

# Alternative Legends for Close Following Final Report Highways Agency

25 April 2014

ATKINS

Plan Design Enable

# Notice

This document and its contents have been prepared and are intended solely for Highways Agency's information and use in relation to Task 176: Alternative Legends for Close Following.

Atkins Limited assumes no responsibility to any other party in respect of or arising out of or in connection with this document and/or its contents.

This document has 28 pages including the cover.

## Document history

Job number: 5125558			Document ref: 5125558/06/01			
Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
Rev 1.0	Draft for comment	Gordon Lee	Joe Castle	Jill Hayden	Jill Hayden	25/04/2014

# Table of contents

Chapter	Pages
<b>Executive summary</b>	<b>4</b>
<b>1. Introduction</b>	<b>6</b>
1.1. Background and Purpose of Study	6
1.2. Overview of Methodology	7
1.3. Legends and Locations	8
1.4. Limitations of Data	10
<b>2. Overview of Data</b>	<b>11</b>
2.1. Context	11
<b>3. Headline Results of Analysis</b>	<b>14</b>
3.1. Impact of Message on Following Category Rates	14
3.2. Impact of Message on Overall Headway Distribution	19
<b>4. Conclusions</b>	<b>21</b>
4.1. Impact of Alternative Legends on Driver Behaviour	21
4.2. Considerations for Guidance	21
4.3. Potential for Future Analysis	21
<b>Appendices</b>	<b>23</b>
<b>Appendix A. Impact of Speed-Flow Relationship</b>	<b>24</b>
<b>Appendix B. Explanation of Differing Impacts on Averages and Categories</b>	<b>25</b>
<b>Tables</b>	
Table 1-1 Distances between VMS and Loop Sites	10
Table 3-1 Impact of Message on Close Following in December	18
Table 3-2 Impact of Message on Close Following in January	18
Table 3-3 Impact of Message on Aggressive Following in December (TBC)	19
Table 3-4 Impact of Message on Aggressive Following in January (TBC)	19
<b>Figures</b>	
Figure 1-1 Timetable for Displaying Legends for Two Days Each in Two Periods	7
Figure 1-2 Alternative Legends and Number of Potential VMS Locations	8
Figure 1-3 Key for VMS and Loop Location Diagrams	9
Figure 1-4 Locations for Could You Stop in Time	9
Figure 1-5 Locations for 'Tailgating Kills'	9
Figure 1-6 Locations for 'Are You Too Close; Keep Your Distance'	9
Figure 1-7 Summary of Data Suitability for Loop and VMS Locations	10
Figure 2-1 Average Speed per Minute per Lane	11
Figure 2-2 Average Time Headway per Minute per Lane	12
Figure 2-3 Average Flow per Minute per Lane	12
Figure 2-4 Average Vehicle Length per Minute per Lane	13
Figure 3-1 Modelled Close and Aggressive Following Rate at 100 kph at Two Sites	14
Figure 3-2 Proportion of Vehicles Close Following in Relation to Speed	14
Figure 3-3 Modelled Percentage of Close Following in December With Message Off and On	16
Figure 3-4 Modelled Percentage of Close Following in January With Message Off and On	17
Figure 3-5 Modelled Distribution of Headways, CYSIT December Data	20
Figure 4-1 Modelled Speed-Flow Curve for the CYSIT December Test Site	24
Figure 4-2 Predicted headway for average vehicle length 4.0 metres, CYSIT December data	25
Figure 4-3 Stylised representation of a message's effect on headways and close following rate	27

# Executive summary

The purpose of this study is to investigate the impact on driver behaviour of three legends that have been proposed as potential alternatives to the Highways Agency's current standard 'Keep Your Distance' message.

The standard 'Keep Your Distance' legend is displayed usually as part of a targeted campaign on VMS in various parts of the country. Three alternative legends were tested as well as 'Keep Your Distance':

- 'Could You Stop in Time'
- 'Tailgating Kills'
- 'Are You Too Close; Keep Your Distance'

Three locations were selected; one for each of three alternative messages to be tested. At each location, the message was displayed on two consecutive Variable Message Signs (VMS). IVR data was collected from three MIDAS loops sites; the loop upstream of the first VMS; the loop site immediately downstream and the loop site next downstream. Data was collected for two days for each legend and the legends were switched 'on' and 'off' for periods of 1 or 1.5 hours during each day, between 06:00 and 22:00.

This study has used an analysis method based on 'Individual Vehicle Records' (IVR) which are more suitable than minutely averages for understanding the behaviour of individual drivers. Two types of analysis were performed. Firstly, the headways were grouped into four categories (not following, normal following, close following and aggressive following) and multivariate linear regression was used to identify whether the messages had a statistically significant impact on the amount of close and aggressive following. Secondly, the impact of the message on the overall headway distribution was assessed by again creating a multivariate linear regression model but on individual vehicle headway data rather than following categories.

The key findings relating to the impact of the alternative legends on driver following behaviour are:

- The best results were obtained for Could You Stop In Time and Tailgating Kills, for which approximately 100 drivers per hour in peaks stop close following with headways less than 1.2s;
- The legend Are You Too Close, Keep Your Distance appears less effective;
- The current standard message, Keep your distance does seem to have a statistically significant impact, albeit half as effective as the two most effective;
- None of the messages has a very great impact on close following, with the maximum improvement being 7%;
- The amount of close following is lower at lower flows / higher speeds, and the impact of the message is also lower;
- The impact appears to last for up to 1.3km downstream of the last VMS;
- The impact of messages on aggressive following with headways less than 0.5s is proportionately higher but due to the far lower occurrence (less than 1% of vehicles) it is limited.

It should be remembered that these findings are based on a relatively small study and other factors may have impacted the results although the results themselves are statistically significant. The comparisons between effectiveness of the messages should be investigated further before drawing final conclusions.

The following could be considered in relation to suggesting updating the guidance for the use of VMS to improve driver behaviour related to close following:

- The long message (Are You Too Close, Keep Your Distance) has least applicability and lowest impact.
- Messages should not be expected to dramatically improve driver behaviour or to improve aggressive following (largest improvement around 7%). So for example if a particular location is identified as a hotspot for aggressive following, VMS should not be recommended as the only solution.
- Two of the alternative legends (Could You Stop In Time and Tailgating Kills) appear to be up to twice as effective as the current standard Keep Your Distance.
- The messages have the highest impact at higher flows, so would be most usefully applied in peaks.
- Drivers temporarily accept lower headways near junctions so messages would be less useful.

There is potential to improve the understanding of the use of alternative legends for close following:

- Further data collection and analysis could be performed to improve robustness of findings and check for any dampening of impact over time. The variability of results between December and January is not fully explained so further data would allow further investigation.
- The use of two downstream loops showed that the impact did not appear to tail off for 1.3km downstream, so collection from loop sites further downstream (up to 10km initially) would allow us to test how far the impact lasts downstream.
- Different messages could be tested in the same location to allow a more direct comparison of their impacts.
- There is anecdotal evidence that chevrons have a greater impact on close following than VMS, possibly because they give drivers clear guidance on what is an appropriate headway. To establish if this is the case, IVR data can be used to compare the impact of chevrons with that of VMS.
- Although the impact of the messages is relatively low, with a maximum 7% reduction, close following is known to be a frequent contributory factor in accidents. The cost of setting VMS is relatively low, so it would be of potential value to perform an economic appraisal based on assumptions on the number of accidents that might be mitigated by the use of the alternative legends.

# 1. Introduction

## 1.1. Background and Purpose of Study

The purpose of this study is to investigate the impact on driver behaviour of three legends that have been proposed as potential alternatives to the Highways Agency's current standard 'Keep Your Distance' message. Two key objectives were defined at the start of the project:

- Objective 1: Provide evidence of any change in close following driver behaviour as a result of alternative legends to 'Keep your distance'.  
This required traffic data to be collected and analysed to identify whether any of the alternative legends do successfully influence the behaviour of drivers, specifically whether there is a sustained and significant increase in headways.
- Objective 2: Develop guidance, based on statistical analysis, for the use of VMS to achieve a sustained reduction in close following.  
There were two main possibilities for this objective. If it was found that actually none of the alternative legends had any significant impact on driver behaviour, the outcome might be to propose to change to the guidance, or suggest a need to investigate other more effective options for reducing close-following behaviour. Alternatively if one or more of the legends is found to be more effective than the current standard legend, the outcome would be to propose updates to the guidance on the circumstances in which VMS should be used, including locations, time periods, use of campaigns, etc.

The standard 'Keep Your Distance' legend is displayed usually as part of a targeted campaign on VMS in various parts of the country. A study performed in 2011 analysed a full year of minutely averaged distance-headway data from 41 VMS sites but did not identify any change in behaviour as a result of the 'Keep Your Distance' legend. This could be either because there was no change (the VMS does not influence drivers) or because the assessment method used was unable to detect any change. Interestingly, the study identified a conflict between drivers stating that the 'Keep your distance' was a helpful reminder to increase headways, and the data analysis results showing that no increase was detected.

This study has used a different method based on 'Individual Vehicle Records' (IVR) which are more suitable than minutely averages for understanding the behaviour of individual drivers.

### 1.1.1. Overview of Driver Following Behaviour

The recommended headway between vehicles is a period of two seconds. Two seconds is not the period of time it would take for the vehicle to come to a complete stop, which at 70mph would be in the region of 7seconds. It is the time in which most drivers should be able to react and adjust their relative speed to avoid a collision with the vehicle in front in most circumstances, including incidents where sudden hard braking may occur.

Research suggests that the average driver prefers a 1.2 second headway, making their own judgement of risk relating to achieving a perceived benefit in progress, making the driver of the vehicle in front aware that they are waiting to pass and preventing most other drivers from entering the gap between them and the vehicle in front.

Some drivers choose much shorter headways than 1.2 seconds, this could be because they:

- have just changed lanes into a small gap;
- are aggressively trying to force another vehicle to move faster or prevent another vehicle changing lane;
- may not be concentrating or aware that the speed they are travelling in proximity to the vehicle in front presents a greater risk of collision.

It is recognised that headways of 0.5 seconds or less, are undesirably dangerous; at 70mph this is a following distance of 15 metres. Close following at less than half a second, also known as 'tailgating,' poses more danger than is acceptable and is a cause of irritation to other drivers.

At the other extreme, a headway greater than two seconds cannot be considered as vehicle following, with headways of greater than two seconds it is likely that the following vehicle’s driver has chosen his speed and his progress is not being hindered by the vehicle in front.

There is no fixed definition of what is considered excessively close and there is no legal definition of tailgating. However close following is considered to be a problem; with Police having recently been given new powers to issue fixed penalty notices for careless driving.

## 1.2. Overview of Methodology

IVR data was used for this study, which contains the following information for each vehicle which passes a MIDAS loop detector pair: timestamp; speed; vehicle length; time headway. (The time headway for each vehicle is the time since the front of the preceding vehicle passed the loop.) This information is averaged each minute to provide Traffic Count Data (TCD) which is made available for all HA MIDAS sites via the MIDAS data website. In contrast, IVR data must be collected from the MIDAS outstation at the roadside.

Three locations were selected; one for each of three alternative messages to be tested. At each location, the message was displayed on two consecutive Variable Message Signs (VMS). IVR data was collected from three MIDAS loops sites; the loop upstream of the first VMS; the loop site immediately downstream and the loop site next downstream. The alternative legends being tested, with their location information, are described in Section 1.3.

Data was collected for two days for each legend and the legends were switched ‘on’ and ‘off’ for periods of 1 or 1.5 hours during each day, between 06:00 and 22:00. This allowed comparison of headways with the legends on and off, for a variety of traffic conditions. The ‘on’ and ‘off’ periods were switched between the two days as shown in Figure 1-1. The effect of the legends was tested in two periods (Days 1 & 2 in December and Days 3 & 4 in January) to determine whether the effect was similar.

**Figure 1-1 Timetable for Displaying Legends for Two Days Each in Two Periods**

	Day 1	Day 2	Interim Days	Day 3	Day 4
06:00 - 08:00	Off	On	Display Message when possible	Off	On
08:00 - 09:30	On	Off		On	Off
09:30 - 11:00	Off	On		Off	On
11:00 - 12:30	On	Off		On	Off
12:30 - 14:00	Off	On		Off	On
14:00 - 15:30	On	Off		On	Off
15:30 - 17:00	Off	On		Off	On
17:00 - 18:30	On	Off		On	Off
18:30 - 20:00	Off	On		Off	On
20:00 - 22:00	On	Off		On	Off

Analysis was also performed for the current standard legend (Keep Your Distance) which was displayed according to the standard HA timetable, i.e. continuously between 06:00 and 22:00 on one day in December.

Two different types of analysis were performed, as described below.

### 1.2.1. Impact of Message on Driver Following Categories

The individual vehicle headways were grouped into four categories:

- aggressive following, headway less than 0.5 seconds;
- close following, headway between 0.5 and 1.2 seconds;
- normal following, headway between 1.2 and 2 seconds;
- not following, headway over 2 seconds.

The percentage of vehicles was calculated in each category and for each minute. The percentages of vehicles classed as 'aggressive' and 'close' following were compared between times with 'Message On' and 'Message Off', in relation to speed.

Multivariate linear regression was conducted for each trial and used to identify whether the coefficient (attached weighting) on the On / Off variable was significantly different from zero. This involved estimating best fit lines and determining if the lines were statistically different from each other. If so, we can be confident that the message has an effect on headway.

As a point of note, statistical significance does not refer to the magnitude of the effect. Instead, statistical significance is a measure of the degree of confidence that one has (in this case, the degree of confidence that the message has an actual effect, however small). As is standard practice, we used a 95% confidence level as a threshold to determine if an effect was present. This means that if the message had no effect, we should only be observing effects larger than our threshold acceptance value less than 5% of the time.

Our analysis allowed for an understanding of the proportion of drivers reclassified from close following to acceptable following, and from aggressive following to close following, as a result of behavioural responses to the messages.

### 1.2.2. Impact of Message on Overall Headway Distributions

The impact of the message on the overall headway distribution was assessed by again creating a multivariate linear regression model but on individual vehicle headway data in relation to individual vehicle speed and length. The effect of the message was then assessed for statistical significance.

This analysis allowed for an understanding of the impact of the message on the size of headways rather than on headway categories.

## 1.3. Legends and Locations

The three alternative legends are shown in Figure 1-2. The VMS available for the messages are predominantly 2x16. It should be noted that other VMS, such as 3x18, are available but there are far fewer of them and they tend to be within 1km of junctions, which makes them unsuitable for this analysis because drivers are willing to temporarily accept shorter headways near junctions, skewing the results. These VMS are strategic and are more likely to be required for higher priority messages.

The first and last messages will fit on a 2x16 VMS, however the second message will not; this message requires a 3x18 signal. This means there are far fewer potential locations which could be used for this legend, as shown in Figure 1-2.

**Figure 1-2 Alternative Legends and Number of Potential VMS Locations**

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total Number of Potential Sites by Lines and Characters				
Alternative Legends																		Totals	2 by 12	2 by 16	3 by 18	Total
C	O	U	L	D		Y	O	U										9	1643	818	449	2910
S	T	O	P		I	N		T	I	M	E							12				
T	A	I	L	G	A	T	I	N	G									10	1643	818	449	2910
K	I	L	L	S														5				
A	R	E		Y	O	U		T	O	O	C	L	O	S	E			17			449	449
K	E	E	P		Y	O	U	R		D	I	S	T	A	N	C	E	18				

Three locations were selected based on:

- gaining agreement from internal HA stakeholders;
- having good, continuous MIDAS coverage;
- having all of the sites in the East Midlands area for ease of implementation of the solution for data collection;
- being not within a Smart Motorways section;
- having the ability to display on two consecutive VMS that are not close to (within 1km of) an on-slip, off-slip, lane gain or lane drop.

The following locations have therefore been identified as suitable for displaying the required messages:

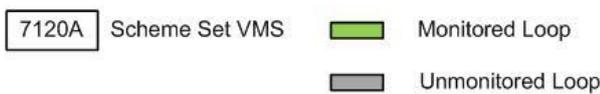
- M1 NB J16 to J17 (avoiding the services)
- M1 SB J17 to J16 (avoiding the services)
- M1 NB J24a to J25 (the only location where 3x18 signals are available)

It should be noted that although two of the locations are on the same motorway in the same direction, they are approximately 45 miles apart and have a number of other major routes and destinations between them, meaning that the proportion of the sample size likely to witness both messages will be small.

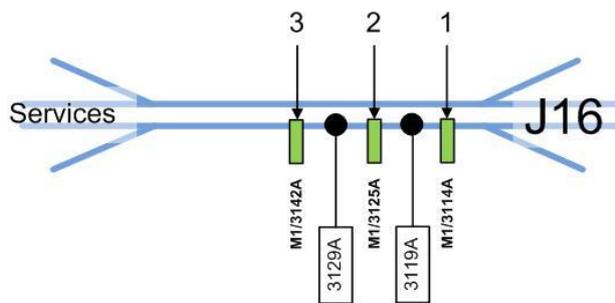
The locations of the VMS and MIDAS loops for each of the three alternative legends are shown in Figure 1-4, Figure 1-5 and Figure 1-6. The VMS locations are shown by a black dot linked to a rectangle containing the geographic of the VMS. Loop locations are shown by rectangles and labelled 1, 2, 3 for the upstream, immediately downstream and further downstream loop sites respectively. (See key in Figure 1-3.)

**Figure 1-3 Key for VMS and Loop Location Diagrams**

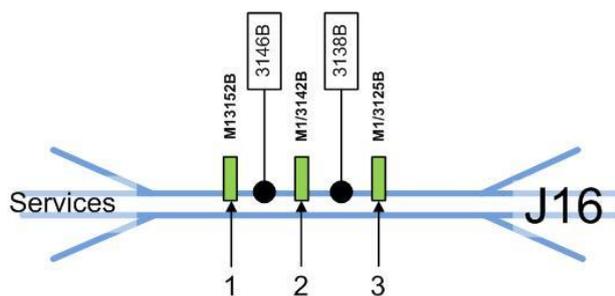
Legend:



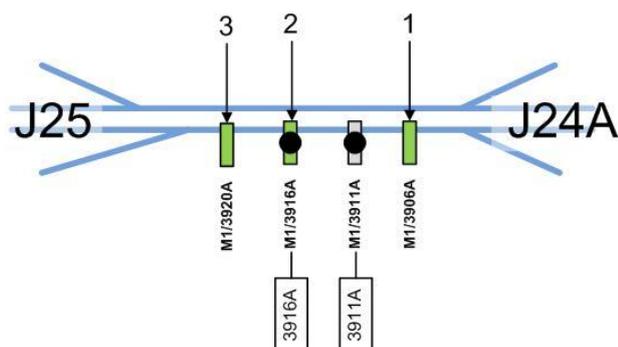
**Figure 1-4 Locations for Could You Stop in Time**



**Figure 1-5 Locations for 'Tailgating Kills'**



**Figure 1-6 Locations for 'Are You Too Close; Keep Your Distance'**



The third location was also used for the standard 'Keep Your Distance' legend. The distances between the VMS and loop site locations are summarised in Table 1-1.

**Table 1-1 Distances between VMS and Loop Sites**

Distance for:	CYSIT	TK	AYCT; KYD & standard KYD
First VMS to Loop 2	600m	400m	500m (Loop 2 adjacent to 2 <sup>nd</sup> VMS)
First VMS to Second VMS	1000m	800m	500m
Second VMS to Loop 3	1300m	1300m	400m

## 1.4. Limitations of Data

In the December period (Days 1&2), faults in the MIDAS outstation meant no IVR data was collected at three loop sites. In addition, the alternative legend was overridden by Journey Time messages on one VMS. This meant that only one downstream loop could be analysed for each alternative legend in December (Loop 3 for 'Tailgating Kills' and Loop 2 for the other legends).

In the January period (Days 3&4), there were no problems with loop data availability and just a small number of occasions where alternative legends were overridden by higher priority messages due to incidents, etc. Data from periods where legends were not displayed when programmed were classed as 'message off'.

Figure 1-7 summarises the suitability of loop and VMS data for each legend.

**Figure 1-7 Summary of Data Suitability for Loop and VMS Locations**

Message	Day	Loop 1	Loop 2	Loop 3	VMS 1	VMS 2
CYSIT	1			no data		
	2			no data		
	3				missing data 1 period	missing data 1 period
	4					
TK	1	no data 12:30-22:00	no data			
	2	no data	no data			
	3				missing data 2 periods	missing data 2 periods
	4					
AYTC KYD	1				no data	no data 17:00-22:00
	2				no data	
	3				missing data 2 periods	missing data 1 period
	4				missing data 2 periods	missing data 1 period
KYD	1					

## 2. Overview of Data

### 2.1. Context

The following plots provide a contextual overview of the collated data. using data from Day 1 and Loop 2 at the M1 Northbound J17-16 location (used for Could You Stop In Time).

Figure 2-1 shows how the minutely average vehicle speed varies across a day between 06:00 and 22:00 for each of the three lanes. Lane 1 has the lowest average speed and variance, with a relatively constant speed of around 87kph or 55mph. This is a result of the high number of HGVs in this lane and the fact that HGVs are limited to 56mph. Lane 3 the highest average speed and variance, which is not surprising because it contains predominantly passenger vehicles so off-peak speeds are higher and more varied due to not being limited; also speeds will drop further during the peaks.

**Figure 2-1 Average Speed per Minute per Lane**

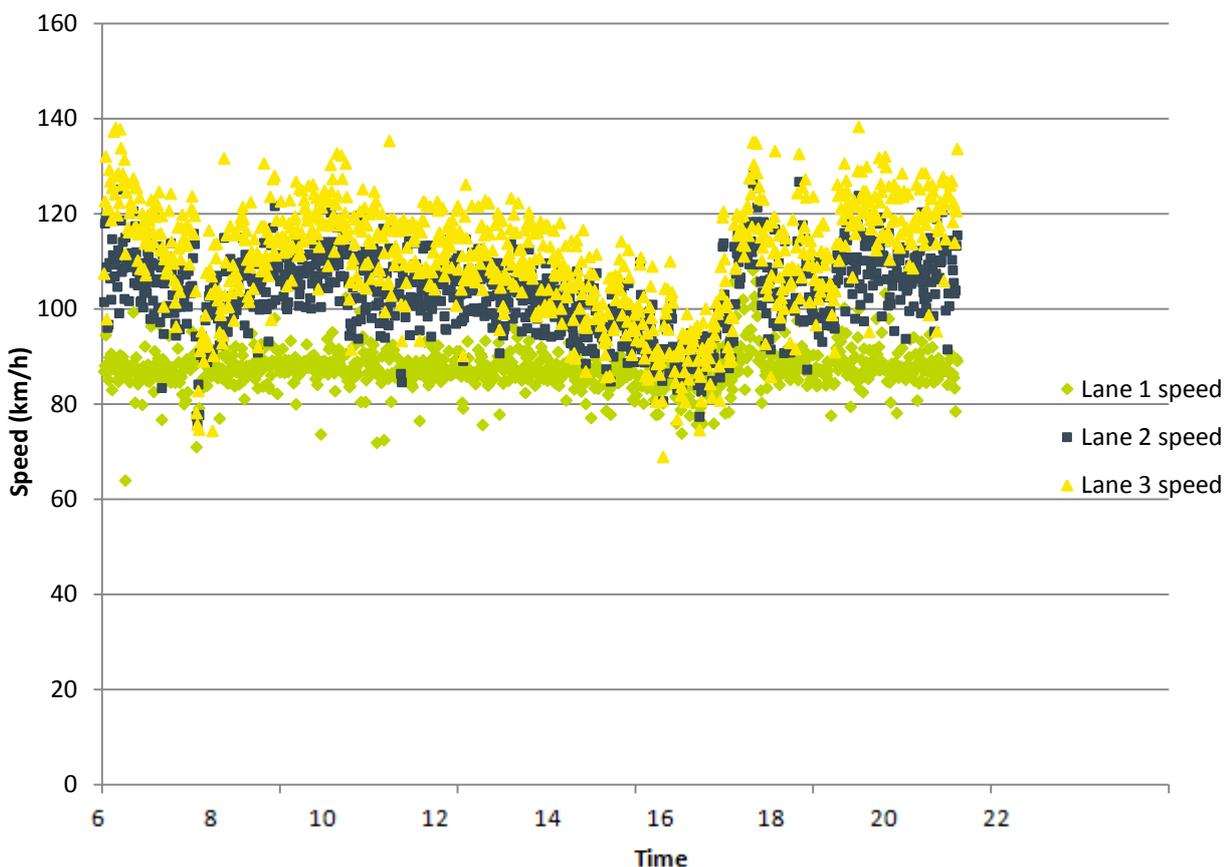


Figure 2-2 shows how the average time headway varies across a day for each of the three lanes. Lane 1 has the largest average headway, generally between 3 and 6 seconds, and Lane 3 the lowest, quite often less than 2 seconds. This is for two main reasons:

- the time headway is the time between the front of one vehicle and the next, so includes vehicle length, therefore will be longer for longer vehicles with the same actual gap;
- drivers move out of Lane 1 to overtake when they come up behind another vehicle, whereas in Lane 3 there is no possibility of overtaking so they will maintain a close following behaviour.

Figure 2-3 shows how the minutely average flow varies across a day for each of the three lanes. Lane 1 has the lowest flow and Lane 3 the highest. Headway and flow are strongly related, i.e. if flow increases then headway must decrease, so this is not surprising. Morning and afternoon peaks in flow can be seen, in particular in Lanes 2 & 3, coinciding with drops in headway.

Figure 2-2 Average Time Headway per Minute per Lane

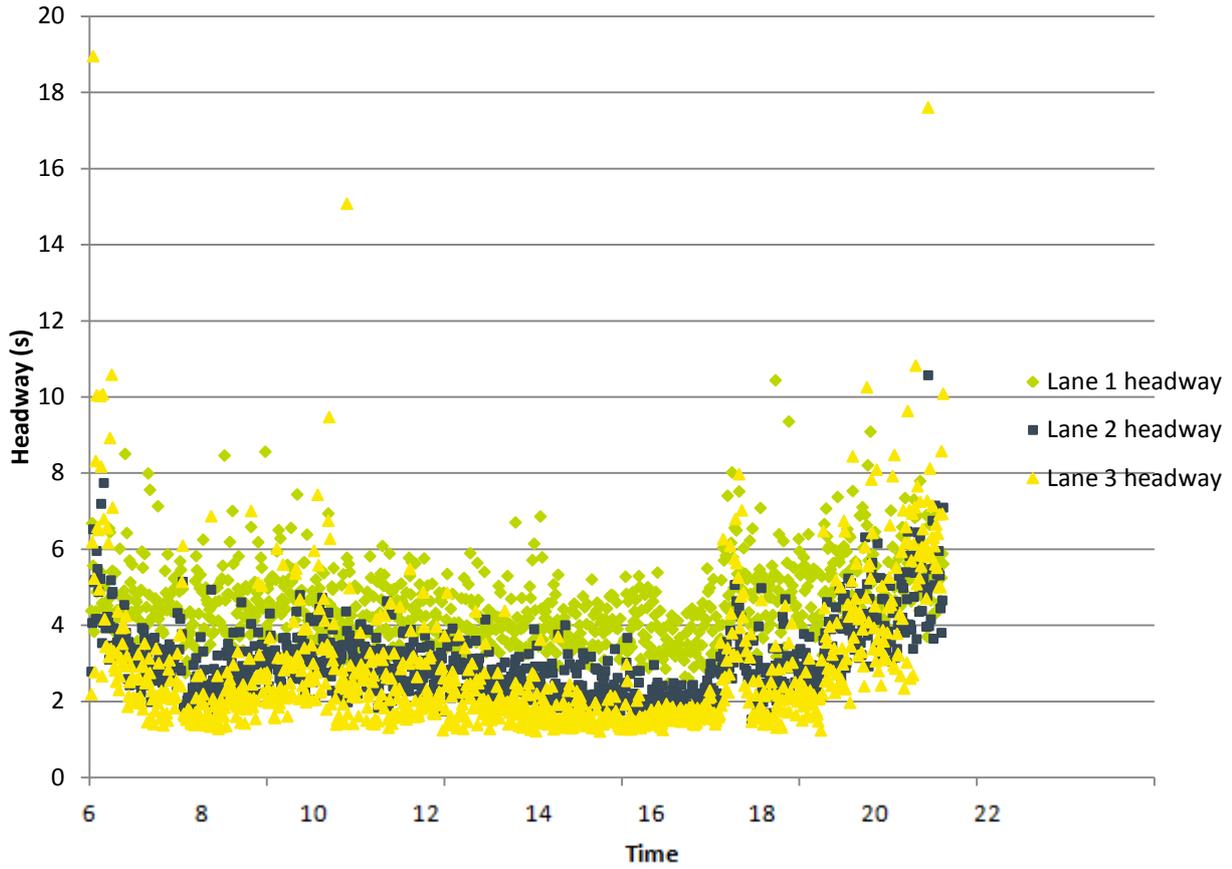


Figure 2-3 Average Flow per Minute per Lane

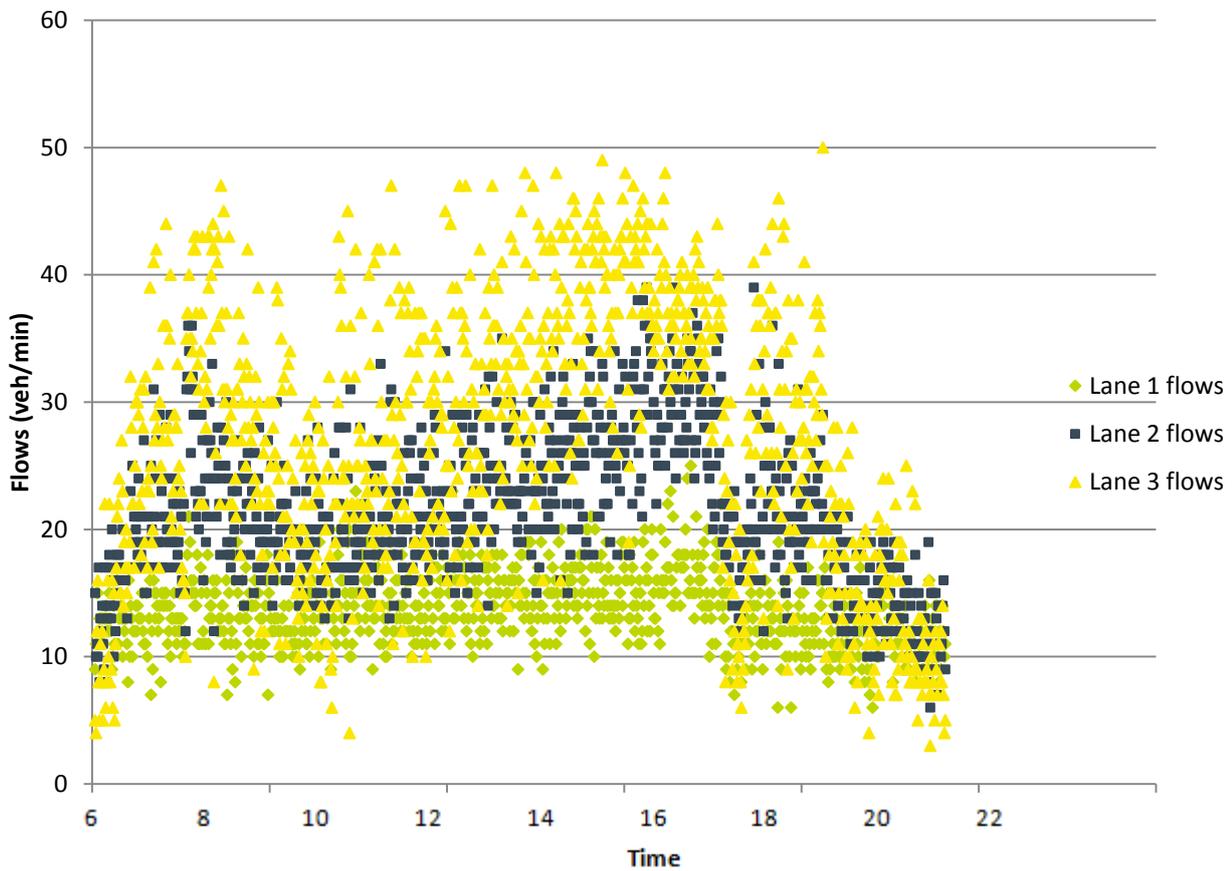
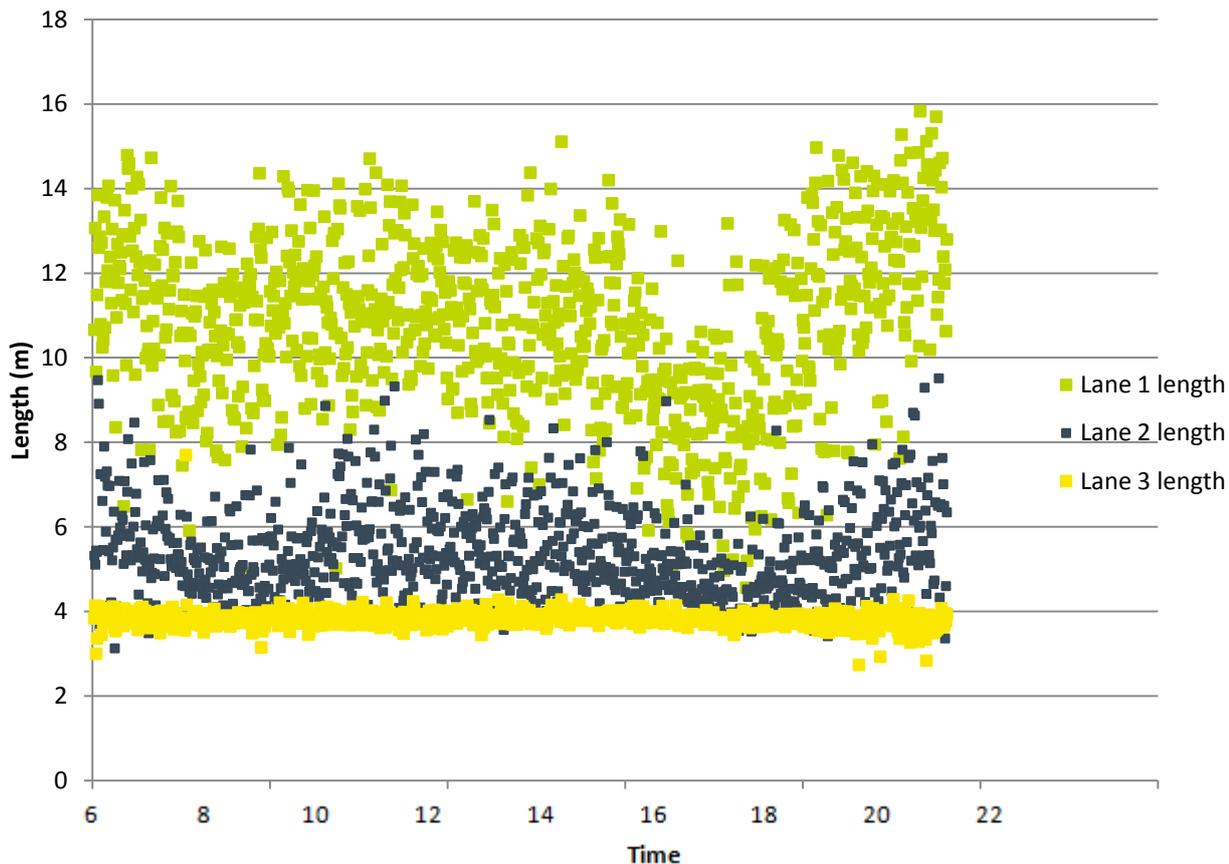


Figure 2-4 shows how the average vehicle length varies across a day for each of the three lanes. Lane 1 has the longest average length of vehicles and a large variance, because of the higher proportion of HGVs in this lane. Average lengths in Lane 2 range from 4 to 8m because most vehicles in this lane are cars or vans. Lane 3 is almost exclusively used by passenger cars has the smallest average length of vehicles (around 4m) and a very small variance.

Interestingly, the average vehicle length in Lane 1, and to a lesser degree Lane 2, drops in the peaks. This is presumably because the number of cars travelling in these lanes during peak periods applies downward pressure on the average figures. There is also a possibility that larger vehicles such as HGVs avoid travelling during these times.

**Figure 2-4 Average Vehicle Length per Minute per Lane**



# 3. Headline Results of Analysis

## 3.1. Impact of Message on Following Category Rates

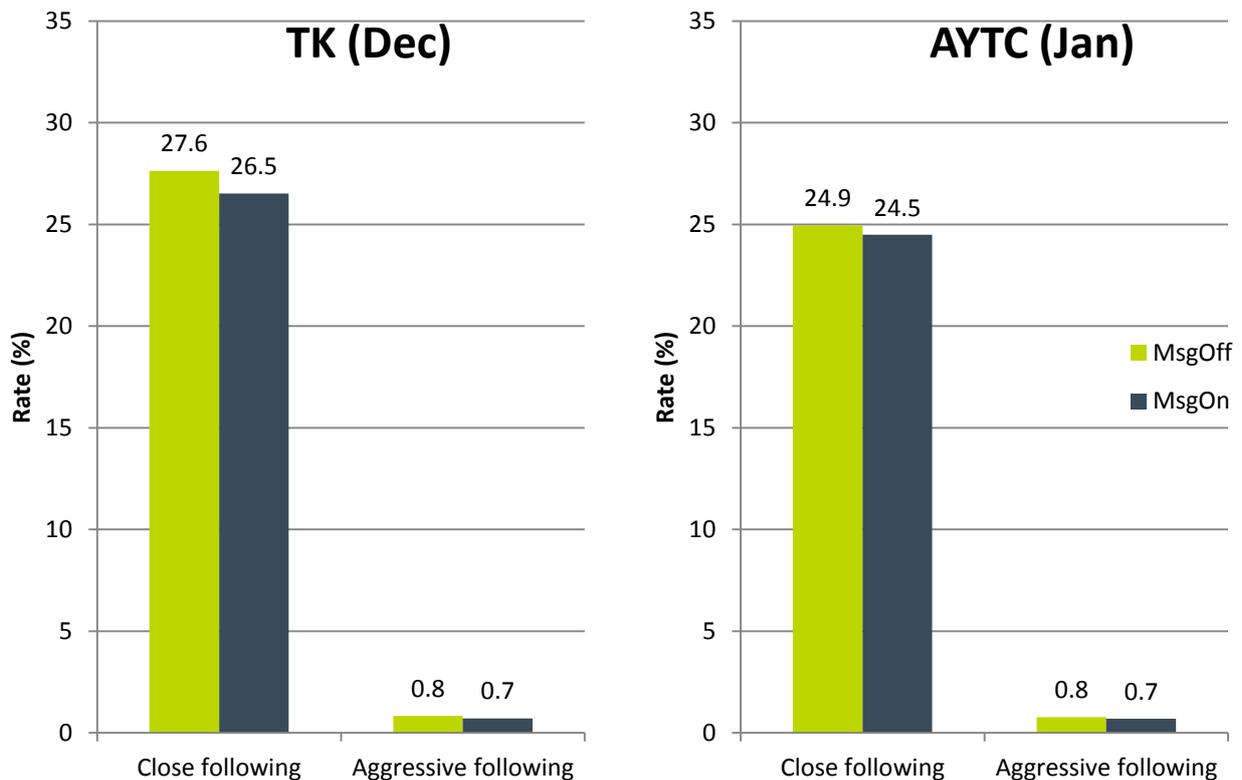
### 3.1.1. General Findings

The proportion of vehicles in the 'close' and 'aggressive' following categories was compared between the Message On and Off scenarios. This section contains some general findings, while more detailed results are described in:

- Section 3.1.2 - Results from December, Close Following;
- Section 3.1.3 - Results from January, Close Following;
- Section 3.1.4 - Results from December & January, Aggressive Following.

A relatively large proportion of vehicles (20-30%) were shown to be close following with headways of less than 1.2 seconds. In contrast, less than 1% of vehicles were found to be aggressively following with headways of less than 0.5 seconds. This is shown in Figure 3-1 using the two tests for which the difference in aggressive following between Message On and Off was statistically significant.

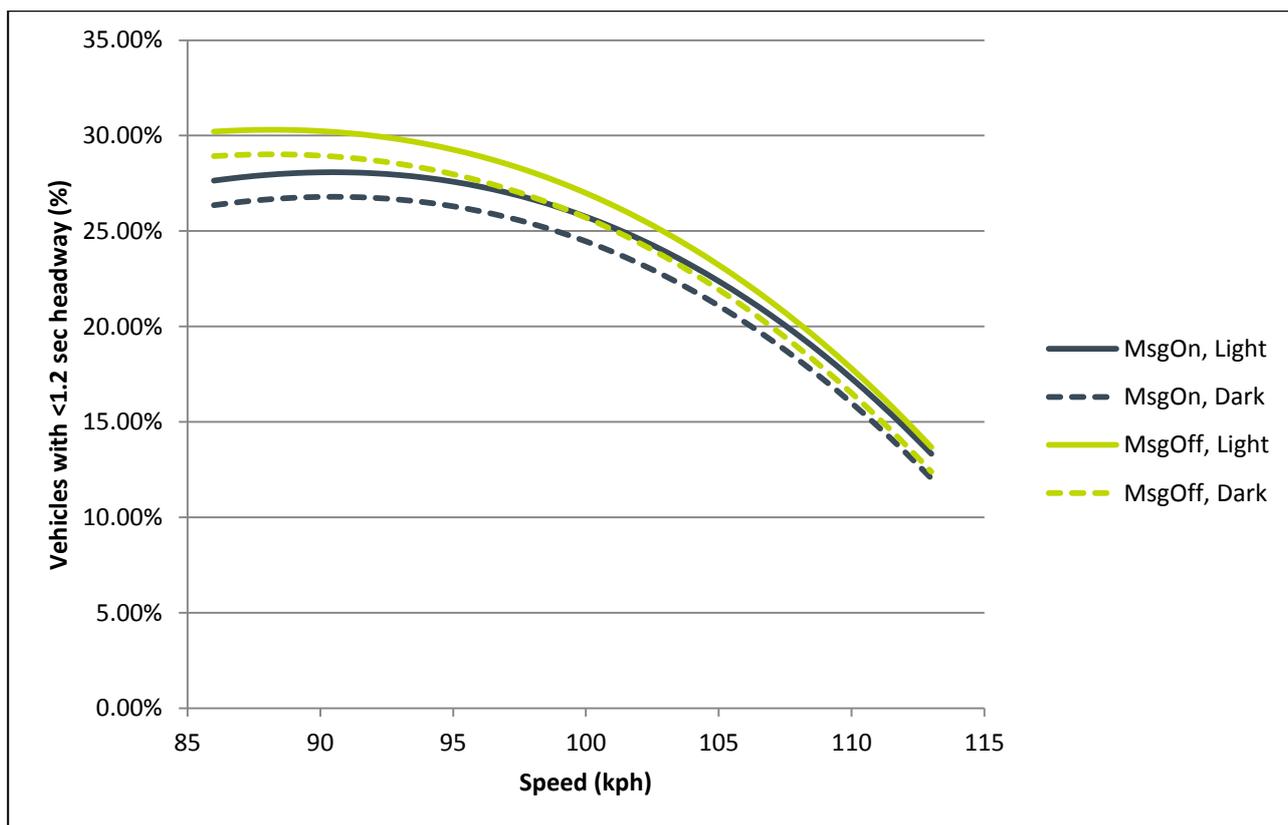
**Figure 3-1 Modelled Close and Aggressive Following Rate at 100 kph at Two Sites**



Controlling for other factors, there is more close and aggressive following at lower speeds, and also in daylight, as seen in Figure 3-2.

The relationship with speed is explained that high speeds are related to low flows, where there are less vehicles to follow so less opportunity for close following. As could be expected, close following rates were higher in daylight likely due to higher visibility. However, the effect of the messages on reducing close following rates was found to be the same in both light and dark, whilst controlling for other factors (e.g. speed and flow).

**Figure 3-2 Proportion of Vehicles Close Following in Relation to Speed, CYSIT December Data**



Controlling for other factors, the effect of the messages on close following was found to decrease with speeds (increase with flows). This can be explained by the proportion of passive, as opposed to aggressive, drivers who are close following at various flows and speeds. This is because passive drivers are the ones on whom the messages are likely to have the largest effect.

When flows are high during peak hours for example, these otherwise passive drivers are persuaded to tailgate in larger numbers. The effect of the messages on this group is thus magnified at higher flows as the group of close followers is composed largely of passive drivers who respond to the messages.

When speeds are high however, the group of close followers is composed largely of aggressive drivers who are less likely to respond to the messages. The effect of the messages on this group is hence dampened at higher speeds.

Appendix A contains more information on the relationship between message impact, speed and flow.

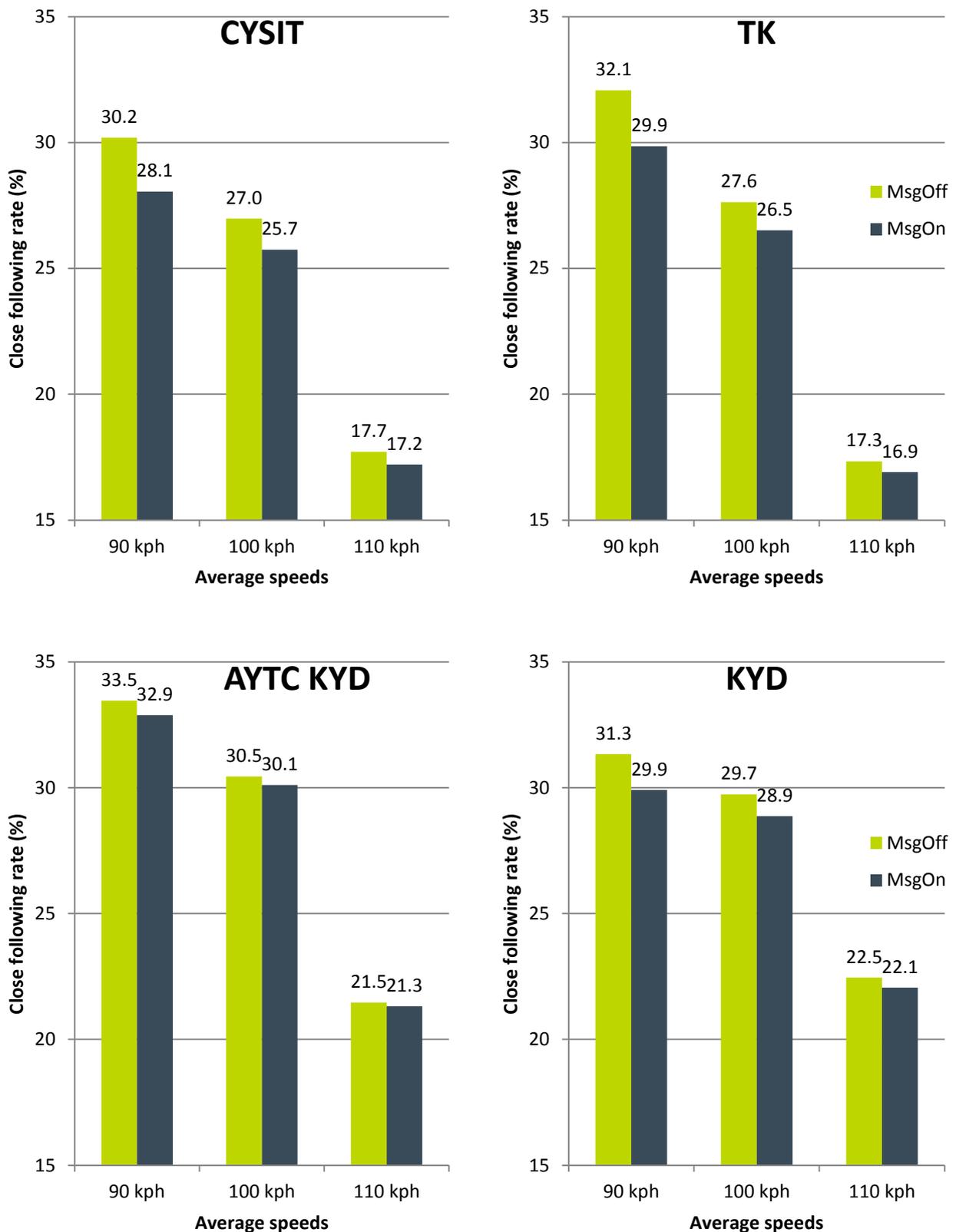
### 3.1.2. December Close Following Rates

Figure 3-3 shows the modelled close following rate with Message On and Off at each of the four different sites from the December data. The effects of the messages on the close following rate are not comparable across the different sites as each site has their own unique characteristics which may affect driver behaviour.

With the exception of the AYTC site where the effect of the message was statistically significant only at the 90% level, at all other sites the effect of the message was statistically significant at the 95% level.

It can be seen that at all sites, the rate of close following was lower with the Message On, meaning that the messages did have an impact on driver behaviour. The impact is lower at higher speeds, as explained above.

**Figure 3-3 Modelled Percentage of Close Following in December With Message Off and On**



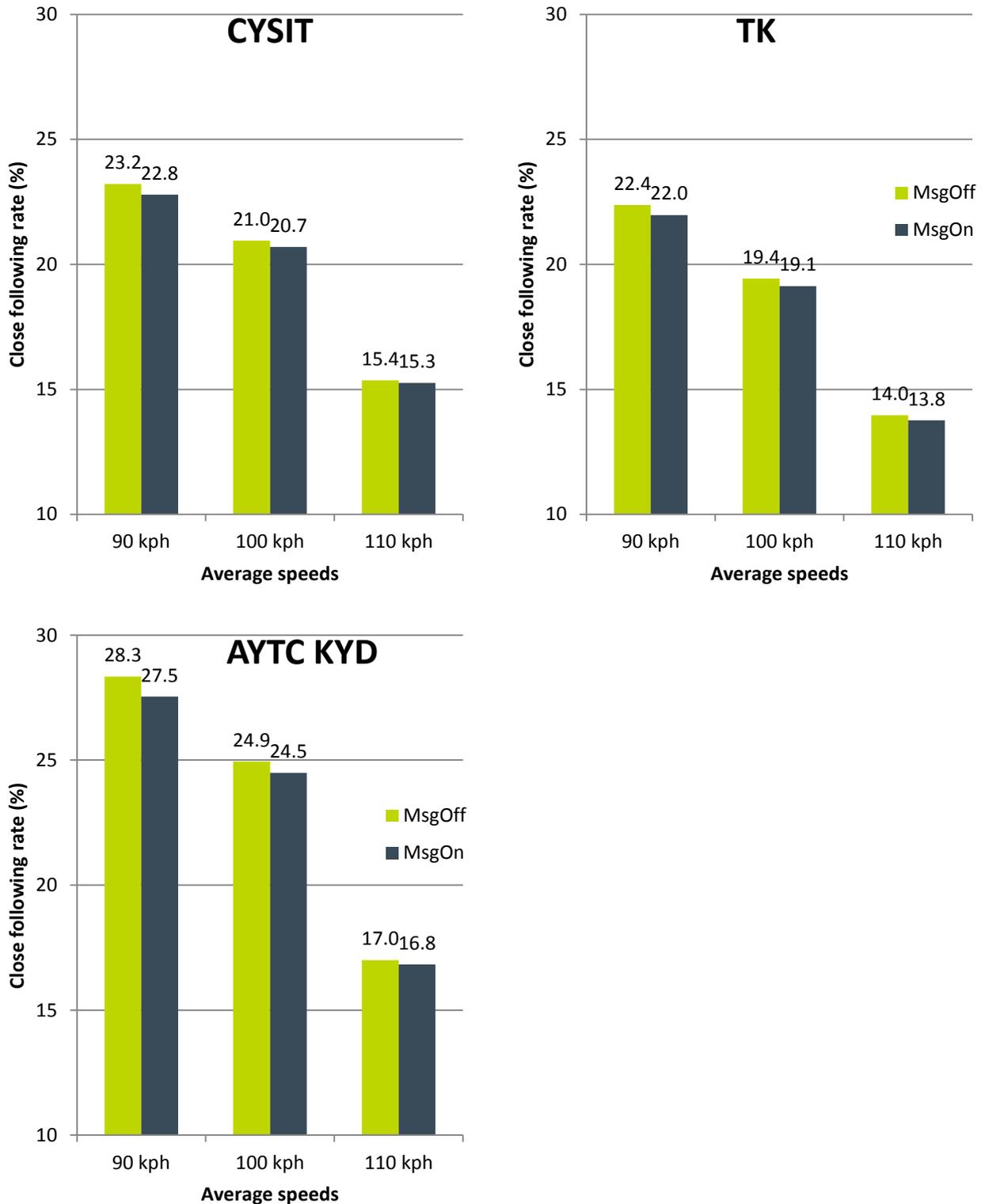
### 3.1.3. January Close Following Rates

Figure 3-4 shows the modelled close following rate with and without displaying messages at each of the four different sites using the January data. As with the December data and for the same reasons, the effects of the messages on the close following rate are not comparable across sites. Moreover, the effects are also not

comparable with that found using the December data as there may be a difference in underlying driver behaviour between the two months. The difference in the underlying (message off) close following rate between the two months seems to suggest that this is the case. The overall flows and speeds were lower in January and as explained previously, at lower flows there is less close-following; this might be due to poor weather (fog and snow were recorded in January on the two test dates).

At all sites the effect of the message was statistically significant at the 95% level.

**Figure 3-4 Modelled Percentage of Close Following in January With Message Off and On**



### 3.1.4. Aggressive Following Rates

The effect of the messages on the aggressive following rate is, though smaller in absolute terms, proportionately larger than that on the close following rate. This suggests that the message works broadly as intended, increasing the headway particularly where the headway is short, and having less of an effect where headway is longer.

The effect of messages on the aggressive following rate was statistically significant at the 95% confidence level in only two of seven test sites, and at the 90% confidence level in one of seven test sites. This is likely a result of the baseline rate of aggressive following being already low, hence reducing the measured effects of the messages.

It is statistically difficult to differentiate an effect close to zero from being non-zero. Corroborating the results of the close following tests against the few statistically significant results of the aggressive following tests lead us to conclude that the messages did cause a small reduction in aggressive following in all sites – albeit detected only in a handful thereof.

### 3.1.5. Summary of Results

The tables in this section summarise the results for close and aggressive following rates in December and January for each legend.

Out of every 10,000 vehicles, the number of vehicles that close follow is shown in the Message Off and On columns, as well as the difference and percentage difference. This information is provided for three speeds: 90, 100 and 110kph.

So for example, based on December results and assuming a peak flow of 5,000 vehicles per hour, the legend Could You Stop In Time would result in 107 fewer vehicles close following per hour at 90kph. A similar result was obtained for Tailgating Kills but a lower result for the current standard Keep Your Distance. The benefit for Are You Too Close, Keep Your Distance was much lower and only statistically significant at the 90% level. However these results were not replicated in January.

**Table 3-1 Impact of Message on Close Following in December**

Legend	Number of vehicles out of every 10,000 that close follow in each scenario:								
	At 90 kph			At 100 kph			At 110 kph		
	Off	On	Difference	Off	On	Difference	Off	On	Difference
CYSIT	3,019	2,805	214 (7.1%)	2,693	2,570	123 (4.5%)	1,772	1,721	51 (2.9%)
TK	3,207	2,985	222 (6.9%)	2,763	2,651	112 (4.1%)	1,734	1,691	43 (2.5%)
AYTC*	3,346	3,288	58 (1.7%)	3,045	3,011	34 (1.1%)	2,147	2,132	15 (0.7%)
KYD	3,133	2,991	142 (4.6%)	2,974	2,887	87 (2.9%)	2,246	2,206	40 (1.8%)

\* Results not statistically significant

**Table 3-2 Impact of Message on Close Following in January**

Legend	Number of vehicles out of every 10,000 that close follow in each scenario:								
	At 90 kph			At 100 kph			At 110 kph		
	Off	On	Difference	Off	On	Difference	Off	On	Difference
CYSIT	2,834	2,754	80 (2.8%)	2,494	2,449	45 (1.8%)	1,700	1,682	18 (1.1%)
TK	2,237	2,197	40 (1.8%)	1,943	1,913	30 (1.6%)	1,396	1,376	20 (1.4%)
AYTC	2,834	2,754	80 (2.8%)	2,494	2,449	45 (1.8%)	1,700	1,682	18 (1.1%)

**Table 3-3 Impact of Message on Aggressive Following in December**

Legend	Number of vehicles out of every 10,000 that close follow in each scenario:								
	At 90 kph			At 100 kph			At 110 kph		
	Off	On	Difference	Off	On	Difference	Off	On	Difference
CYSIT*	74	72	2 (3.5%)	86	84	2 (1.7%)	74	74	0 (0.8%)
TK	55	30	15 (45.0%)	83	71	12 (15.1%)	83	78	5 (5.8%)
AYTC*	91	91	0 (0%)	80	80	0 (0%)	82	82	0 (0%)
KYD*	81	68	13 (16.0%)	121	113	8 (6.6%)	121	117	4 (3.1%)

\* Results not statistically significant

**Table 3-4 Impact of Message on Aggressive Following in January**

Legend	Number of vehicles out of every 10,000 that close follow in each scenario:								
	At 90 kph			At 100 kph			At 110 kph		
	Off	On	Difference	Off	On	Difference	Off	On	Difference
CYSIT*	45	45	0 (0%)	57	57	0 (0%)	66	66	0 (0%)
TK*	47	47	0 (0%)	58	58	0 (0%)	70	70	0 (0%)
AYTC	61	47	14 (22.8%)	78	70	8 (10.0%)	80	77	3 (3.9%)

\* Results not statistically significant

The impact of the message on aggressive following is only statistically significant in two of the seven scenarios but is proportionately higher than on close following, as discussed.

In December, the data availability limitations described in Section 1.4 meant that only one loop could be analysed for each location. In January both downstream loops were analysed but there was no statistically significant difference between the impact of the message at the two loop sites, for any of the legends. This suggests that the impact of the message lasts for at least 1300m.

### 3.2. Impact of Message on Overall Headway Distribution

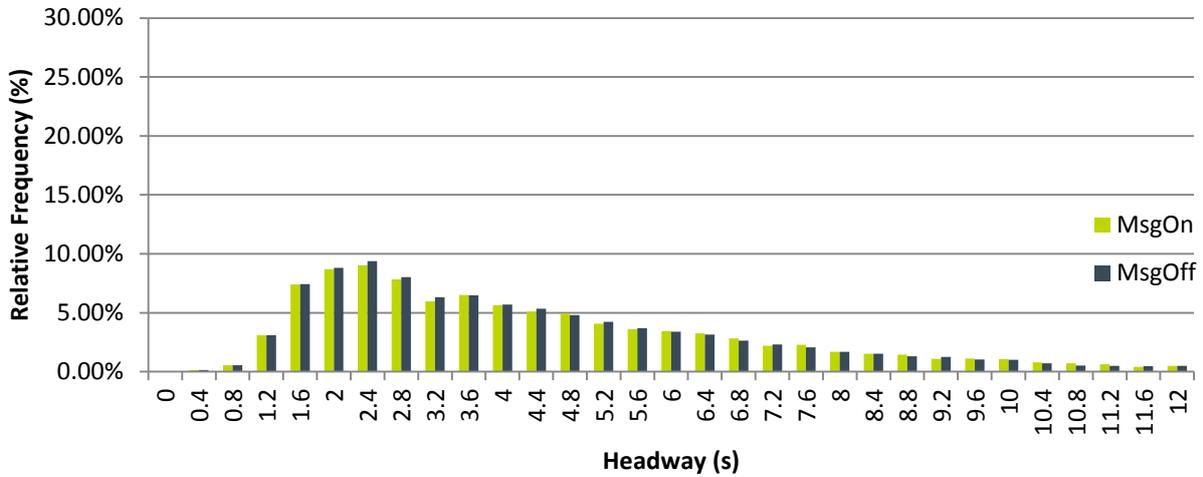
Analysis was undertaken on the raw non-aggregated December data from the CYSIT test site. The lane choice, speed and length of individual vehicles were used to model the expected headway for that vehicle. An examination of the effect of the message on headway was also conducted.

By applying our statistical model to the observed distribution of headways, we were able to understand how the distribution of headway of all vehicles in the day would have differed between the Message On and Off scenarios. This is shown in Figure 3-5.

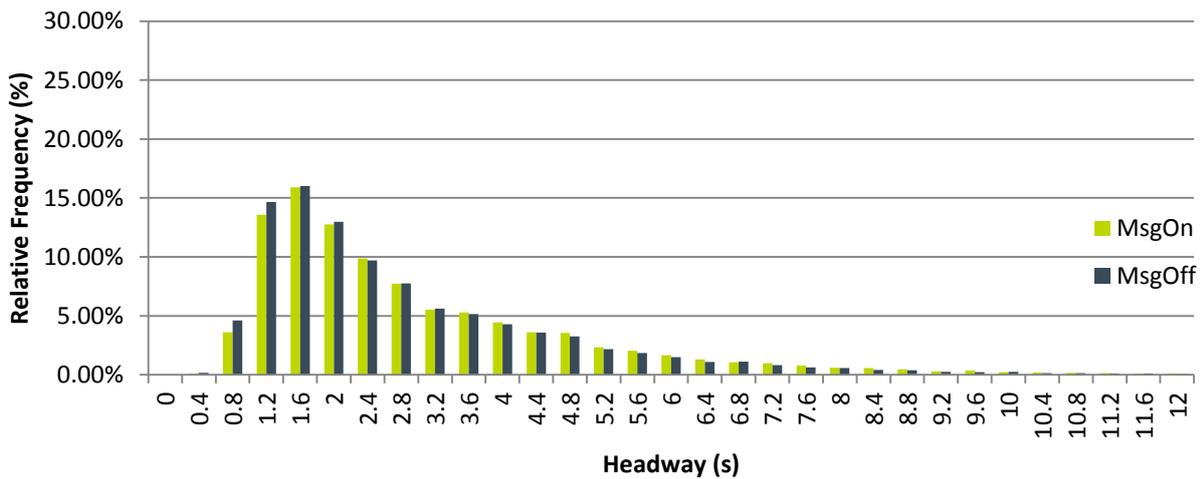
This demonstrates that as well as reducing the number of vehicles in the close following category, the message also increases the headways of vehicles inside the close following category. There are fewer vehicles with headways of 0.8 seconds with the message on. The impact is more marked in Lanes 2 & 3.

Figure 3-5 Modelled Distribution of Headways, CYSIT December Data

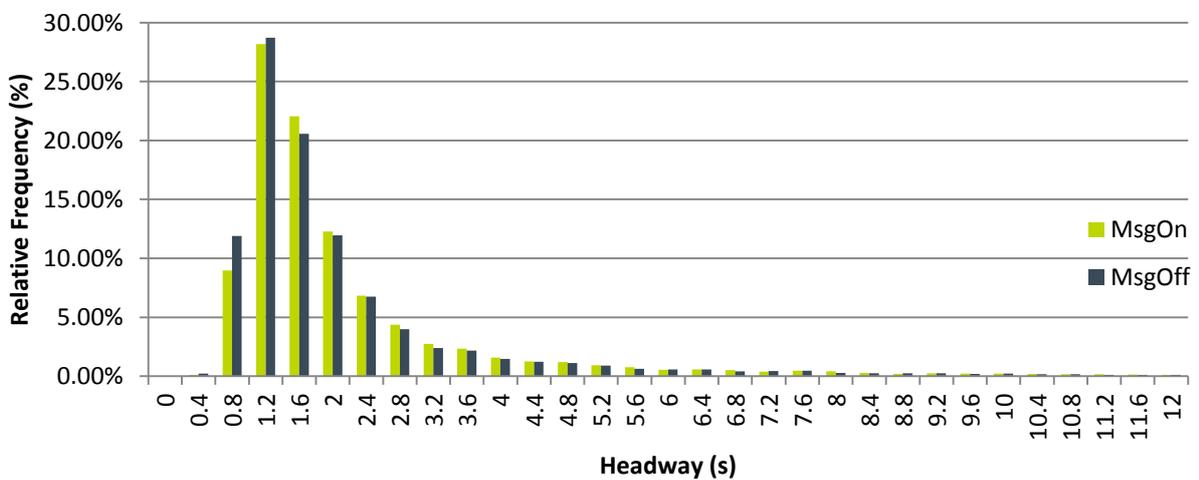
### Distribution of Headway (Lane 1)



### Distribution of Headway (Lane 2)



### Distribution of Headway (Lane 3)



## 4. Conclusions

### 4.1. Impact of Alternative Legends on Driver Behaviour

The key findings relating to the impact of the alternative legends on driver following behaviour are:

- The best results were obtained for Could You Stop In Time and Tailgating Kills, for which approximately 100 drivers per hour in peaks stop close following with headways less than 1.2s;
- The legend Are You Too Close, Keep Your Distance appears less effective;
- The current standard message, Keep your distance does seem to have a statistically significant impact, albeit half as effective as the two most effective;
- None of the messages has a very great impact on close following, with the maximum improvement being 7%;
- The amount of close following is lower at lower flows / higher speeds, and the impact of the message is also lower;
- The impact appears to last for over 1.3km downstream of the last VMS;
- The impact of messages on aggressive following with headways less than 0.5s is proportionately higher but due to the far lower occurrence (less than 1% of vehicles) it is limited.

### 4.2. Considerations for Guidance

The following could be considered in relation to suggesting updating the guidance for the use of VMS to improve driver behaviour related to close following:

- The long message (Are You Too Close, Keep Your Distance) has least applicability and lowest impact.
- Messages should not be expected to dramatically improve driver behaviour or to improve aggressive following (largest improvement around 7%). So for example if a particular location is identified as a black spot for aggressive following, VMS should not be recommended as the only solution.
- Two of the alternative legends (Could You Stop In Time and Tailgating Kills) appear to be up to twice as effective as the current standard Keep Your Distance.
- The messages have the highest impact at higher flows, so would be most usefully applied in peaks.
- Drivers temporarily accept lower headways near junctions so messages would be less useful.

### 4.3. Potential for Future Analysis

There is potential to improve the understanding of the use of alternative legends for close following:

1. Further data collection and analysis could be performed to improve robustness of findings and check for any dampening of impact over time. The variability of results between December and January is not fully explained so further data would allow further investigation.
2. The use of two downstream loops showed that the impact did not appear to tail off for 1.3km downstream, so collection from loop sites further downstream (up to 10km initially) would allow us to test how far the impact lasts downstream.
3. Different messages could be tested in the same location to allow a more direct comparison of their impacts.

4. There is anecdotal evidence that chevrons have a greater impact on close following than VMS, possibly because they give drivers clear guidance on what is an appropriate headway. It would be interesting to use IVR data to compare the impact of chevrons with that of VMS.
5. Although the impact of the messages is relatively low, with a maximum 7% reduction, close following is known to be a frequent contributory factor in accidents. The cost of setting VMS is relatively low, so it would be interesting to perform an economic appraisal based on assumptions about how many accidents might be mitigated by the use of the alternative legends.

# Appendices

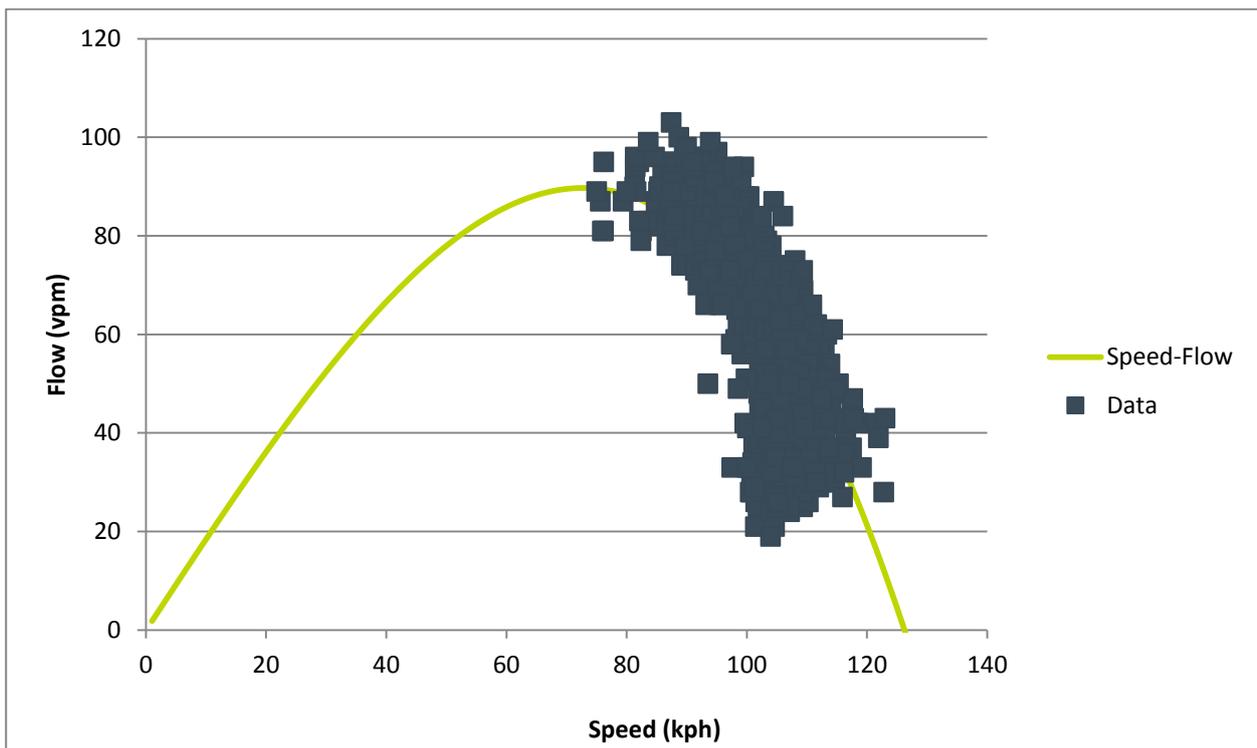
# Appendix A. Impact of Speed-Flow Relationship

*Reduction in close following rate when  $MsgOn = \beta \frac{Flow^2}{Speed^2}$ , where  $\beta$  is a number*

The message works best at high flows and/or low speeds.

A speed-flow curve like that in Figure 4-1 helps to determine the expected flow at a particular speed. For that particular curve, an increase in speed corresponds to a decrease in flow from about 80 kph. This means that the effect of the message on the following rate decreases particularly from 80 kph because of the dual effect of higher speeds and lower flows, whereas the effect of the message is largely constant below 80 kph as the effect of higher speeds mitigates the effect of higher flows.

**Figure 4-1 Modelled Speed-Flow Curve for the CYSIT December Test Site**

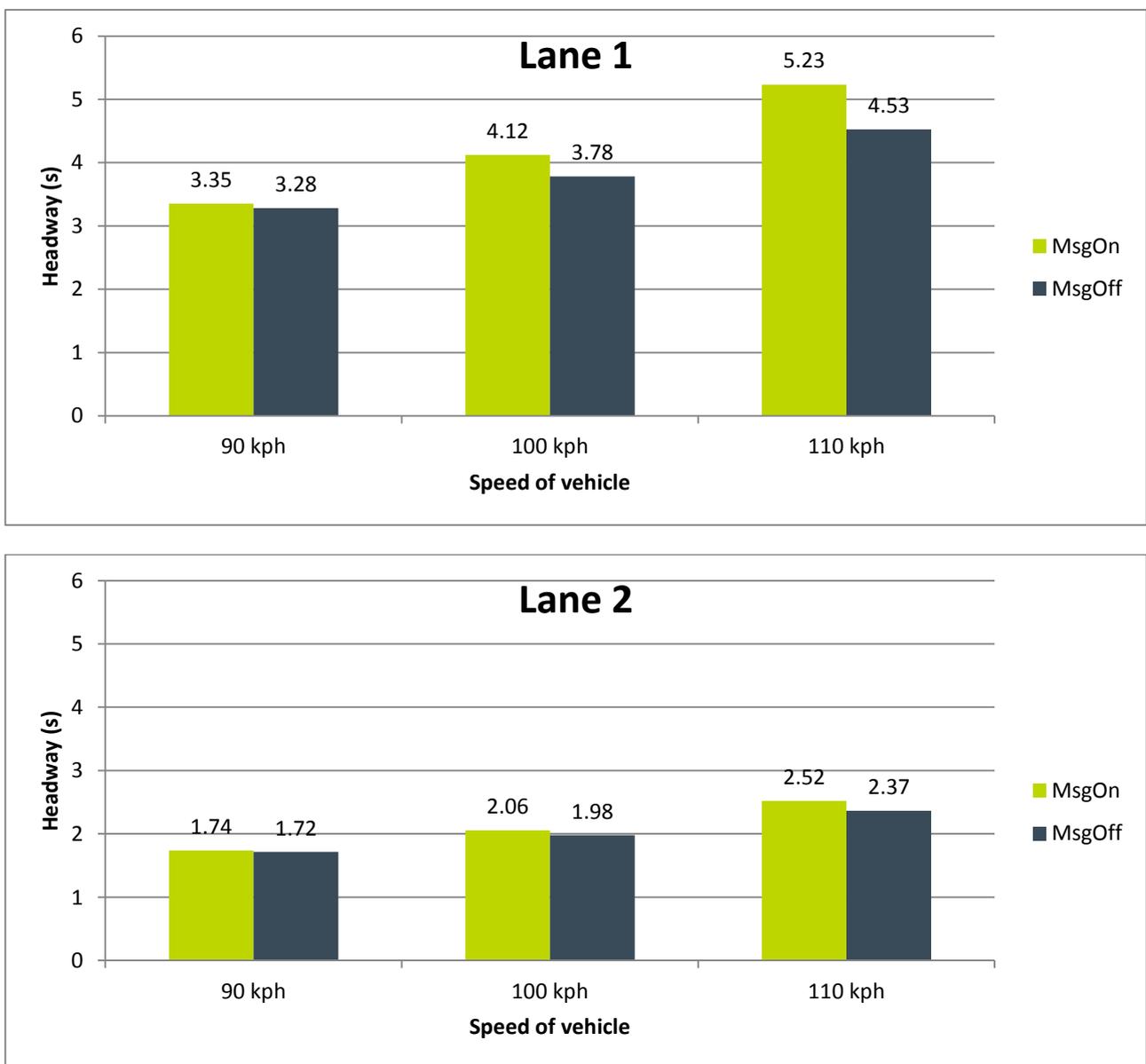


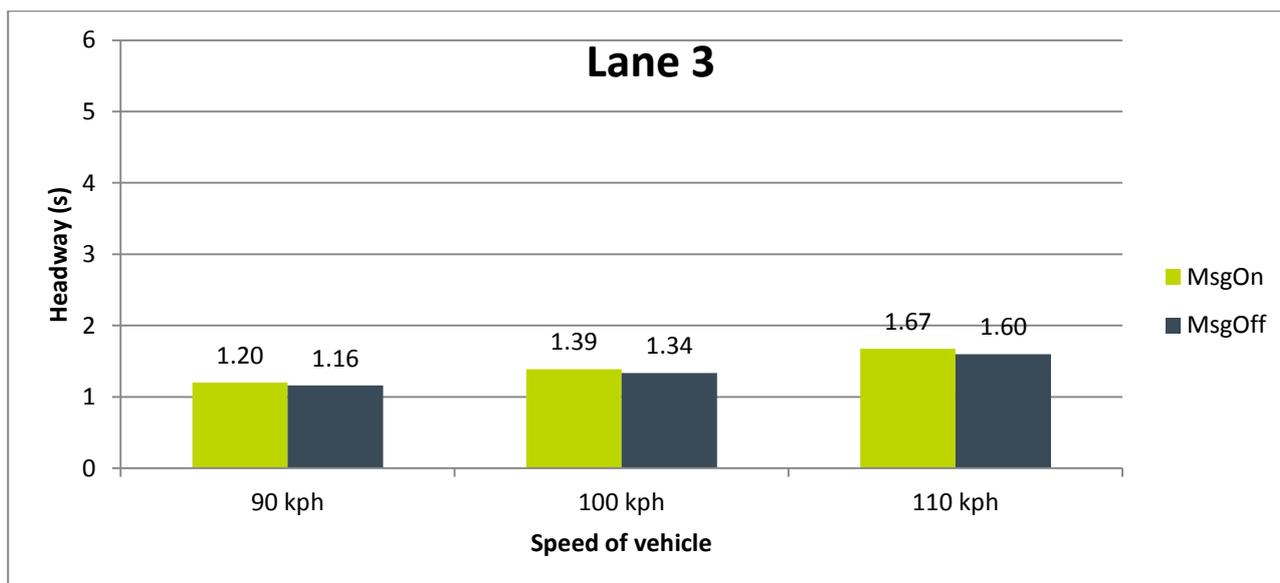
# Appendix B. Explanation of Differing Impacts on Averages and Categories

Analysis was undertaken on the raw non-aggregated December data from the CYSIT test site. The lane choice, speed and length of individual vehicles were used to model the expected headway for that vehicle. An examination of the effect of the message on headway was also conducted.

Figure 4-2 illustrates how the modelled headway of a typical vehicle varies with speed in each of the three lanes, when the message is displayed and when it is not.

**Figure 4-2 Predicted headway for average vehicle length 4.0 metres, CYSIT December data**





The proportionate effect of the message on the expected headway of a vehicle is higher at faster speeds. This could be explained in two ways:

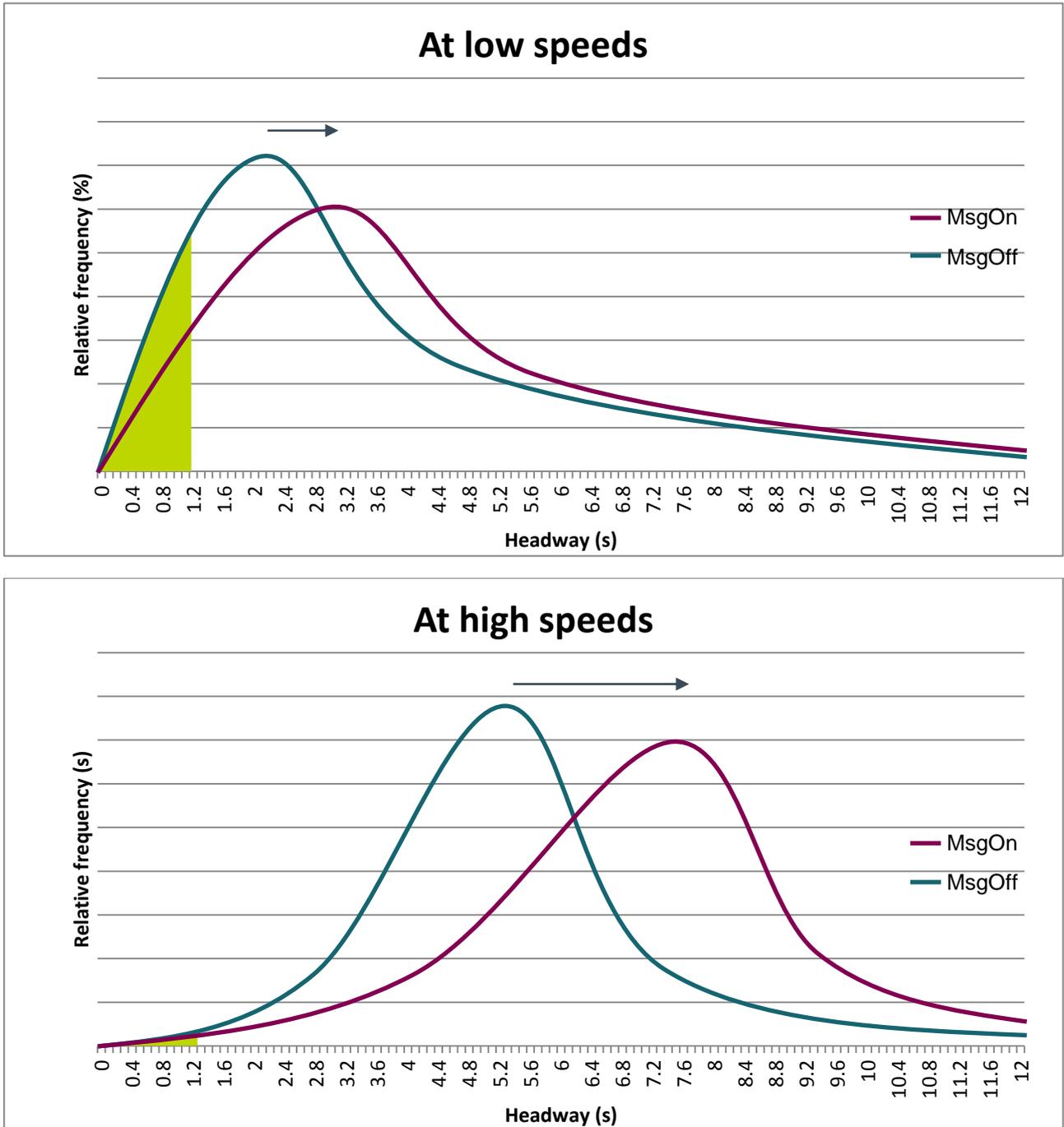
1. At higher speeds, drivers become more conscious of maintaining an appropriate headway. They are thus more easily persuaded by the message when they are travelling quickly.
2. High speeds correspond to low flows, as described by a speed-flow curve. It may be that the message is equally persuasive in cases of high and low flows, the only difference is that it is easier for a driver to increase their headway in a low flow (less congested) situation than a high flow (more congested) one.

That the proportionate effect on the expected headway of a vehicle is higher at faster speeds is not necessarily inconsistent with the earlier finding that the proportionate effect on the following rate is lower at faster speeds. Figure 4-3 shows a stylised explanation that illustrates this.

- The message has a larger effect at higher speeds: The rightward shift in the distribution of headways caused by the message is higher in the lower panel compared to in the upper panel.
- The message has a smaller proportionate effect on close following at higher speeds: The proportionate reduction in the close following rate (the proportionate reduction of the light green zone) is lower in the lower panel than in the upper panel.

The reason why the above two points do not contradict is that headways are larger at faster speeds. This is shown by the distribution being weighted to the left in the upper panel, and to the right in the lower panel. This means that the close following rate (light green zone) is in a fatter tail at lower speeds, increasing the potential for a larger proportionate reduction when the distribution is shifted right.

Figure 4-3 Stylised representation of a message's effect on headways and close following rate



**Dr Jill Hayden**  
Atkins  
Woodcote Grove  
Ashley Road  
Epsom  
KT18 5BW

**jill.hayden@atkinsglobal.com**  
**07702 595 661**

© Atkins Ltd except where stated otherwise.

The Atkins logo, 'Carbon Critical Design' and the strapline  
'Plan Design Enable' are trademarks of Atkins Ltd.