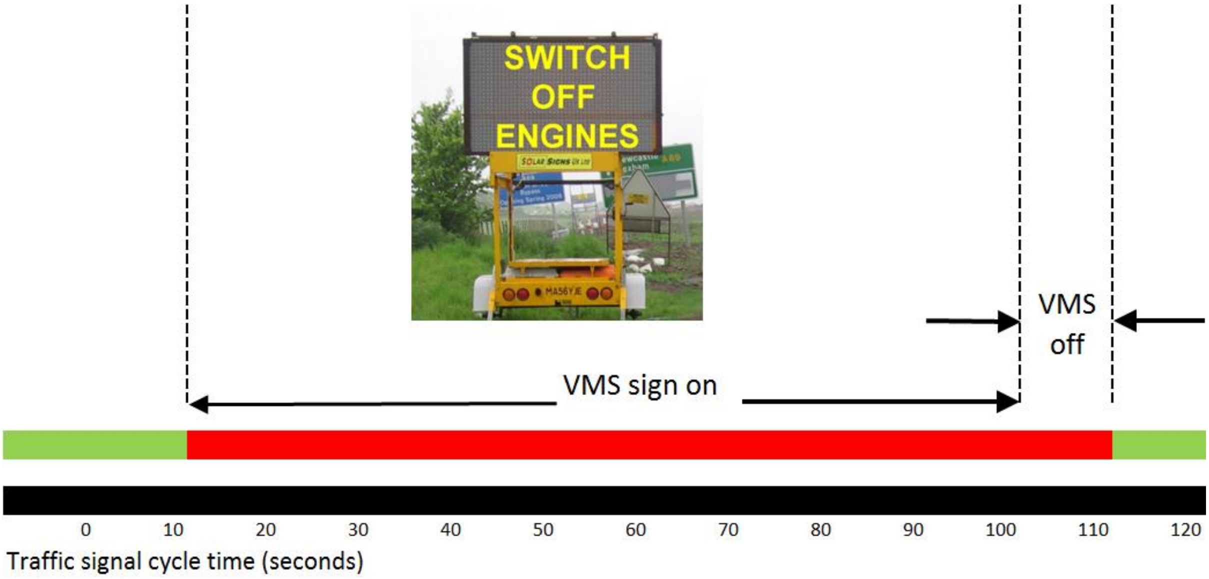

Figure 13: Illustration of possible system operation

This would be relatively straightforward to implement in the case of a signalised junction operating on a fixed time plan. However, as highlighted by the consultation with TfL discussed earlier, the situation is more complex when traffic signals are controlled by an adaptive system such as SCOOT or MOVA.

The adaptive nature of the SCOOT traffic control system operating at many major junctions in London means that nobody knows in reality when a ‘red’ signal aspect is going to change to ‘red/amber’ until between 1 and 4 seconds before it happens (the typical lead time of the SCOOT split and offset optimisers).

However, as was seen in section 4.2 above, it has been observed in practice that ‘red’ signal timings at SCOOT junctions on a minor arm (such as at Horn Lane northbound or Wales Farm Road southbound) can be quite stable in congested conditions (because SCOOT is allocating most green time to the major traffic demand, in this case the A40). Given this system characteristic, there may be pragmatic methods of estimating when the traffic signal aspect is going to change, sufficient to provide drivers with some indication of the probable wait time. This could be achieved, for example, by basing the estimate on a calculation of a moving average of signal timings over say three cycles immediately preceding (subject to the logical constraint that the VMS sign must be switched off when the traffic signal aspect is red/amber or green). Such an approach may be feasible in localities such as Horn Lane or Wales Farm Road where SCOOT signal timings are observed to be ‘relatively’ stable.

An alternative compromise might be to have VMS signs ‘on’ only when there is a red aspect displayed, but this would not provide drivers with ‘useful’ information on likely wait times, and so would fall short of the aspired ideal.

5.2 Vehicle technology

It is not proposed that such an active management system be implemented at all traffic signals. Such an active management system would only be applicable to manage vehicle idling at ‘hot spot’ locations which meet the criteria of high cycle time, low relative green time, and large traffic demand (queuing). This is significant because vehicles not equipped with automated stop/start systems are not necessarily designed for repeated stop/start cycles of operation.

Windover et al (2015) have investigated this issue in a US context in some depth in a study carried out at Argonne National Laboratory, a laboratory of the US Department of Energy. They conclude that:

“While aggressive start cycles (>20 cycles per day) could lead to premature failure in the starter system of light-to-medium-duty commercial fleet vehicles, modern fuel injection and engine control systems have eliminated any issues associated with drivers of typical light-duty vehicles turning the engine off while stationary for short periods and restarting for <10 start events per day.”

“…this study concluded that the majority of drivers of light duty vehicles could improve their fuel efficiency and reduce fuel costs with minimal, if any, noticeable reduction in the life of starter system components by eliminating some short-duration idling throughout the day.”

Gaines et al (2012) carried out limited measurements on a single late-model American petrol car (2011 Ford Fusion). They determined that idling for more than 10 seconds uses more fuel and emits more CO_2 than restarting the engine. With this petrol engine, other emissions from idling were found to be low, so that longer idling times were preferable before they exceeded restart emissions; these crossover times were found to vary by pollutant. The restart emissions were found to be much smaller than those from cold starts. However, the authors noted that these results were very limited and more research is necessary. No results were presented for diesel engines.

6. Limitations, assumptions and uncertainty

- This study utilised exhaust emissions data derived from roadside remote sensing surveys. This is not ideal for quantifying exhaust emissions during idling, and will not capture possible transient high emission events (spikes) during actual engine stop/start cycles. The available evidence from the literature indicates with reasonable confidence that switching off light vehicle engines for stops greater than around 10 seconds results in benefits for fuel consumption and CO_2 emissions. However, the available evidence is less clear cut for other exhaust pollutants, including NO_x. The ‘optimal’ idle durations(s) for the minimisation of NO_x exhaust emissions should be researched further, observing actual engine stop/start cycles. This may require new primary research if existing datasets prove inadequate;

- The analysis to date has focused on light vehicles, primarily because data on vehicle dynamics in the case study locations is not currently available to the author for heavy goods vehicles and buses;

- Vehicle emission rates utilised in the analysis have been obtained from remote sensing survey data collected in 2012. It would be desirable to validate the assumptions regarding emission rates with more current data, particularly relating to Euro 6 vehicles;

- Assumptions regarding fuel consumption rates at idle have been derived from PEMS survey data which is now somewhat dated (2007). It would be advisable to obtain more current data, if possible, on idle fuel consumption rates for the current vehicle fleet;

- Only a subset of vehicle manufacturers (representing approximately 40% of UK light vehicle sales) responded to the postal survey relating to the market penetration of automated stop/start systems. It would be desirable to increase this sample size to improve confidence in the characterisation of the existing vehicle fleet, and the likely direction of future vehicle technologies;

- There is uncertainty regarding the degree to which existing drivers with vehicles already fitted with automated stop/start systems actually use these systems (and how their usage of such systems might vary). Consideration should be given to addressing whether this issue is significant, and if so, how it should be addressed / measured / quantified.

7. Intellectual property rights

A number of vehicle manufacturers supplied data to the study on the understanding that it would <u>not</u> be distributed to third parties. For this reason, this public version of the study report has anonymised manufacturers, and has aggregated data to preserve confidentiality.

8. Practical applications of the concept

The proposed initiative has the potential to achieve significant reductions in road vehicle related exhaust emissions in air quality ‘hot spot’ locations which meet certain criteria, namely high cycle time, low relative green time, and large traffic demand (queuing). In this context, a ‘hot spot’ is defined as short sections (perhaps 100 - 200m) of highway network where high concentrations of vehicle related exhaust emissions are generated due to issues such as queuing and congestion, with consequent severe negative impacts on local air quality.

The calculation of the impact of exhaust emissions reductions on local air quality must, of course, take account of the contribution of both road transport and other sources of pollutant emissions (including non-road transport, domestic, and industrial). It would be necessary to deploy air quality sensors at much greater spatial resolution than the existing Ealing diffusion tube network to measure the impact of active management of air quality ‘hot spots’ on the urban road network in Ealing in detail. However, a number of existing diffusion tube sites are located close to, or adjacent to, known ‘hot spots’, which would facilitate longer term monitoring of impacts. Measurement of changes in air quality in ‘real time’ would require fast response sensors with high time resolution, which are commercially available, and could be deployed as part of the ‘next steps’ programme of work.

The active management of air quality ‘hot spots’ on the urban road network in real time has the potential to be deployed as a generic intervention in virtually all urban areas with local air quality problems where the above criteria are met.

The proposed intervention directly engages with three of DfT’s priority areas:

- Characterising with greater spatial, temporal and source resolved detail the air pollutant emissions from the transport fleet, and the effect of mitigation measures in real-time or near real-time;
- Using smart traffic management systems to reduce air pollution emissions, and;
- Modifying driving style to reduce air pollution emissions.

The proposed solution is plausible and deployable with existing or near to market technologies. Research to date indicates that there is a strong potential for it to be used to significantly reduce concentrations or impacts of both NO_x, CO_2, and other pollutants in air quality 'hot spot' locations.

The cost of implementation of a mobile VMS system at a single location would likely be of the order of £15,000 to £20,000 per annum. An additional budget allocation would need to be allocated for any additional necessary algorithm / logic development and implementation, perhaps of the order of £5,000 (costings to be confirmed in due course with commercial suppliers based on local site characteristics and configuration if the Department is minded to proceed). High time resolution and high spatial resolution air quality monitoring appropriate for 'before' and 'after' monitoring is a potentially significant outlay, and again would depend on detailed scheme design. However, detailed monitoring at a single 'hotspot' site for a reasonable period of time (perhaps 6 – 12 months) is likely to cost in the region of £30,000 to £40,000 (costings to be confirmed in due course with commercial suppliers, as required).

9. Recommendations and next steps

- It is recommended that the issues identified in Section 6 above (Limitations, assumptions, and uncertainty) are addressed as a priority to ensure as far as possible that the study findings remain robust and are not materially undermined by changes in assumptions;

- The available evidence indicates with reason confidence that switching off light vehicle engines for stops greater than around 10 seconds results in benefits for fuel consumption and CO_2 emissions. However, the evidence is less clear cut for other exhaust pollutants, including NO_x. Alternative existing datasets should be reviewed to determine whether relevant evidence is available (for example, commercial PEMS data). If existing data is not available to reduce uncertainty regarding the recommended / optimal minimum idle duration, then consideration should be given to commissioning appropriate research to address these areas of uncertainty.

- If new data availability introduces uncertainty, then sensitivity analyses should be carried out to test the robustness of adopted / revised assumptions;

- If a pilot trial is to be implemented in Ealing (or elsewhere in London), formal project engagement should be made with Transport for London (as a formal project partner) to ensure effective engagement and coordination, and consistency with local air quality and highway policies. If a pilot trial is considered outside of London, then the same arrangements should be made with the relevant local highway authority.

10. Conclusions

- The study has confirmed that particular combinations of circumstances relating to traffic infrastructure design, operation, traffic demand, and road fleet characteristics can result in elevated levels of vehicles emissions, based on available data;

- The identification and investigation of case study locations in Ealing has enabled the quantification of relevant factors such as prevailing traffic signal timings, vehicle dynamics, and traffic demand volumes, resulting in the estimation and quantification of aggregate exhaust emissions of NO, NO_2, and NO_x, when combined with pre-existing emissions datasets;

- The causal linkage between these calculated exhaust emission values and resultant local air quality is probable, but yet to be confirmed at the local level (further work required);

- Consultation with local stakeholders such as TfL has identified particular issues that require attention in any future work, in particular the requirement for specific, targeted, and real time driver information. 'General' information and education campaigns have historically been found to have limited efficacy;

- Surveys of vehicle manufacturers have quantified, for the first time, the degree of penetration of automated stop/start technology into the UK light vehicle fleet. Insights have also been gained into the likely future trajectories of such technologies (although the picture is currently incomplete, and uncertainties still exist);

- The basic principle of reducing light vehicle engine idling in relatively long duration (>30 seconds) stationary queuing conditions to reduce fuel consumption and CO_2 emissions appears to be supported;

- The available evidence suggests that significant reductions in polluting exhaust emissions such as NO_x may be achievable in 'hotspot' locations, but there are current uncertainties relating to the desirable minimum / optimal idling duration for such pollutants, particularly in the case of diesel engines. Further investigation of alternative data sources is indicated, perhaps followed by additional research and data collection if existing data sources are found to be inadequate to answer the research question;

- A number of areas of uncertainty have been identified which should be addressed before such active management of air quality 'hotspots' is adopted as a matter of general policy.

References

Eckl T. and Kirchner E. (2014). The Long Path from Discomfort to Customer Acceptance. Start-Stop: Yesterday, today, and tomorrow. 10th Schaeffler Symposium April 3/4, 2014. DOI: 10.1007/978-3-658-06430-3_24

EPA (2012). Idle free schools leaflet. US Environmental Protection Agency. Downloadable from http://www2.epa.gov/region8/idle-free-schools

Gaines L.; Rask, E.; Keller, G. (2012). Which is greener: Idle, or stop and restart? Comparing fuel use and emissions for short passenger-car stops. Argonne National Laboratory, Argonne, IL USA, 2012. http://www.anl.gov/energy-systems/publications

Rhys-Tyler, G. (2014). Scenario development to inform air quality action planning in the London Borough of Ealing" DEFRA project report reference 334b2012. (Downloadable from https://www.glynrhys-tyler.com/publications.html)

TfL, 2011. No idling proposition development research (Ref. 11047). Transport for London, September 2011.

TfL, 2016. Changing driver behaviour: Within the context of idling. A summary of existing insights. Customer & Employee Insight, TfL Marketing. February 2016.

Windover, P.R.; Owens, R. J.; Levinson, T. M.; and Laughlin, M. D. (2015). Stop and Restart Effects on Modern Vehicle Starting System Components. Argonne National Laboratory, Argonne, IL USA, 2015. http://www.anl.gov/energy-systems/publications

Annexes

Annex 1 - List of consultees / stakeholders

Dr John Freeman – Regulatory Services, London Borough of Ealing
Rizwan Yunus – Regulatory Services, London Borough of Ealing
Russell Roberts – Principal Transportation Engineer, London Borough of Ealing
Michelle Curran - Business Development Manager, Mobile Variable Message Signs Ltd
Kate Barber – Research Development Manager, Transport for London
Stuart Reid – Travel Demand Management Programme Director, Transport for London
Elaine Seagriff – Head of London Wide Policy and Strategy, Transport for London
Andrew Wiseall – Area Performance Manager (West), Transport for London

Annex 2 - Acknowledgement to data suppliers

Audi UK
Department for Transport
Ford Motor Company Ltd
Honda (UK)
Kia Motors (UK) Ltd
London Borough of Ealing
Mazda Motors UK Ltd
Mitsubishi Motors
Peugeot Citroën Automobiles UK Ltd
Porsche Cars GB Ltd
ŠKODA UK
Suzuki GB PLC
Toyota (GB) PLC
Transport for London
Vauxhall Motors
Volvo Car UK Ltd

Annex 3 – Calculated vehicle emissions by case study location (12 hour average weekday values)

Horn Lane

Moving – NO grams

		A	B	Total
Car	Diesel	326	248	574
Car	Petrol	117	89	206
Van	Diesel	256	195	451
Taxi	Diesel	6	5	11

Base stationary – NO grams

		A	B	Total
Car	Diesel	313	46	359
Car	Petrol	107	16	123
Van	Diesel	263	38	301
Taxi	Diesel	6	1	7

Heavy vehicles (fixed)

Bus	Diesel	53	53	105
HGV	Diesel	531	531	1062

Stationary

Max idle 10 secs – NO grams

		A	B	Total
Car	Diesel	69	15	84
Car	Petrol	24	5	29
Van	Diesel	58	12	71
Taxi	Diesel	1	0	2

Max idle 20 secs – NO grams

		A	B	Total
Car	Diesel	121	25	146
Car	Petrol	41	9	50
Van	Diesel	101	21	123
Taxi	Diesel	2	1	3

Max idle 30 secs – NO grams

		A	B	Total
Car	Diesel	165	33	198
Car	Petrol	57	11	68
Van	Diesel	138	28	166
Taxi	Diesel	3	1	4

Horn Lane

Moving – NO_2 grams

		A	B	Total
Car	Diesel	175	133	308
Car	Petrol	9	7	16
Van	Diesel	132	101	233
Taxi	Diesel	2	1	3

Base stationary – NO_2 grams

		A	B	Total
Car	Diesel	170	25	195
Car	Petrol	17	3	20
Van	Diesel	137	20	157
Taxi	Diesel	2	0	2

Heavy vehicles (fixed)

Bus	Diesel	18	18	36
HGV	Diesel	104	104	208

Stationary

Max idle 10 secs – NO_2 grams

		A	B	Total
Car	Diesel	38	8	46
Car	Petrol	4	1	5
Van	Diesel	30	6	37
Taxi	Diesel	0	0	1

Max idle 20 secs – NO_2 grams

		A	B	Total
Car	Diesel	66	14	79
Car	Petrol	7	1	8
Van	Diesel	53	11	64
Taxi	Diesel	1	0	1

Max idle 30 secs – NO_2 grams

		A	B	Total
Car	Diesel	89	18	107
Car	Petrol	9	2	11
Van	Diesel	72	14	87
Taxi	Diesel	1	0	1

Horn Lane

Moving – Total NO_x grams (NO_2 equiv.)

		A	B	Total
Car	Diesel	674	513	1188
Car	Petrol	189	143	332
Van	Diesel	525	399	925
Taxi	Diesel	11	8	19

Base stationary – Total NO_x grams (NO_2 equiv.)

		A	B	Total
Car	Diesel	650	95	745
Car	Petrol	182	27	208
Van	Diesel	540	79	619
Taxi	Diesel	11	2	13

Heavy vehicles (fixed)

Bus	Diesel	99	99	198
HGV	Diesel	918	918	1836

Stationary

Max idle 10 secs – Total NO_x grams (NO_2 equiv.)

		A	B	Total
Car	Diesel	144	30	174
Car	Petrol	40	8	49
Van	Diesel	120	25	145
Taxi	Diesel	3	1	3

Max idle 20 secs – Total NO_x grams (NO_2 equiv.)

		A	B	Total
Car	Diesel	251	53	304
Car	Petrol	70	15	85
Van	Diesel	208	44	252
Taxi	Diesel	4	1	5

Max idle 30 secs – Total NO_x grams (NO_2 equiv.)

		A	B	Total
Car	Diesel	342	69	411
Car	Petrol	96	19	115
Van	Diesel	284	57	341
Taxi	Diesel	6	1	7

Wales Farm Road

Moving		NO grams A	B	Total
Car	Diesel	396	298	693
Car	Petrol	141	107	248
Van	Diesel	274	208	481
Taxi	Diesel	7	5	13

Base stationary		NO grams A	B	Total
Car	Diesel	429	62	490
Car	Petrol	147	21	168
Van	Diesel	318	46	364
Taxi	Diesel	8	1	10

Heavy vehicles (fixed)				
Bus	Diesel	172	172	345
HGV	Diesel	701	701	1402

Stationary

Max idle 10 secs		NO grams A	B	Total
Car	Diesel	90	33	123
Car	Petrol	31	11	42
Van	Diesel	67	25	92
Taxi	Diesel	2	1	2

Max idle 20 secs		NO grams A	B	Total
Car	Diesel	153	46	200
Car	Petrol	53	16	68
Van	Diesel	114	34	148
Taxi	Diesel	3	1	4

Max idle 30 secs		NO grams A	B	Total
Car	Diesel	206	52	258
Car	Petrol	71	18	89
Van	Diesel	153	39	192
Taxi	Diesel	4	1	5

Wales Farm Road

Moving		NO_2 grams A	B	Total
Car	Diesel	215	161	375
Car	Petrol	12	9	21
Van	Diesel	143	108	251
Taxi	Diesel	2	2	4

Base stationary		NO_2 grams A	B	Total
Car	Diesel	233	33	266
Car	Petrol	23	3	27
Van	Diesel	166	24	190
Taxi	Diesel	3	0	3

Heavy vehicles (fixed)				
Bus	Diesel	60	60	119
HGV	Diesel	136	136	271

Stationary

Max idle 10 secs		NO_2 grams A	B	Total
Car	Diesel	49	18	67
Car	Petrol	5	2	7
Van	Diesel	35	13	48
Taxi	Diesel	1	0	1

Max idle 20 secs		NO_2 grams A	B	Total
Car	Diesel	83	25	108
Car	Petrol	8	3	11
Van	Diesel	59	18	77
Taxi	Diesel	1	0	1

Max idle 30 secs		NO_2 grams A	B	Total
Car	Diesel	112	28	140
Car	Petrol	11	3	14
Van	Diesel	80	20	100
Taxi	Diesel	1	0	2

Wales Farm Road

Moving		Total NO_x grams (NO_2 equiv.) A	B	Total
Car	Diesel	821	617	1438
Car	Petrol	229	172	401
Van	Diesel	563	427	990
Taxi	Diesel	13	10	23

Base stationary		Total NO_x grams (NO_2 equiv.) A	B	Total
Car	Diesel	890	128	1018
Car	Petrol	249	36	285
Van	Diesel	654	94	748
Taxi	Diesel	16	2	18

Heavy vehicles (fixed)				
Bus	Diesel	324	324	648
HGV	Diesel	1211	1211	2421

Stationary

Max idle 10 secs		Total NO_x grams (NO_2 equiv.) A	B	Total
Car	Diesel	187	69	256
Car	Petrol	52	19	72
Van	Diesel	138	51	188
Taxi	Diesel	3	1	5

Max idle 20 secs		Total NO_x grams (NO_2 equiv.) A	B	Total
Car	Diesel	319	96	415
Car	Petrol	89	27	116
Van	Diesel	234	71	305
Taxi	Diesel	6	2	7

Max idle 30 secs		Total NO_x grams (NO_2 equiv.) A	B	Total
Car	Diesel	428	108	536
Car	Petrol	120	30	150
Van	Diesel	315	79	394
Taxi	Diesel	8	2	9

Ealing Broadway

Moving

Vehicle	Fuel	NO grams A	NO grams B	NO grams Total	NO_2 grams A	NO_2 grams B	NO_2 grams Total	Total NO_x grams (NO_2 equiv.) A	Total NO_x grams (NO_2 equiv.) B	Total NO_x grams (NO_2 equiv.) Total
Car	Diesel	149	139	288	82	73	155	310	287	596
Car	Petrol	53	50	103	4	4	8	86	80	165
Van	Diesel	62	57	119	33	29	62	128	117	245
Taxi	Diesel	14	13	27	4	4	8	26	24	50

Base stationary

Vehicle	Fuel	NO grams A	NO grams B	NO grams Total	NO_2 grams A	NO_2 grams B	NO_2 grams Total	Total NO_x grams (NO_2 equiv.) A	Total NO_x grams (NO_2 equiv.) B	Total NO_x grams (NO_2 equiv.) Total
Car	Diesel	49	5	54	26	3	29	101	11	112
Car	Petrol	17	2	19	3	0	3	28	3	31
Van	Diesel	22	2	24	11	1	13	45	5	50
Taxi	Diesel	5	1	6	2	0	2	9	1	10

Heavy vehicles (fixed)

Vehicle	Fuel	NO grams A	NO grams B	NO grams Total	NO_2 grams A	NO_2 grams B	NO_2 grams Total	Total NO_x grams (NO_2 equiv.) A	Total NO_x grams (NO_2 equiv.) B	Total NO_x grams (NO_2 equiv.) Total
Bus	Diesel	331	361	692	97	107	204	604	661	1265
HGV	Diesel	101	110	211	21	23	44	176	192	368

Stationary

Max idle 10 secs

Vehicle	Fuel	NO grams A	NO grams B	NO grams Total	NO_2 grams A	NO_2 grams B	NO_2 grams Total	Total NO_x grams (NO_2 equiv.) A	Total NO_x grams (NO_2 equiv.) B	Total NO_x grams (NO_2 equiv.) Total
Car	Diesel	28	5	33	15	3	18	57	11	68
Car	Petrol	9	2	11	2	0	2	16	3	19
Van	Diesel	12	2	15	6	1	8	25	5	30
Taxi	Diesel	3	1	3	1	0	1	5	1	6

Max idle 20 secs

Vehicle	Fuel	NO grams A	NO grams B	NO grams Total	NO_2 grams A	NO_2 grams B	NO_2 grams Total	Total NO_x grams (NO_2 equiv.) A	Total NO_x grams (NO_2 equiv.) B	Total NO_x grams (NO_2 equiv.) Total
Car	Diesel	41	5	47	22	3	25	86	11	97
Car	Petrol	14	2	16	2	0	3	24	3	27
Van	Diesel	19	2	21	10	1	11	38	5	43
Taxi	Diesel	4	1	5	1	0	2	8	1	9

Max idle 30 secs

Vehicle	Fuel	NO grams A	NO grams B	NO grams Total	NO_2 grams A	NO_2 grams B	NO_2 grams Total	Total NO_x grams (NO_2 equiv.) A	Total NO_x grams (NO_2 equiv.) B	Total NO_x grams (NO_2 equiv.) Total
Car	Diesel	47	5	53	26	3	29	99	11	110
Car	Petrol	16	2	18	3	0	3	28	3	31
Van	Diesel	21	2	24	11	1	12	44	5	49
Taxi	Diesel	5	1	5	2	0	2	9	1	10