



# Assessment of current guidance in relation to Safe Carriageway Crossing (CIS53) on high speed roads

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This work has assessed the adequacy of current guidance - HSE Construction Information Sheet 53 (CIS53) - aimed at clients, designers and workers involved in road works on motorways/high speed dual carriageways (50mph or greater). The work has comprised of: a literature review; observing workers setting up temporary traffic management; and analysis of traffic flow data. The findings broadly support the present rules set out in CIS53 for crossing a carriageway on foot, but have indicated that traffic flows for many motorways make crossing impossible in practice for much of the day. Potentially safe gaps can be assessed by measuring the traffic flow in terms of vehicles per minute. At less than 20 vehicles per minute across all lanes, it is likely that sufficient safe gaps occur so that workers would not have to wait more than 5 minutes to cross. Between 20 and 40 vehicles per minute, it is suggested that site specific assessment is undertaken to determine if sufficient safe gaps exist. At greater than 40 vehicles per minute it is very unlikely that the carriageway can be crossed safely on foot. These flow rates are intended to be used as a guide and are not to be treated as absolute.

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## EXECUTIVE SUMMARY

The Construction Division Technology Unit of the Health and Safety Executive (HSE) commissioned the Risk Science Unit of the Health and Safety Laboratory (HSL) to assess the adequacy of the current guidance in HSE Construction Information Sheet 53 (CIS53). CIS53 is aimed at clients, designers, contractors and workers involved in roadworks on motorways and high-speed dual carriageways (50mph or greater).

### Objectives

The scope of the project was limited to evaluating the guidance on safe crossing provided in CIS53. The key objectives for this work were:

- To review existing available research, information and current guidance in relation to crossing the carriageway, especially with respect to the setting up and removal of traffic management equipment;
- To assess the adequacy of the guidance provided in CIS53 in order to identify where the guidance corresponds with current good practice and traffic flow, and areas where the guidance needs strengthening;
- To make recommendations for revision or strengthening of the guidance to redress deficiencies.

One additional aim of the work was to examine whether the current guidance is still applicable for carriageways with four or more lanes.

### Main Findings

The objectives have been met by carrying out a literature review, observing workers setting up temporary traffic management and analysing traffic flow data.

The information found in the literature review focussed on keeping crews safe by rejecting crossing the carriageways on foot in favour of other means of setting up temporary traffic management works. No further research on the safe crossing rules was found. However, two reports suggest carrying out night-time road works before midnight in preference to after due to the higher accident rate after midnight.

The video footage of workers setting up a temporary traffic management scheme showed that workers generally took 7-8 seconds to cross a 3-lane carriageway. However, they did not appear to wait for safe gaps, as defined by the '3 second per lane' rule in CIS53, before crossing. This may be because the traffic flow was relatively high (approximately 32 vehicles per minute) and therefore safe gaps were not appearing with enough regularity.

For the motorway data analysed in this report, it has been shown that there are not enough safe crossing opportunities between the hours of 7 am and 7 pm on weekdays and between 10 am and 6 pm at weekends for workers to cross without having to wait more than 5 minutes.

It appears that there are potentially three categories of carriageways when considering the times of day when there are sufficient safe crossing opportunities to allow workers to cross multiple times without having to wait more than 5 minutes:

1. Traffic flow too high at most times except for a few hours, e.g. between 1 am and 4 am;

2. Traffic flow level such that crossing is possible at certain limited times, e.g. after 10 pm and before 6 am;
3. Traffic flow low enough to allow crossing at many times of day (with the possible exception of the morning and evening rush hours).

The analysis in this report suggests that sufficient safe gaps appear such that a worker would not have to wait for longer than 5 minutes when the traffic flow across all lanes is less than 20 vehicles per minute. This criteria holds for both 2- and 3-lane carriageways in general but appears to be too high for 4-lane carriageways. The guidance in Chapter 8 of The Traffic Signs Manual states that safe gaps are **only likely** to occur in traffic flows of less than 40 vehicles per minute on a 3-lane carriageway. This work does not necessarily disagree with the Traffic Signs Manual as the guidance does not give any indication of how frequent the safe gaps are below 40 vehicles per minute.

## **Recommendations**

This project broadly supports the present rules in CIS53 for crossing a carriageway on foot but has found that the traffic flows for many motorways are such that, at most times of day in practice, crossing is impossible. The distribution of potentially safe gaps can be easily assessed by measuring the traffic flow in terms of vehicles per minute. When the traffic flow across all lanes is less than 20 vehicles per minute it is likely that sufficient safe gaps occur so that workers would not have to wait more than 5 minutes for crossing opportunities. As the traffic flow increases from 20 up to 40 vehicles per minute it is suggested that some form of site specific assessment is carried out to determine if there are sufficient safe gaps. When the flow is greater than 40 vehicles per minute it is very unlikely that the carriageway can be crossed safely on foot. It should be noted that these flow rates are intended to be used as a guide and are not to be treated as absolute.

# 1 INTRODUCTION

The Construction Division Technology Unit of the Health and Safety Executive (HSE) commissioned the Risk Science Unit of the Health and Safety Laboratory (HSL) to assess the adequacy of the current guidance in HSE Construction Information Sheet 53 (CIS53). CIS53 (HSE, 2000) is aimed at clients, designers, contractors and workers involved in roadworks on motorways and high-speed dual carriageways (50mph or greater). It contains guidance for workers crossing the carriageway on foot carrying signs and street sign furniture when setting up or removing temporary traffic management signing in central reservations.

## 1.1 OBJECTIVES

The scope of the project was limited to evaluating the guidance on safe crossing provided in CIS53. The key objectives for this work were:

- To review existing available research, information and current guidance in relation to crossing the carriageway, especially with respect to the setting up and removal of traffic management equipment;
- To assess the adequacy of the guidance provided in CIS53 in order to identify where the guidance corresponds with current good practice and traffic flow, and areas where the guidance needs strengthening;
- To make recommendations for revision or strengthening of the guidance to redress deficiencies.

One additional aim of the work was to examine whether the current guidance is still applicable for carriageways with four or more lanes.

The objectives have been met by carrying out a literature review, observing workers setting up temporary traffic management and analysing traffic flow data.

## 1.2 CURRENT GUIDANCE

### 1.2.1 CIS53

CIS53 provides advice on health and safety issues where traffic management workers cross (on foot) the carriageways of high-speed roads which are open to traffic. The health and safety criteria detailed in the guidance should be met before workers cross the carriageway on foot and is used as part of the safe system of work. Crossing the carriageway on foot should only be considered as a system of work when traffic flows are low enough to regularly produce sufficient safe gaps between vehicles. Traffic flows should be assessed at the design and planning stage, and before beginning temporary traffic management works to ensure flows are appropriate for the system of work employed.

The guidance states that workers should not be expected to wait for longer than 5 minutes before a safe gap occurs in the traffic. When estimating how long it will take to cross and judging what is a safe gap in the traffic, two rules are used:

- Allow at least 3 seconds per lane when estimating crossing times, e.g. at least 9 seconds for crossing three lanes;



- To estimate the length of a safe gap in metres, multiply the number of lanes to be crossed by 150.

The guidance also recommends that more time is allowed in poor weather and when carrying loads and that greater distances are allowed when judging safe gaps at night and where traffic speeds and/or crossing times are high.

### **1.2.2 The Traffic Signs Manual, Chapter 8, Traffic Safety Measures and Signs for Road Works and Temporary Situations**

Chapter 8 is a Department for Transport (DfT) publication (DfT, 2006) which gives guidance on the use of traffic signs and road markings prescribed by the Traffic Signs Regulations and covers England, Wales, Scotland and Northern Ireland. Chapter 8, Part 1, Design and Part 2, Operations deal with traffic safety measures and signs for road works and temporary situations and gives guidance for crossing the carriageway on foot (see Chapter 8, Operations, Section 3.5). This DfT guidance references HSE Construction Information Sheet (CIS53) and uses the same rules for estimating crossing times. Chapter 8, Part 2, Operations also contains an additional piece of guidance to help determine when safe gaps are likely to occur. It states that “safe gaps are only likely to occur in traffic flows of less than 40 vehicles per minute on three-lane carriageways”.

### **1.2.3 Highways Agency**

The Highways Agency (HA) have produced two complementary documents which give guidance for temporary traffic management (HA, 2002a and 2002b). The first guidance document (HA, 2002a) states that as part of the project design, off-peak periods of traffic flow should be identified so that in ideal circumstances, traffic management arrangements can be implemented during periods of low traffic flow. Crossing the carriageway on foot should be planned so that the location provides adequate sight lines and gaps in the traffic. No specific rules to identify safe gaps are stated but CIS53 is referenced.

The second document (HA, 2002b) states that crossing live traffic lanes on foot should be minimised and not done whilst working alone. It specifies that safe gaps are likely to occur in traffic flows of less than 40 vehicles per minute on 3-lane carriageways and that crossing of carriageways in excess of 3 lanes on foot should only be carried out following a location specific risk assessment. It also gives the ‘3 second per lane’ rule from CIS53 when estimating crossing times.

## **1.3 STRUCTURE OF REPORT**

The report is structured as follows:

- Section 2 describes the literature review carried out;
- Section 3 briefly discusses and analyses video footage of workers crossing the carriageway to erect road signs;
- Section 4 describes the extraction and analysis of traffic flow data;
- Section 5 presents the results of the analysis of traffic flow data and discusses the findings;
- Section 6 summarises the main findings of the work.

## 2 LITERATURE REVIEW

### 2.1 DATABASES AND SEARCH TERMS

A variety of databases were searched in order to identify the range of issues that should be taken into consideration during activities that require high speed carriageways to be crossed, particularly when dealing with the setting up and removal of temporary traffic management equipment.

A range of keywords and search terms were determined so that a complete range of references could be obtained that would cover all areas of the project. They are as listed in Table 1.

**Table 1** Database search terms

Search Terms
Roadworks + design
Roadworks + planning
Roadworks + fatalities
Carriageway + design
Carriageway + planning
Carriageway + fatalities
Crossing + carriageways
Roadworks + good practice
Roadworks + safety
Carriageway + traffic flow

Table 2 illustrates the databases that were searched and the number of references that were found using the search terms in Table 1. In total, 345 references were found and after scanning through each abstract, 36 references were considered to be appropriate for further examination. Of the 36, eight references contained suitable information concerning setting up or removing temporary traffic management.

**Table 2** Databases searched

Database	No. of References
Oshupdate	45
NTIS, Pascal, Transportation Research Information Services, Compendex and ABI/Inform	92
EbscoToc	34
Ergonomics Abstracts	8
HSELINE, CISDOC, NIOSHTIC, RILOSH and OSHLINE	102
Healsafe and International Transport Research Documentation	64

## **2.2 REVIEW**

This section details the contents of each of the eight references that contain useful information. Each sub section contains a summary of the most important information; for a more complete understanding, reference should be made to the full document.

### **2.2.1 SHRP reviews work-zone safety tools (Sears, 1998)**

This document describes the work by the Strategic Highway Research Program (SHRP) on the use of large dump trucks that act as a barrier between workers and oncoming vehicles by following the work crews as they move down the carriageway. This method should largely protect the workers, but other issues arise concerning driver safety. It also goes on to describe a remotely driven vehicle (RDV) that can be operated by the driver from the roadside, thus reducing risks.

### **2.2.2 Motorway roadworks: effects on traffic operations (Yousif, 2002)**

As capacity is reduced when one or more lanes on the carriageway are closed, lower operating speeds may be observed, possibly due to temporarily imposed speed limits or driver caution. Observations have found that traffic behaviour varies considerably on the approach to road works, for example, on approach to the tapered section, some drivers perform last minute lane-changing manoeuvres and press themselves into smaller gaps in adjacent lanes as they merge, increasing the risk of harm for any work operatives in the area.

The author also describes research where drivers failed to observe the 50mph speed limit at road works. This is an issue that should be taken into consideration when setting up and removing temporary traffic management equipment.

### **2.2.3 Temporary traffic management on high speed roads – good working practice (HA, 2002b)**

This document covers issues relating to planning and the workforce that could be of importance to crews setting up and removing temporary traffic management systems. It is also included in the discussion of current guidance in Section 1.2.3.

#### **2.2.3.1 *Planning Issues***

The author states that any organisation undertaking temporary traffic management operations should be informed of any issues concerning the carriageway on which the work is to take place, for example, narrow central reservations, traffic data or lack of hard shoulder. Rolling block techniques are also mentioned as a way of supporting operations at the initial stages.

#### **2.2.3.2 *Workforce Issues***

Crossing the carriageway on foot should be minimised, especially in the presence of traffic or when working alone. It is thought that safe gaps in the traffic are likely to occur over 3 lane carriageways when the flow is less than 40 vehicles per minute. If greater than 3 lane carriageways need to be crossed on foot, a location specific risk assessment is required. Allowing 3 seconds per lane then provides enough time for safe crossing.

The central reservation should be adequate enough to provide a safe working place, otherwise operatives should not be encouraged to cross the carriageway on foot. The operatives involved should be competent, have sufficient level of fitness and should not be under the influence of

drugs and/or alcohol. High visibility garments should be worn and should conform to the relevant standards.

#### **2.2.4 Safety at road works (Marlow, 1990)**

This report details the results of surveys that have been carried out during 1982 and 1987. It states that higher accident rates occur more frequently between midnight and 3 am, for situations that do and do not involve road works. Weekend accident rates with road works are higher than those during the week. Traffic operatives should take this into consideration when planning road works. The study goes on to say that approximately half of all personal injury accidents occur during dry conditions at road works. Furthermore, the majority of personal injury accidents occur in fine weather, with and without road works.

#### **2.2.5 Traffic management and safety at highway work zones (OECD, 1989)**

The author states that road works should only be carried out when traffic volumes are at a minimum and should not be considered during peak times including the height of the holiday season, weekends and rush hours. A suggested time of before midnight for night-time works is preferred, as accident rates are much higher during the hours after midnight.

The paper also lists advantages of night-time working such as:

- Less congestion resulting in less delays for night-time users;
- Expansion of the work zone due to lack of traffic, allowing extra space for workers;
- Cooler temperatures and fewer interruptions from traffic allowing workers to be more productive as well as safer;
- Better access and fewer interruptions resulting in street furniture being set up more efficiently.

However, it details that night working also has its disadvantages, including:

- High speed traffic being more common during the night, leading to reduced reaction times;
- Driver intoxication through the use of alcohol and/or drugs leading to inattentiveness;
- Limited visibility preventing drivers from observing work crews until the last minute. The crews themselves experiencing restricted visibility even with temporary lighting.

#### **2.2.6 Assessing the safety environment in work organisation of road maintenance jobs (Niskanen, 1994)**

This paper focuses on a wide range of statistical analysis concerning the safety of workers in road maintenance jobs in the USA so it is largely irrelevant to the purpose of this project. However, some useful facts can be obtained. For example, the questionnaire that is the basis of the paper determines that 3% of maintenance workers believe that 'risk taking is very much a part of their job', while 12% believe it is 'rather much a part of their job'. It also states that road workers believe that the greatest risk to themselves is due to hazards caused by drivers, including overtaking and approaching works at high speeds, rather than their own actions such as incorrectly estimating the speed of approaching vehicles. Workers thought that carelessness

and rushing are fundamental causes that can affect accident probabilities. Lack of safe working practices is also an issue.

It also states that worker injury rates are lower when employees and supervisors have daily contact. Management plays a role with regular one-on-one contact with employees.

### **2.2.7 Highway works on high speed roads (Warner, 1991)**

The author describes how there is more danger to the personnel who install temporary traffic management signs than for the workers that carry out the repairs. The paper also states that not all accidents that result in minor injuries and near misses are reported to HSE, so these accidents could be more common than is first thought. Issues are also raised concerning the consistency of, for example, road signs across the high-speed road network, as well as from county to county.

### **2.2.8 Improving safety at road works. How far can you go? (Kusters, 2001)**

The author states that there is a proposed ban on crossing more than one lane of a motorway on foot within the Netherlands and that some areas have implemented a complete ban. In these incidences, if the roads have no lane signalling, then works are only permitted if mobile lane signalling is used.

## **2.3 DISCUSSION**

In general, the documents reviewed focussed on keeping crews safe by rejecting crossing the carriageways on foot in favour of other means of setting up temporary traffic management works. Only one document (HA, 2002b) refers to the guidance, and associated crossing rules, the project aims to investigate, namely the '3 second per lane' rule that dictates the time required to safely cross a carriageway of  $n$  or more lanes (safe crossing time =  $3 \times n$ ). However, this document itself references CIS53 so it is not relevant in determining how appropriate the rule is by current traffic flow standards.

However a number of interesting points that are relevant to this work are raised. The first is the issue of vehicle speed, with research (Yousif, 2002 and Niskanen, 1994) suggesting that drivers often fail to observe speed restrictions in road works. The second issue relates to the optimum time of day to set up road works. Marlow (1990) states that there are higher accident rates between midnight and 3 am and also at weekends. This finding is also reported in OECD (1989) which suggests carrying out night-time road works before midnight due to the higher accident rate after midnight.

### **3 OBSERVATION OF WORKERS CROSSING THE CARRIAGEWAY**

At the outset of the project, it was envisaged that the project team would undertake familiarisation visits to observe workers setting up/removing temporary traffic management works. Unfortunately, due to a number of factors beyond our control this was not possible to arrange within suitable timescales for the project.

However, discussions with HSL's Visual Presentation Services (VPS) identified video footage that had been taken for some earlier HSE work that showed workers setting up temporary traffic management systems on the M25 (HSL, 2001).

#### **3.1 ANALYSIS OF VIDEO FOOTAGE**

The video footage obtained from VPS was transferred to DVD and allowed the project team to gain an understanding of the factors that need to be considered when crossing the motorway and also to view common working practice for crossing the carriageway on foot. The DVD shows workers placing signs on both the hard shoulder and central reservation overnight on the 6/6/01 on a three lane section of motorway. It clearly shows workers crossing the motorway on foot to erect signs in the central reservation. The time of day (in hours, minutes and seconds) is displayed on all of the footage and this enabled a high level analysis to be carried out of:

- typical crossing times;
- the length of gaps in traffic when crossing was attempted;
- the length of time workers waited before crossing; and
- traffic flow.

The DVD shows workers placing three signs in the central reservation warning drivers that the outside lane was closing in 800 yds, 600 yds and 400 yds. The footage therefore shows the motorway being crossed on six different occasions. In all cases, two workers crossed together, one carrying a cone and the other a lamp. It appeared that the signs and any necessary sandbags had previously been placed in the central reservation. The two workers waited on the hard shoulder (close to the edge of the inside lane) carrying their equipment until a suitable gap in the traffic appeared. They crossed, walking briskly, in a diagonal direction (i.e. not at right angles to the carriageway). Once inside the central reservation they erected the sign and then waited for another gap in the traffic to appear. As a gap appeared the workers placed one leg over the barrier in preparation for crossing. On all occasions, the workers either started to cross before cars in the middle or outer lane had passed, or cars passed in the inner lane whilst the workers were still crossing the outer lanes. That is, whilst crossing the carriageway, cars were passing either in front or behind them.

Table 3 shows the results of the high level analysis carried out for the six carriageway crossings observed on the video footage. Crossing A refers to workers crossing from the hard shoulder to the central reservation and crossing B refers to workers crossing back from the central reservation to the hard shoulder. The crossing times are the length of time it took the workers to walk from one side of the carriageway to the other. The vehicle gap is an indication of the gap between vehicles that the workers are electing to cross between. However, this time is deceptive because on all occasions (where it was possible to measure), the workers started to cross before a car in a lane other than the one closest to them had passed. The vehicle gap therefore measures

the gap between the two vehicles they are walking between and not the gap between the last vehicle to pass before they start to cross and the next one to pass after they reach the other side of the carriageway. The implications of this difference will be discussed later in the report. The waiting time measures the length of time the workers waited either in the hard shoulder or central reservation before they decided to cross. The traffic flow gives an approximate count of the number of vehicles per minute travelling along the carriageway whilst the workers were waiting to cross. It is likely that this is an underestimate of the true value as the positioning of the camera often resulted in smaller vehicles in the outer lanes being obscured by larger ones travelling in the inner lane. Missing data in the table is also a consequence of the camera angle preventing either the workers or vehicles being observed.

**Table 3** Analysis of carriageway crossing observations

Crossing	Crossing time (s)	Vehicle gap (s)	Waiting time (s)	Traffic flow (vehicles per min)
800 yds - A	7	7	-	21
800 yds - B	7	5	26	39
600 yds - A	7	5	14	26
600 yds - B	8	-	70	27
400 yds - A	7	9	88	31
400 yds - B	8	-	29	47

### 3.2 DISCUSSION

CIS53 (see Section 1.2.1) states that workers should allow 3 seconds per lane when estimating crossing times which equates to 9 seconds for a 3-lane carriageway. The DVD clearly shows that the workers in this case took around 7-8 seconds to cross the road, which suggests that allowing 3 seconds per lane is a reasonable guide for estimating crossing times.

As discussed earlier in Section 3.1, the vehicle gaps in Table 3 do not count as safe gaps as the workers started to cross before a car in a lane other than the one closest to them had passed. This is not considered to be a safe gap as there is nothing to stop the cars that are passing while the workers are on the carriageway, changing lanes. If the driver has not seen the workers, the car could potentially move into the same lane as the workers. The analysis carried out in this work therefore only considers a gap between vehicles to be safe if it occurs simultaneously in all lanes.

Although the workers did not wait more than 5 minutes in either the hard shoulder or central reservation before crossing, they did not wait for a safe gap. The mean traffic flow, over the periods crossing was attempted, has been calculated to be approximately 32 vehicles per minute. However, as stated in Section 3.1, this is likely to be an underestimate as smaller vehicles were often obscured from the camera by larger ones.

It would appear that the traffic flow during the filming of the video footage was too high for the workers to find safe gaps in the traffic to cross (although this may not necessarily be the case if the workers were choosing to cross before a safe gap appears rather than waiting for a safe gap).

## 4 TRAFFIC FLOW DATA

HSL contacted the Transport Research Laboratory (TRL) to gain access to their Traffic Count Data and Logs online database. This database is part of the Motorway Incident Detection and Automatic Signalling (MIDAS) system managed by Mott MacDonald. The MIDAS system continuously monitors vehicle data on a per lane basis. Vehicle counts, together with speed, headway and length data for individual vehicles are calculated. Table 4 shows the different fields that are recorded together with a description of what they represent.

**Table 4** Traffic data values and units

<b>Value</b>	<b>Description</b>	<b>Units</b>
Date	The date that the data was recorded (dd/mm/yy)	Date
Time	The time of the minute timeslot that data was recorded over (hh:mm)	Hours, Minutes
Number of Lanes	The number of running lanes at the site	Lanes
Flow (Category 1)	Count of vehicles less than 5.2 m in length (e.g. motorcycles and small cars) recorded for all lanes at the site in a given minute	Vehicle count
Flow (Category 2)	Count of vehicles that are 5.2 m or more in length but less than 6.6 m (e.g. estate cars) recorded for all lanes at the site in a given minute	Vehicle count
Flow (Category 3)	Count of vehicles that are 6.6 m or more in length but less than 11.6 m (e.g. vans and minibuses) recorded for all lanes at the site in a given minute	Vehicle count
Flow (Category 4)	Count of vehicles that are 11.6 m or more in length (e.g. HGVs) recorded for all lanes at the site in a given minute	Vehicle count
Speed (Lane <i>n</i> )	Average speed of vehicles in this lane over the minute	Kilometres per hour
Flow (Lane <i>n</i> )	Count of vehicles in this lane over the minute	Vehicle count
Occupancy (Lane <i>n</i> )	Percentage of the minute in which a vehicle was over, 'occupying', the MIDAS site. This indicates the level of congestion	Percentage of a minute
Headway (Lane <i>n</i> )	The average time between passing vehicles in the minute for a specified lane	Tenths of a second

The traffic counting data files are binary files (TCD files) and one is created for every day of the year. Each TCD file holds 1440 traffic data records, one for each minute of the day. TCD files for the dates and motorways of interest were downloaded from the MIDAS website. They were then extracted and converted into Common Separated Values (CSV) text files to allow the analysis to be carried out. Appendix A contains a detailed description of this procedure and the analysis that was undertaken.

### 4.1 SELECTION OF DATES AND MOTORWAYS

Discussions were held with the HSE customer (Wright, 2008) before the motorways to be analysed were finalised. The project team decided to analyse motorways that had differing levels of traffic flow: high, medium and low. Discussions with the MIDAS Helpdesk (Mott MacDonald, 2008) confirmed that it was unlikely that traffic monitoring devices would be installed on quieter roads unless the road was a new trunk route. One other criteria that was used in the selection of motorways to analyse was the number of lanes, it was necessary to include 2-, 3-, and 4-lane stretches of motorway to determine how this difference affects traffic flow. Table 5 list the stretches of motorway selected.



**Table 5 Motorways analysed**

Motorway	Stretch (junctions)	Number of Lanes	TCD file code
M65	J2 – J3	2	M65/4049A
M65	J1 – J2	3	M65/4020A
M55	J2 – J3	3	M55/5229A
M2	J3 – J4	3	M2/8555A
M25	J3 – J4	3	M25/4164A
M6	J17 – J18	3	M6/6740A
M25	J8 – J9	4	M25/4565A
M6	J20 – J21	4	M6/6998A

Initial analysis on days sampled throughout the year showed that it was not unusual for the traffic monitoring system to fail particularly when the traffic flow was low. It was therefore necessary to look at a much larger sample of days to get a more complete picture that was less prone to seasonal variation, significant large-scale events and traffic congestion. June is often used as an exemplar month for traffic management (Wright, 2008) as the longer days mean that more work can be carried out in daylight. It was therefore agreed that the analysis for all of the motorway stretches in Table 5 would be carried out for the whole of June 2008. This assumes that for each motorway analysed, June is a representative month and, in general, will not give substantially different results to any other month.

#### **4.2 ANALYSIS PROCESS**

The traffic data was downloaded from the MIDAS website, extracted and converted into CSV format. There was one file for each day of June 2008 and each one contained a large amount of data, most of which was not required for this exercise. The headway and flow data for every minute of every day of the month were extracted for each motorway of interest and written to smaller files which could then be imported into a spreadsheet. The data was then manipulated to produce information for each hour of the day and the existing safe crossing rules were applied to see how often they were satisfied. The results of this analysis could then be used to determine whether or not the existing rules (detailed in Section 4.3) are still satisfactory given the increase in traffic seen over the last few years.

The original data contains information for every minute of the day and across all the days in June 2008. Where appropriate, means were taken to produce hourly statistics. On the graphs, '1' on the time axis represents the mean of the data from midnight until 1 am, '2' is for 1 am to 2 am etc. In most cases, means have also been calculated to show typical statistics for each day of the week e.g. the data for Tuesday has been averaged across all four Tuesdays in the month, unless specified otherwise.

#### **4.3 APPLICATION OF THE SAFE CROSSING RULES**

As stated in Section 1.2, there are four different rules that give guidance to workers when deciding whether it is safe to cross the carriageway:

- Allow at least 3 seconds per lane when estimating crossing times, e.g. at least 9 seconds for crossing three lanes;

- To estimate the length of a safe gap in metres, multiply the number of lanes to be crossed by 150;
- Workers should not be expected to wait for longer than 5 minutes before a safe gap occurs in the traffic; and
- Safe gaps are only likely to occur in traffic flows of less than 40 vehicles per minute on three-lane carriageways.

The analysis carried out on the traffic counting data files examined whether or not these rules were being met, in general, by the traffic travelling on the motorways of interest. However, it was not straightforward to use the second rule in the analysis as the data files do not directly measure gaps between vehicles in terms of distance. It could theoretically be calculated using the average headway and average speed (from the MIDAS data) but any results would be subject to considerable uncertainty given that the two variables are both averages. Therefore, to allow an analysis of whether or not large enough gaps in the traffic are likely to occur on a particular motorway, the rule to estimate crossing times was used, i.e. on a 2-lane carriageway an average gap of 6 seconds between vehicles, on a 3-lane carriageway a gap of 9 seconds and on a 4-lane carriageway a gap of 12 seconds. These are the gaps that would allow workers to cross and this rule is subsequently termed the 'safe crossing rule' in this report. Gaps that meet the safe crossing rule are termed either safe gaps or safe crossing opportunities. It should be noted that for a gap in the traffic to count as meeting the safe crossing rule, all lanes must concurrently have large enough gaps in the traffic. The application of this rule in the data analysis is discussed in more detail in Section 5.1.

In addition to determining when and how often the '3 second per lane' rule is met, the data was analysed to see whether large enough gaps in the traffic were occurring frequently enough to ensure workers did not have to wait on either the hard shoulder or central reservation for longer than 5 minutes.

The mean traffic flow in terms of vehicles per minute on the carriageway was also calculated in order to determine any correlation between the occurrence of potentially safe crossing gaps and the traffic density.

#### **4.4 ASSUMPTIONS**

The downloaded data sometimes contained either a '0' or '-1'. The MIDAS Helpdesk (Mott MacDonald, 2008) confirmed that:

- a '0' in the flow category means that no vehicles were counted during a particular minute,
- a '0' in the headway category means that the average time between passing vehicles in a particular minute was greater than 25.4 seconds (a limitation of the 8-bit system),
- a '-1' in any category reflects that there is no data available for that entity in the one minute sample. This is generally due to an error in the measuring device or the transmission of data.

All '0's in the headway data were therefore replaced with the value 254 as headway data is measured in tenths of seconds. Table 6 lists the remaining assumptions that were made during the data analysis.

One further point is the use of an averaged headway per minute, i.e. the MIDAS headway data represents the average distance between vehicles for a given minute. Whilst this gives a good indication of the times of day when large enough gaps appear, it is not absolute. The possible impact of this assumption is discussed in detail in Section 4.4.2.

**Table 6 Assumptions made during data analysis**

<b>Problem</b>	<b>Assumption made</b>
-1 in headway data (2-lane motorways)	Assumed that the safe crossing rule is not satisfied in this instance.
-1 in headway data (3- and 4-lane motorways)	If data was missing for one lane but the others satisfied the safe crossing rule then it was assumed that the missing lane also satisfied the rule. If data was missing for more than one lane then it was assumed that the safe crossing criteria was not met.
Averaging to give mean hourly statistics	This assumes a fairly even distribution of traffic across the hour. If, for example, there are a number of safe crossing opportunities in an hour, then this assumes that they are evenly distributed across that hour when, in reality, they could occur at any time leading to a potential underestimation of the time taken to wait for a safe crossing opportunity to occur. It also eliminates large scale fluctuations in the flow rates within any given hour.
-1s in flow data	Replaced by 0s but the mean was calculated over the total number of minutes in each hour for which data was available so the missing data is not included.
Each day of the week has approximately the same flow across the month of June	It was assumed that every Sunday in June (for example) would have similar flow and so a mean could be calculated across all the Sundays in the month. This eliminates any potential spurious variability in the days across the month.
Missing data for one Tuesday	For some motorways, data was missing for 11 hours on one Tuesday of the month. The mean was therefore calculated for the remaining Tuesdays of that month, thereby eliminating the missing data which may skew the results.
Data missing for a continuous stretch of 80 minutes from 13:13 on 12 <sup>th</sup> June 2008 for the M55	The rest of the data for this motorway indicated that the '3 second per lane' rule was never met at this time of day and so it was considered safe to ignore this section of information.

#### **4.4.1 Impact of missing data**

Appendix C shows how much headway data was missing from the extracted traffic counting data files. The tables show the number of minutes in each hour of each day for which data was missing. There appears to be a strong correlation between the traffic flow and missing data, i.e. more data seems to be missing at quieter times of the day and is rarely missing during the busy peak times.

The missing data was found to have the largest effect on the 2-lane motorway analysed. This is due to the fact that wherever headway data was missing the assumption was made that the safe crossing rule was not met. Appendix C shows that, for the 2-lane motorway, data was missing, in general, for up to 30 minutes per hour (i.e. 50% of the time). However, the analysis shows that during the periods when the headway data was missing, those minutes which had complete headway data, satisfied the safe crossing rule. This is demonstrated graphically in Figure 2 in Section 5.4.

Due to the fact that data was more likely to be missing when the traffic flow was low, the analysis carried out in this report has probably underestimated the number of minutes with crossing opportunities and the time to wait for a safe gap during periods of low traffic flow. However, Appendix C demonstrates that although, due to missing data, the number of safe crossing opportunities per hour will have been underestimated in periods of low flow, this has not resulted in reduced periods of time when safe crossing is calculated to be possible. It should also be noted that there was generally very little missing flow data.

#### **4.4.2 Impact of assumptions**

As stated previously, the MIDAS headway data represents the average distance between vehicles for a given minute. It is acknowledged that this is an approximation and does not fully represent the actual distribution of vehicles within any given minute. The use of average headway may therefore lead to an underestimation of the presence of safe gaps. However, this work also had to make the assumption that if a safe gap occurs in each lane in a given minute, then it is likely that a safe gap occurs across all lanes simultaneously at some point during that minute, i.e. if the average headway in each lane was greater than or equal to the time needed to cross the carriageway safely then it was assumed that a safe crossing opportunity existed. This assumption may lead to the number of safe crossing opportunities being overestimated. It is not known which of these two effects will dominate and for the purposes of this report they are assumed to cancel each other out.

A number of alternative methods exist for determining the distribution of safe gaps on carriageways although each of these has their own drawbacks. Individual vehicle data measures actual gaps between successive vehicles irrespective of lane and this would allow actual headways to be calculated. However, extraction and analysis of this data would be time consuming and only likely to be feasible for a limited period and range of sites. Another approach would be to use a theoretical model to investigate the statistical distribution of gaps in traffic. This would also be based on assumptions and would not allow the time of day to be easily included.

It can therefore be seen that all possible approaches have disadvantages and it is believed that the best approach was taken given the data made available to HSL. It should be noted that the results of this work are intended to be used as a guide for judging when safe gaps are likely to occur and are not intended to be absolute.

In order to determine how sensitive the results of this work are to the assumptions made regarding the use of headway data, a number of tests were carried out. The first test investigates the hourly mean minimum headway across all lanes for the first Tuesday of June 2008 for each motorway analysed. The minimum headway indicates the smallest average gaps that occur in any lane for a particular minute. The results are shown in Appendix E and the appropriate headway required for a safe gap is also shown on each graph. These graphs show that the times of day when the minimum headway is greater than the '3 second per lane' rule correlate with the conclusions of the report and also indicate that, in most cases, the minimum headway during periods when safe crossing is not possible is much lower than the headway required for a safe gap. The fact that the minimum headway is generally significantly lower than the headway necessary for a safe gap (as defined in this work) at times when safe crossing opportunities do not appear demonstrates that the findings of this work are not likely to be particularly sensitive to the use of average headway.

A second sensitivity test was carried out by investigating whether the times of day when it was safe to cross were significantly altered by reducing the crossing time to 5 seconds for two 3-lane motorways (i.e. reducing the crossing time from 9 seconds). It would be reasonable to assume

that when the average headway across all three lanes is less than 5 seconds then the number of actual gaps that are greater than 9 seconds is greatly reduced. If the analysis was sensitive to the use of averaged headway data then it might be expected that this would substantially increase the time periods when it is safe to cross. The results of this test are shown in Appendix F and show that there is not a significant increase in the number of safe crossing opportunities.

#### **4.4.3 Summary**

The missing data appears to have little effect on the results of the data analysis. Appendix C shows that headway data is generally only missing in periods of low traffic flow and whilst this leads to potential underestimating of the number of minutes of safe crossing opportunities per hour when the safe crossing rules are met, it does not change the time periods when the rule is not met.

The use of average headway data also appears to have little effect on the analysis carried out. Whilst it is acknowledged that the use of 9 seconds average headway (for a 3-lane motorway) to identify safe crossing opportunities could lead to an underestimation of safe gaps, the sensitivity test that was carried out using a greatly reduced headway gave similar results. This shows that although average headways that are less than 9 seconds will in reality contain gaps that are 9 seconds or larger, the analysis carried out in this report is not particularly sensitive to the potential underestimation of safe gaps through the use of average headway data rather than actual headway data.

## 5 DATA ANALYSIS RESULTS

Traffic flow data for June 2008 was downloaded and converted into a format suitable for analysis (see Appendix A for a detailed description of this process). Data for each of the categories in Table 4 (in Section 4) was available for each minute of each day. In order to make the analysis both manageable and meaningful, hourly values for each data category of interest were calculated. On the graphs, '1' on the time axis represents the hourly value for each minute from midnight until 1 am, '2' is for 1 am to 2 am etc. In most cases, means have also been calculated to show typical statistics for each day of the week, e.g. the hourly values have been averaged for all Mondays, Tuesdays etc.

As stated in the assumptions in Section 4.4, the traffic flow data contained missing data points due to technical errors with the roadside recording/transmission devices. For the headway data, for those minutes where too much data was missing to be confident that a safe crossing rule could be met, it was pessimistically assumed that the headway was smaller than the '3 second per lane' rule. Appendix C shows the number of minutes per hour for each day of the month that data was missing for each motorway analysed. It should be noted that data tended to be missing during quiet periods on each motorway and so had little impact on the results for the times of day where safe crossing would not be possible.

### 5.1 SAFE CROSSING OPPORTUNITIES

To determine the times of day for each motorway where crossing opportunities were likely to occur, the headway data (the average time between passing vehicles in the minute for a specified lane in tenths of a second) was interrogated. As stated earlier, the '3 second per lane' rule was applied to determine when the headway data met this rule. For a 2-lane motorway, if the average headway in both lanes for a particular minute was greater than 6 seconds, then the rule criteria was met, for a 3-lane motorway, the headway in all three lanes for a particular minute had to be greater than 9 seconds and for a 4-lane motorway, the headway in all four lanes for a particular minute had to be greater than 12 seconds.

The number of minutes per hour with safe crossing opportunities, i.e. the number of minutes per hour that the mean headway between vehicles was greater than the safe crossing rule, were determined. The data was also averaged across all Mondays, Tuesdays etc. to show how the safe crossing opportunities varied with day of the week. Plots of the number of minutes per hour with safe crossing opportunities over a 24-hour period for all days of the week are shown for each motorway in sections 5.4.1 to 5.4.8.

As these plots only show the minutes when there was enough data to be sure that the headway in all lanes was greater than the safe crossing rule, the remaining minutes where the rule is adjudged not to be satisfied will actually be a combination of minutes where the headway is too low or there is missing data. Therefore, a second graph is shown in each case which gives the percentage of each hour for which there was data, that has safe crossing opportunities. For instance, if, for a particular hour, there were 40 minutes that satisfied the safe crossing rule but there was no data for the remaining 20 minutes, the percentage of safe crossing opportunities for that hour would be 100%. This shows that, for that particular hour, although there were only 40 out of 60 minutes with safe crossing opportunities, there was only data for 40 minutes and every minute satisfied the safe crossing rule.

The minimum headway in a particular minute across all lanes of the carriageway has also been calculated. Hourly means have been taken to give an indication of the smallest gaps between vehicles for a particular hour of the day. Appendix E shows these graphs for the first Tuesday of

June 2008 for each motorway analysed. The headway required for a safe crossing opportunity is also shown on each graph.

## **5.2 TIME TO WAIT FOR A SAFE GAP**

For every hour on each day of the week, the length of time a worker would have to wait, on average, before a safe crossing opportunity occurs has been determined. This has been calculated in seconds for each hour by dividing the number of seconds in an hour by the number of minutes per hour that had safe crossing opportunities. The graph is capped at 300 seconds (5 minutes) as the current guidance states that a worker must not have to wait more than 5 minutes for a safe crossing opportunity. The data was also averaged across all Mondays, Tuesdays etc. to show how time to wait for a safe gap varied with day of the week.

This analysis assumes that the safe crossing opportunities are evenly distributed across the hour whereas, in reality, they could occur at any time within that hour. However, these graphs still provide a good indicator of the likely wait a worker would have between crossings of the carriageway. It should also be noted that these waiting times are also likely to be underestimated as no account is taken of the minutes where data was missing.

## **5.3 MEAN FLOW**

The fourth set of graphs in Section 5.4 show the hourly mean flow (the total number of vehicles across all lanes in any minute averaged over an hour) for each day of the week. The existing guidance (Chapter 8, Operations, Section 3.5) states that for a 3-lane carriageway, the flow rate must be less than 40 vehicles per minute in order for a safe crossing opportunity to occur. These graphs can be used in conjunction with the 'mean time to wait for a safe crossing opportunity' graphs to see whether this rule still holds true (see Appendix B).

## **5.4 ANALYSIS RESULTS**

The following sections graphically illustrate the results of the analysis described in Sections 5.1 to 5.3 for each motorway.

5.4.1 M65 2-lane

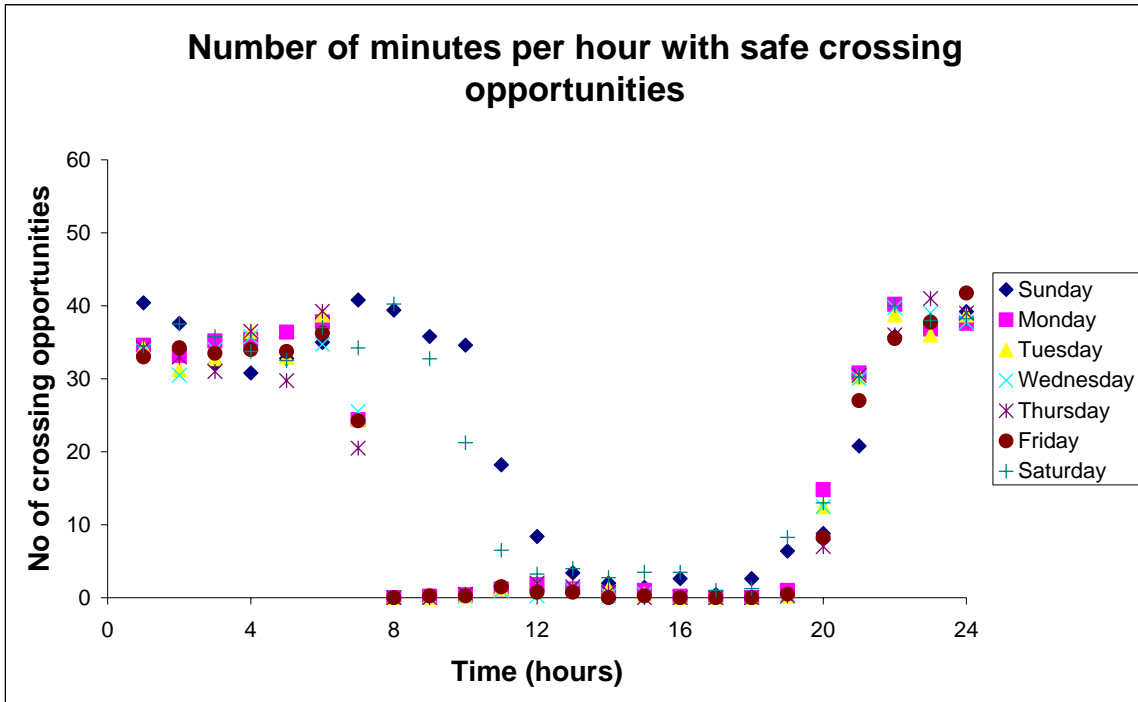


Figure 1 Graph showing the number of minutes per hour with safe crossing opportunities for each day of the week for a 2-lane stretch of the M65

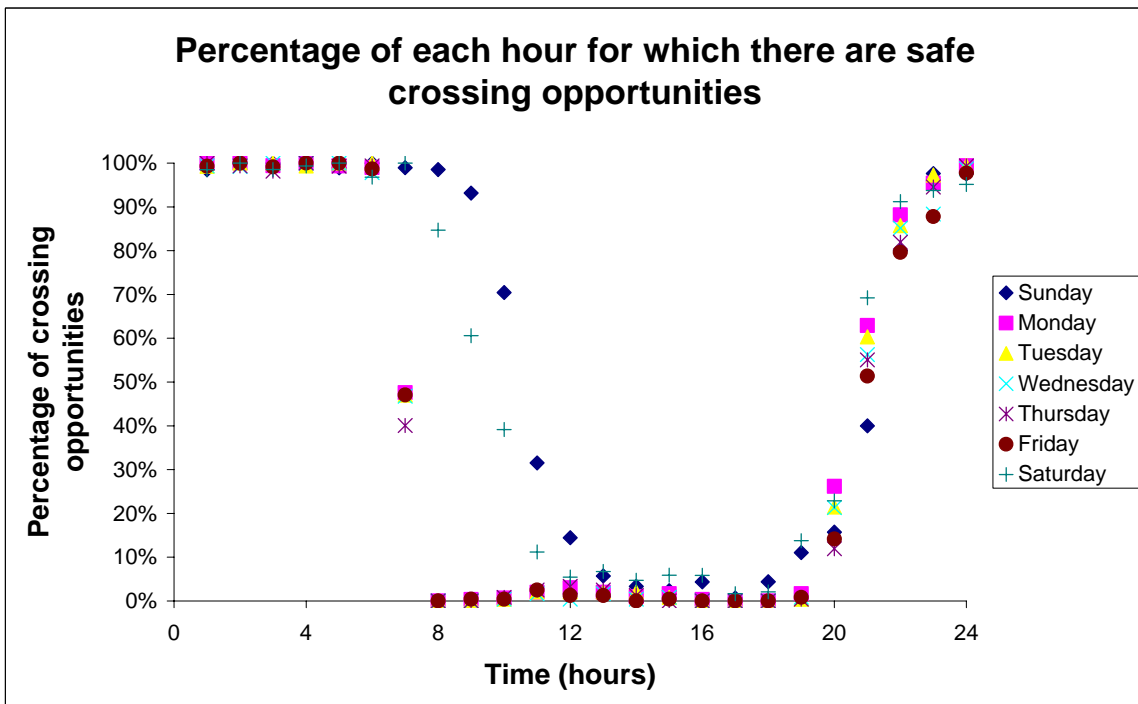
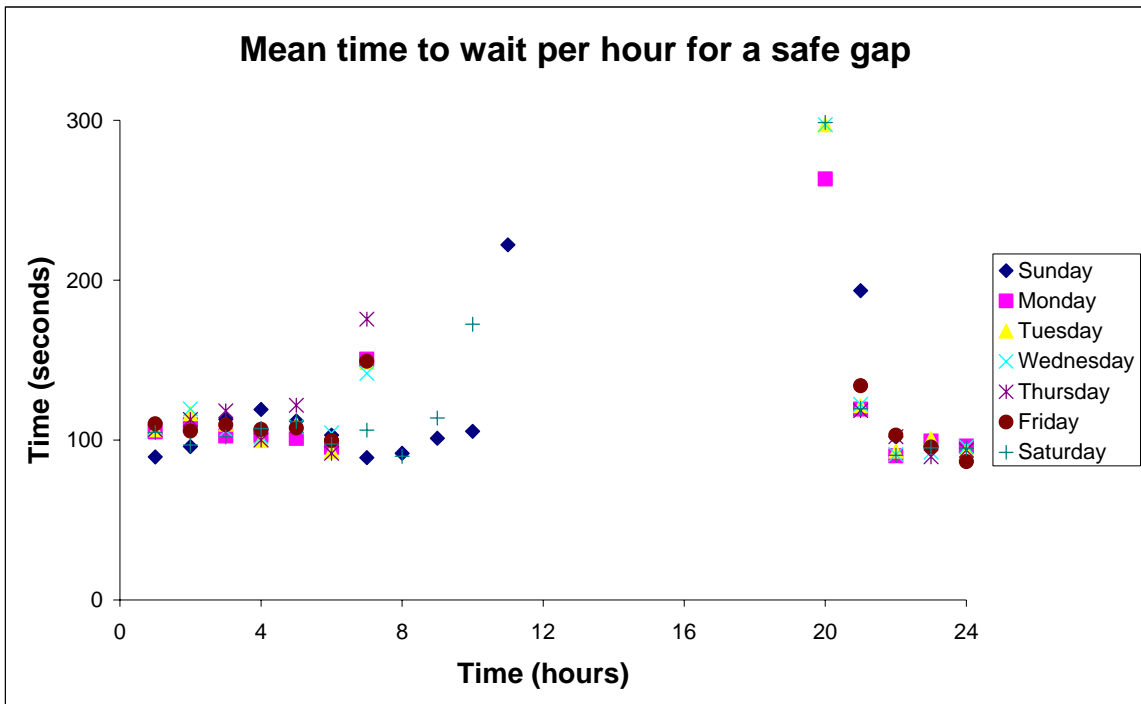
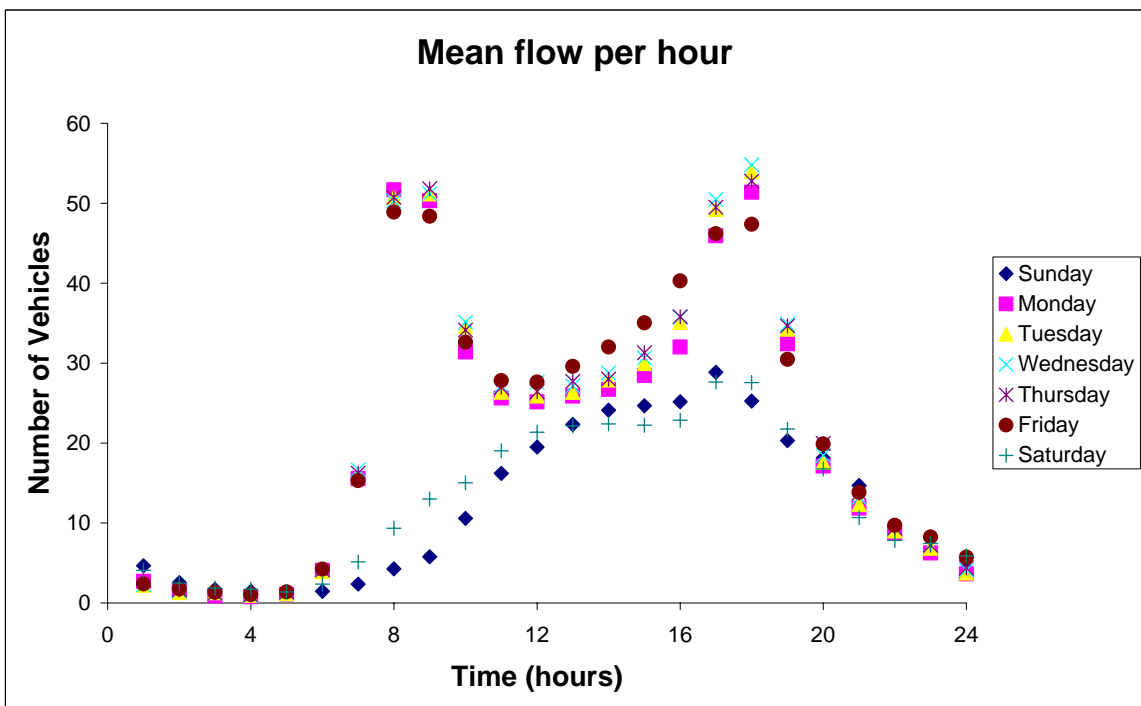


Figure 2 Graph showing the percentage of each hour for which there are safe crossing opportunities for each day of the week for a 2-lane stretch of the M65





**Figure 3** Graph showing the mean time to wait per hour for a safe crossing opportunity on a 2-lane stretch of the M65. The graph is capped at 5 minutes as this is the accepted maximum waiting time that a worker should have to wait for a safe gap



**Figure 4** Graph showing the hourly mean flow per minute for each day of the week for a 2-lane stretch of the M65

5.4.2 M65 3-lane

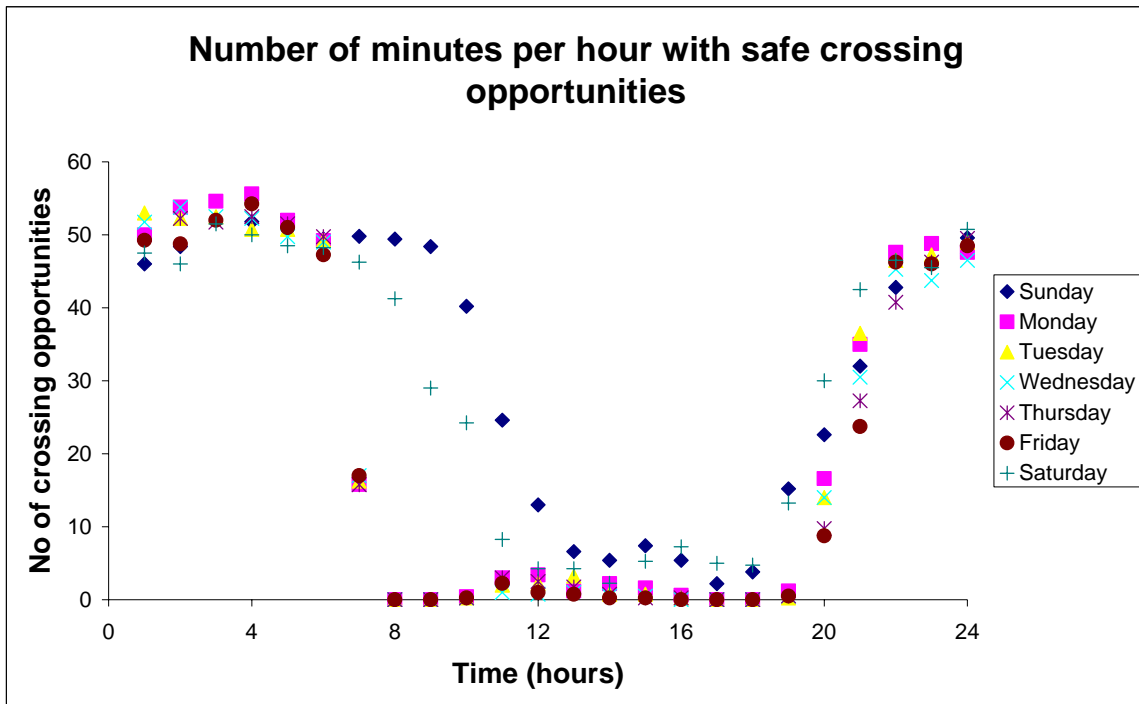


Figure 5 Graph showing the number of minutes per hour with safe crossing opportunities for each day of the week for a 3-lane stretch of the M65

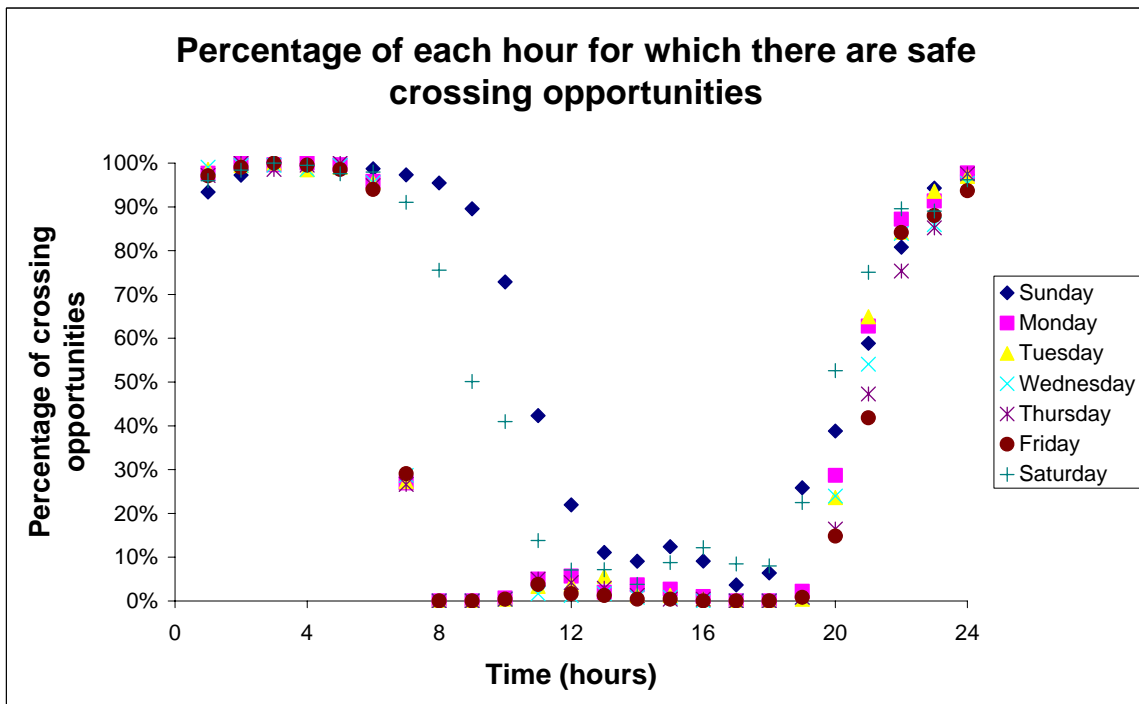
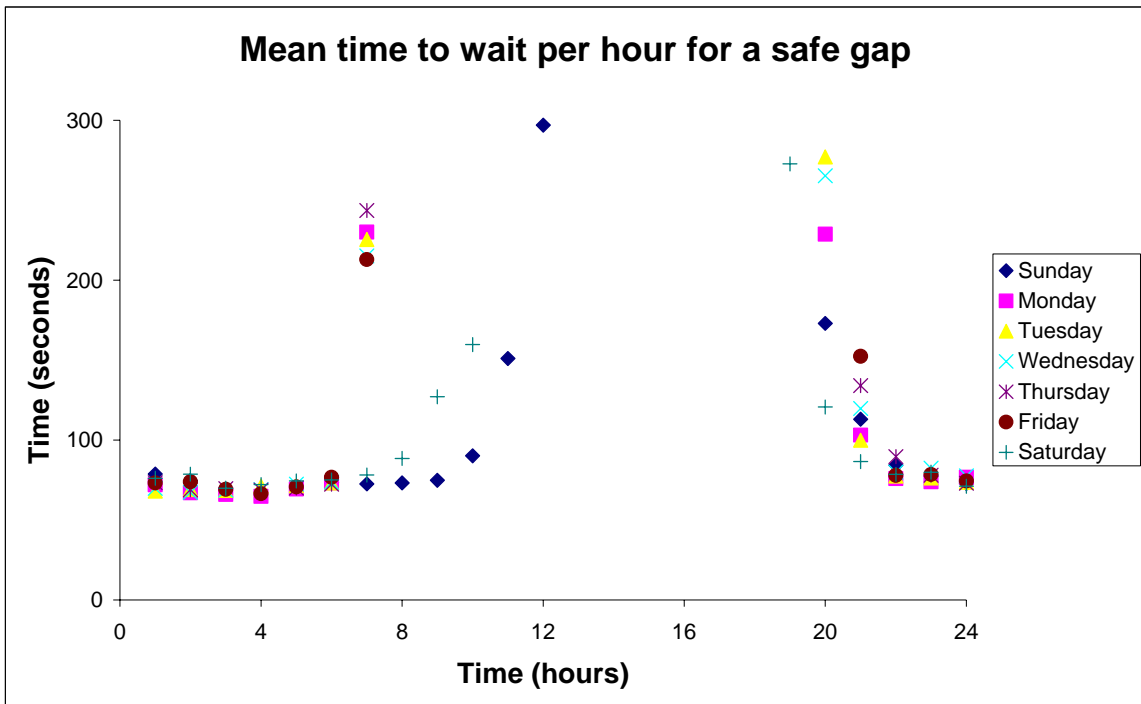
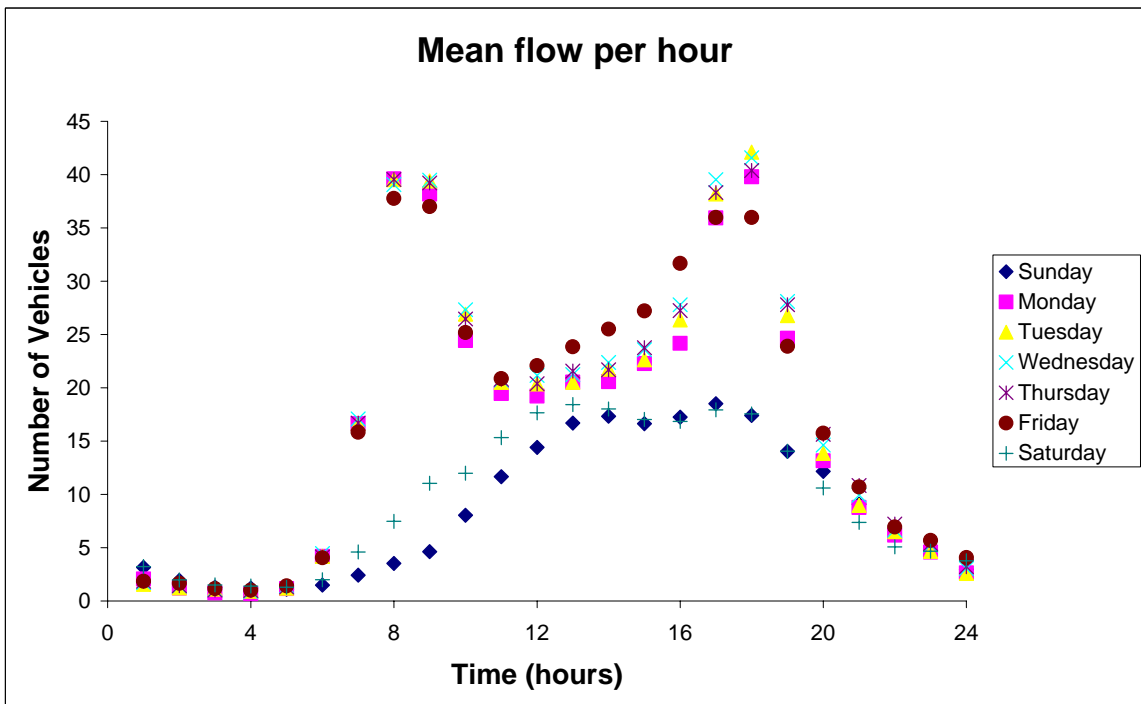


Figure 6 Graph showing the percentage of each hour for which there are safe crossing opportunities for each day of the week for a 3-lane stretch of the M65



**Figure 7** Graph showing the mean time to wait per hour for a safe crossing opportunity on a 3-lane stretch of the M65. The graph is capped at 5 minutes as this is the accepted maximum waiting time that a worker should have to wait for a safe gap



**Figure 8** Graph showing the hourly mean flow per minute for each day of the week for a 3-lane stretch of the M65

5.4.3 M55 3-lane

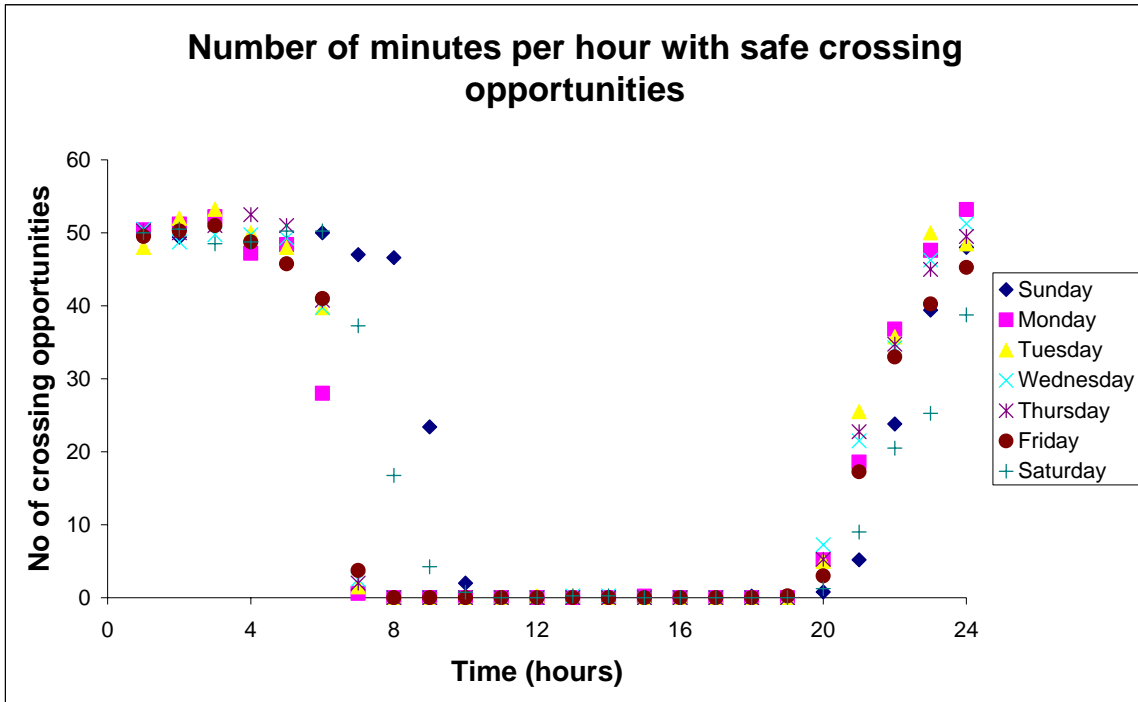


Figure 9 Graph showing the number of minutes per hour with safe crossing opportunities for each day of the week for a 3-lane stretch of the M55

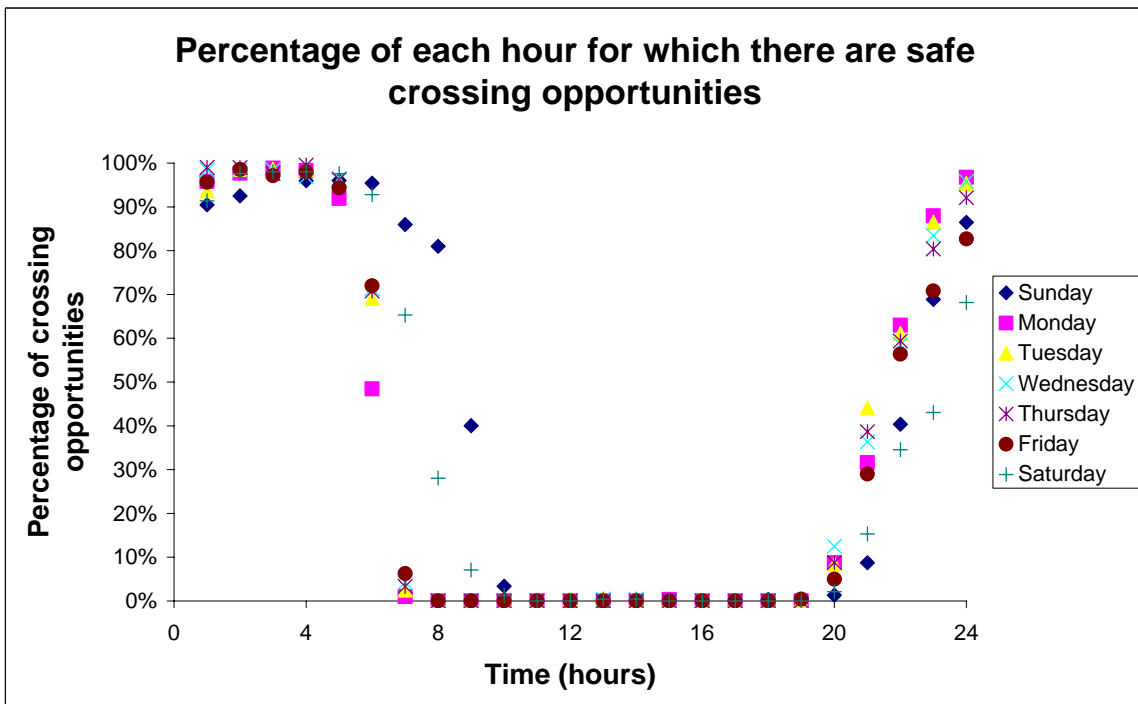


Figure 10 Graph showing the percentage of each hour for which there are safe crossing opportunities for each day of the week for a 3-lane stretch of the M55





































assumed that the '3 second per lane' rule was not met. In the case of the three and four-lane motorways, if data for one lane was missing but the other lanes satisfied the rule, then it was assumed the missing lane also satisfied the rule. If data for two or more lanes was missing then it was assumed that the rule was not satisfied.

10. For the two-lane motorways, a sheet was produced indicating when data was missing for either or both of the lanes. For the three-lane motorways, this sheet indicated when data was missing for two or more of the lanes whilst, for the four-lane motorways, this was divided into two sheets; one showing when data was missing for two lanes and the other indicating when it was missing for three or more lanes.
11. In all cases, the information gathered from step 10 was totalled up by the hour to show hourly rates of missing data for each day of the month.
12. The total number of safe crossing occasions (i.e. the number of occasions that the '3 second per lane' rule was satisfied) was then totalled up for each hour of the day.
13. The average time between each safe crossing occasion for each hour was then calculated. If there were no safe crossing incidents in an hour then this was set to 3600 to indicate that the whole hour passed without a safe crossing occasion occurring.
14. Percentages were then calculated to indicate what proportion of each hour was safe to cross. The missing data recorded in steps 11 and 12 above was taken into account so that the percentages were worked out on the basis of the total number of minutes in each hour for which reliable data was available.
15. The flow data was then input for each of the lanes.
16. As in the case of the headway data, if data was missing then a -1 appeared in the field. A sheet was produced that put in a value of 500 if data for one lane was missing, 1000 if two lanes were missing, 1500 if 3 lanes were missing and 2000 if four lanes were missing (these values were used to make it easier to visually spot large areas of missing data). If there was no missing data then a value of 0 was used.
17. The values in step 16 were then totalled for each hour and divided by 500 to give the total number of missing data points. It was shown that, if flow data is missing for one lane, then it is missing for all of them.
18. To correct for the -1s, new sheets of flow data were produced with 0 substituted for -1.
19. The next step was to total the corrected flow across all three lanes for each minute of the day.
20. A table was then produced of mean flow per minute across each hour. This mean took into account the missing data by dividing by the minutes in each hour for which data was available.
21. The total number of safe crossing occasions in each hour was then meaned for each day of the week. In June 2008 there were 5 Sundays and Mondays whilst there were 4 of the rest of the days of the week. This data was then plotted as a graph of number of crossing opportunities against time.
22. The mean time between each safe crossing was then meaned for each day of the week. This was plotted as number of minutes between each safe crossing occasion against the hour of the day. The y-axis was limited to 300 seconds (5 minutes) as the current guidance states that no one should have to wait longer than 5 minutes for a safe opportunity to occur.
23. The mean flow for each day of the week was then calculated for each hour of the day and this was then plotted.
24. Plots of flow against headway were plotted for each day of the week and across each hour of the day.
25. A table was then produced indicating what the mean flow rate per minute was in each hour when the '3 second per lane' rule was satisfied for 20% of that hour. In other words, if the mean time to wait for a safe crossing opportunity was 5 minutes or less in a particular hour, what was the mean flow per minute in that hour.

26. The mean minimum headway across all three lanes was then calculated for each hour on the first Tuesday of the month i.e. the 3<sup>rd</sup> June 2008. Standard deviations were also calculated and these were plotted

NB: For the M2 and the M25 between junctions 3 and 4, all data was missing for the first 11 hours of 24<sup>th</sup> June 2008. The average plots per day of the week were therefore calculated for the 3 days of data that did exist during these hours.

NB: Data was missing for a continuous stretch of 80 minutes from 13.13 on 12<sup>th</sup> June 2008 for the M55. The rest of the data for this motorway indicated that the '3 second per minute' rule was never met at this time of day and so it was considered safe to ignore this section of information.

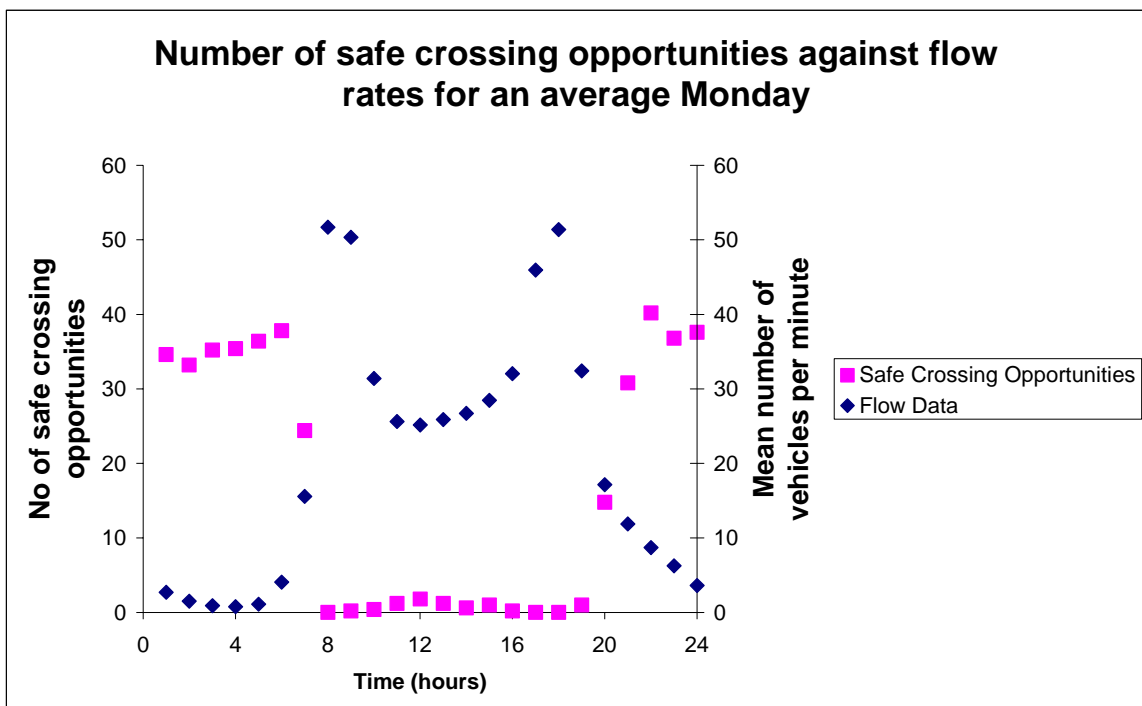
One extra check was performed on some of the motorways to see if the way of averaging the flow affected the results of the analysis. The flow per lane was totalled for each hour of the day and then divided by the number of minutes in that hour (taking into account missing data points). The values across all the lanes were then added together and a percentage difference between this and the values obtained from step 21 was calculated. This showed a negligible difference for all hours (majority < 1% difference, largest difference 5%).

## 8 APPENDIX B – RELATIONSHIP BETWEEN SAFE GAPS AND TRAFFIC FLOW RATE

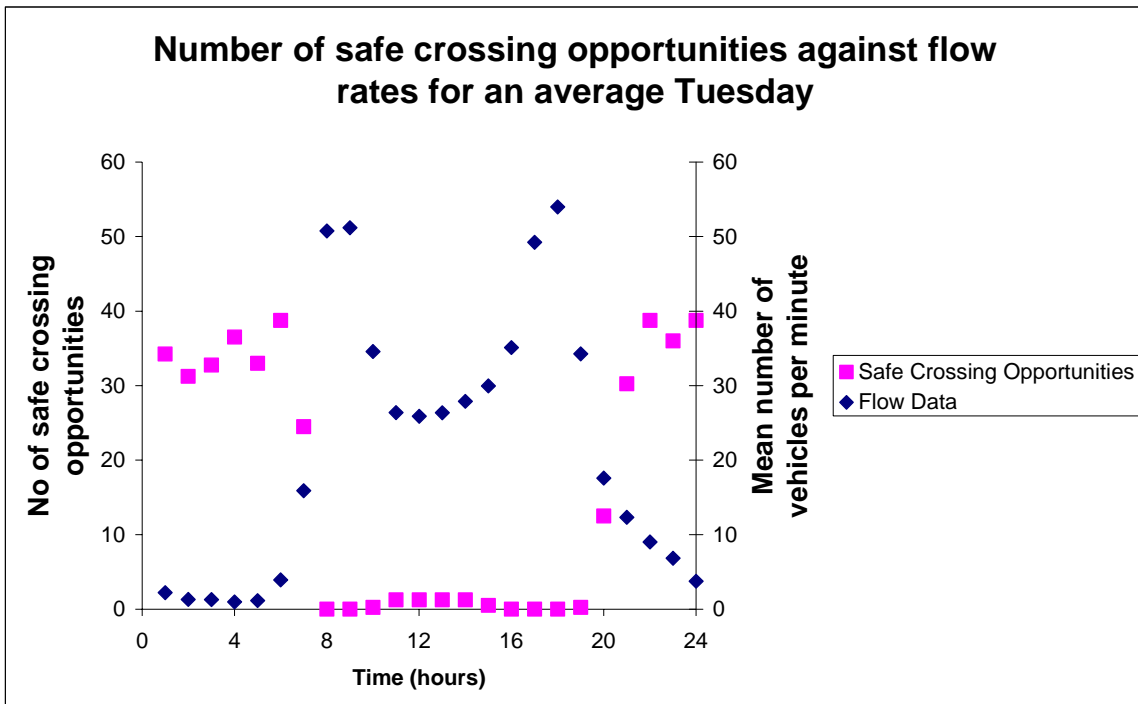
The following graphs illustrate the relationship between the hourly mean flow per minute (number of cars per minute over all lanes), averaged over each day of the week, and the number of safe crossing opportunities each hour. There is one graph for each day of the week using the mean values for a particular day. As expected, as the traffic flow increases, the number of safe crossing opportunities decreases.

NB The scales on these graphs vary according to the maximum mean flow rate for the motorway concerned.

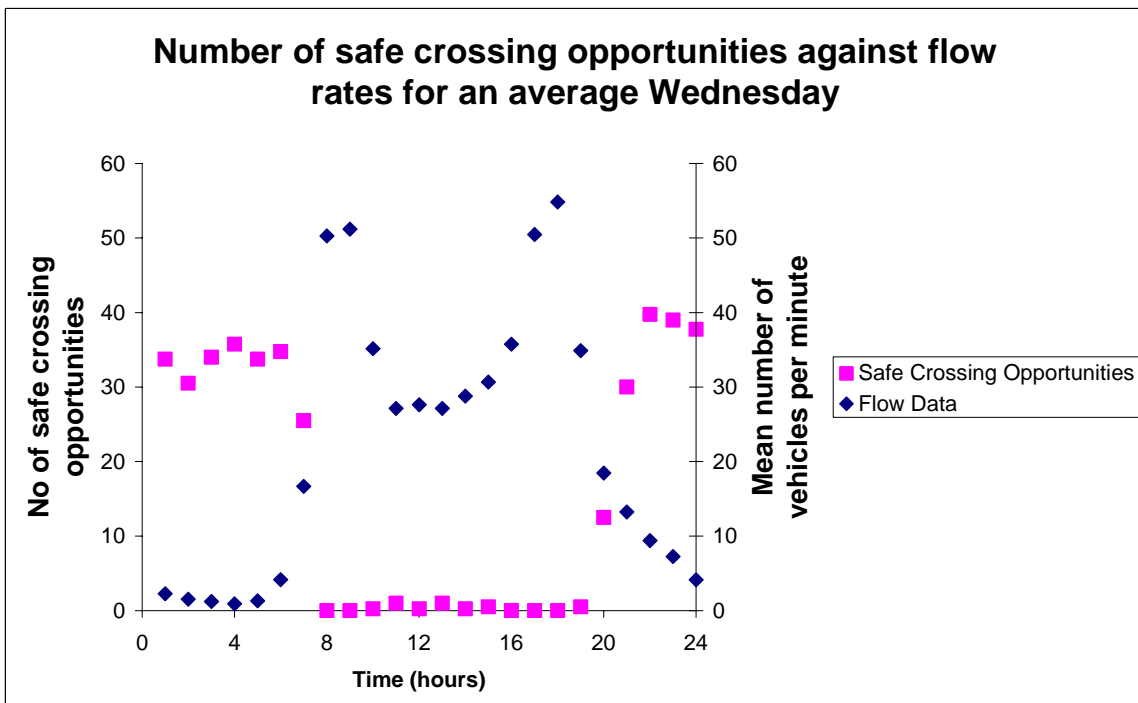
### 8.1 M65 2-LANE



**Figure B1** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Monday on a 2-lane stretch of the M65



**Figure B2** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Tuesday on a 2-lane stretch of the M65



**Figure B3** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Wednesday on a 2-lane stretch of the M65







8.2 M65 3-LANE

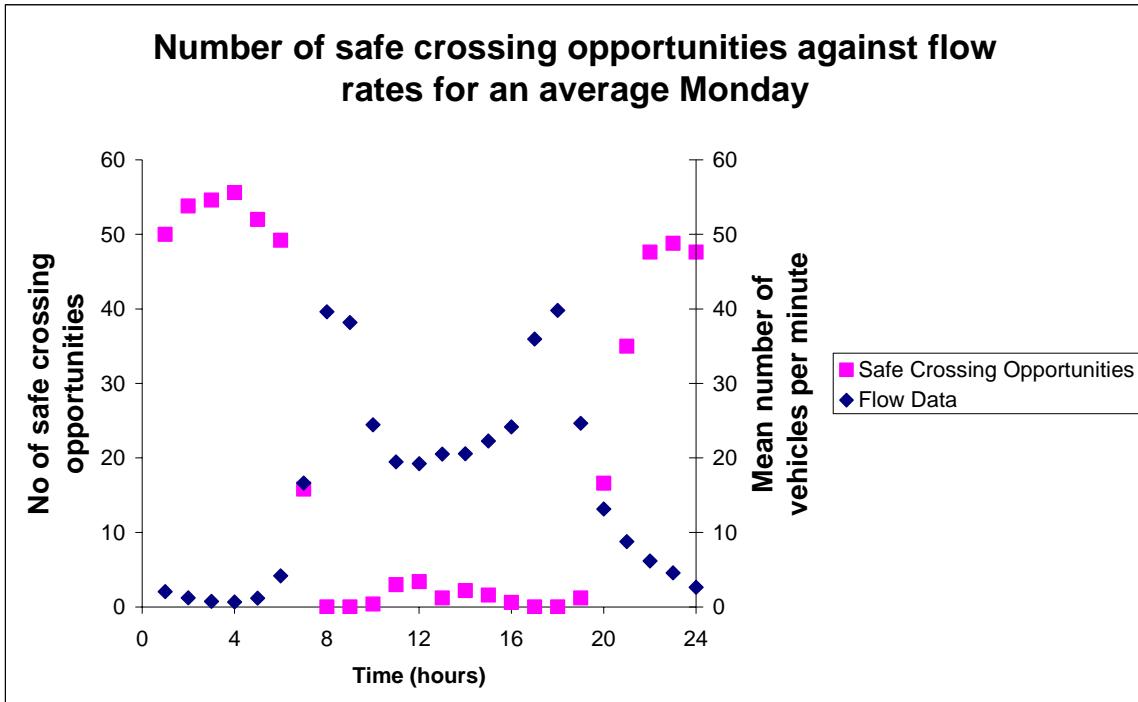


Figure B8 Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Monday on a 3-lane stretch of the M65

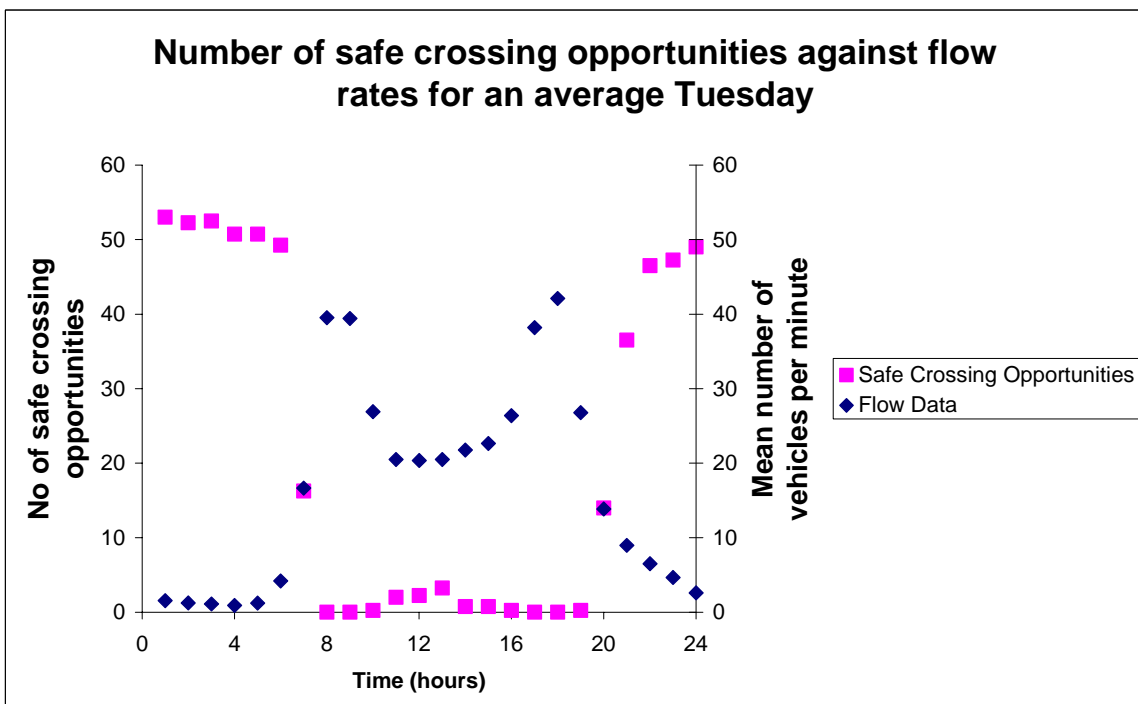
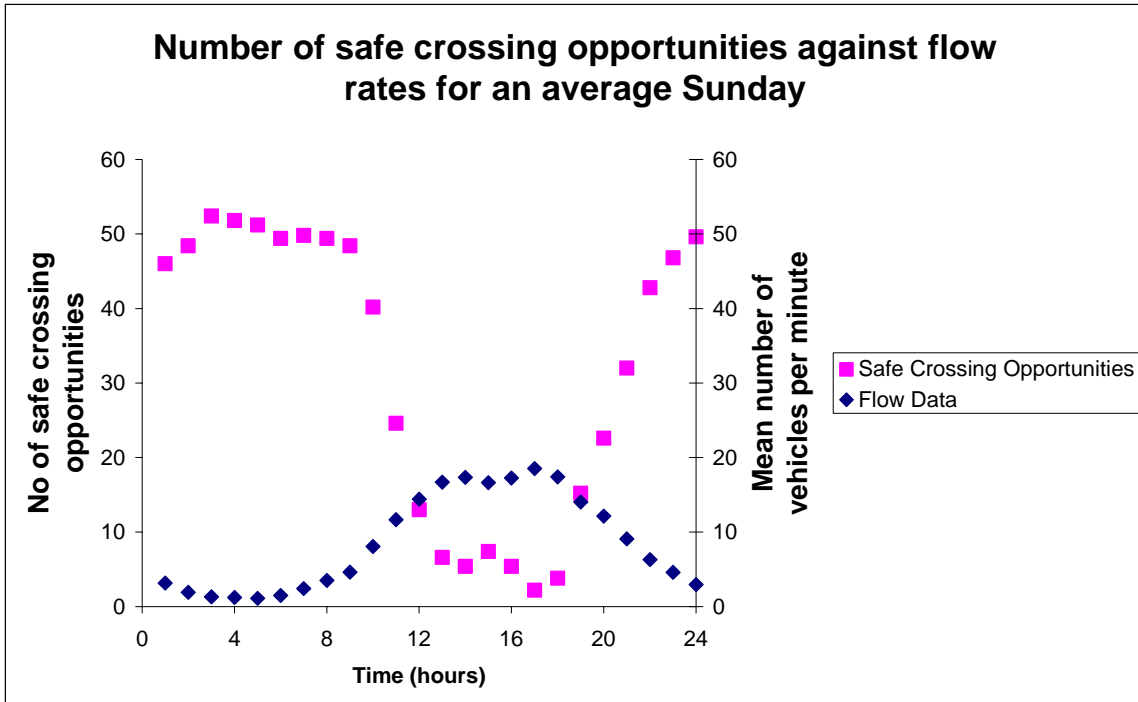


Figure B9 Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Tuesday on a 3-lane stretch of the M65

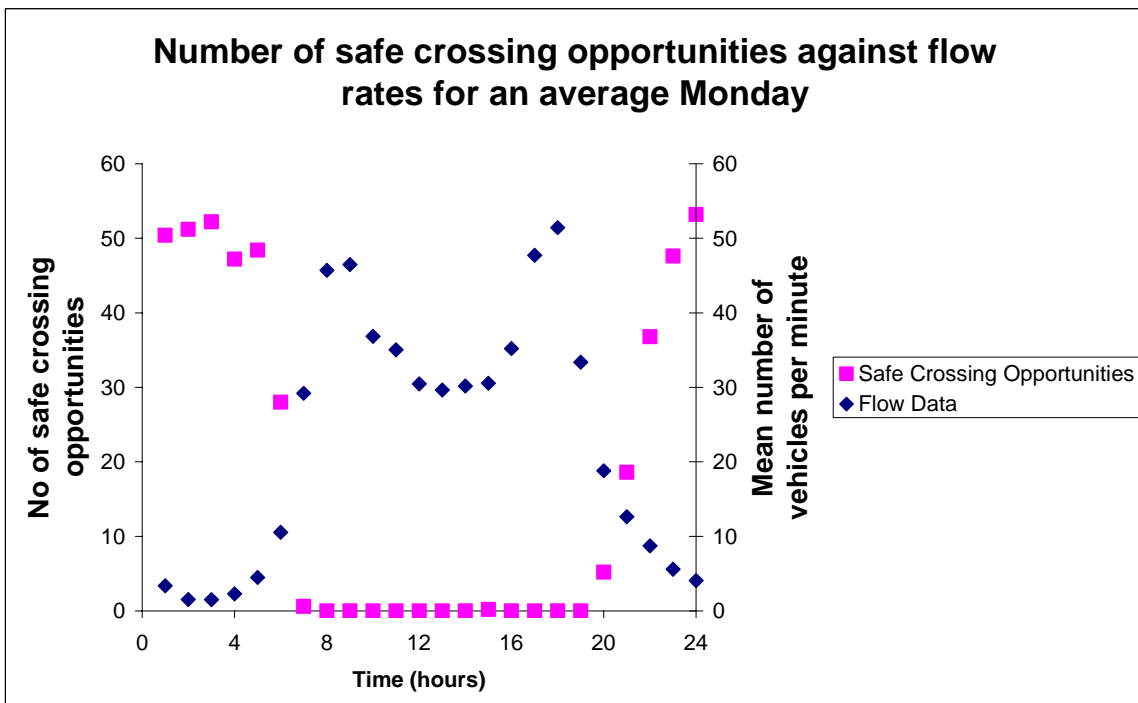




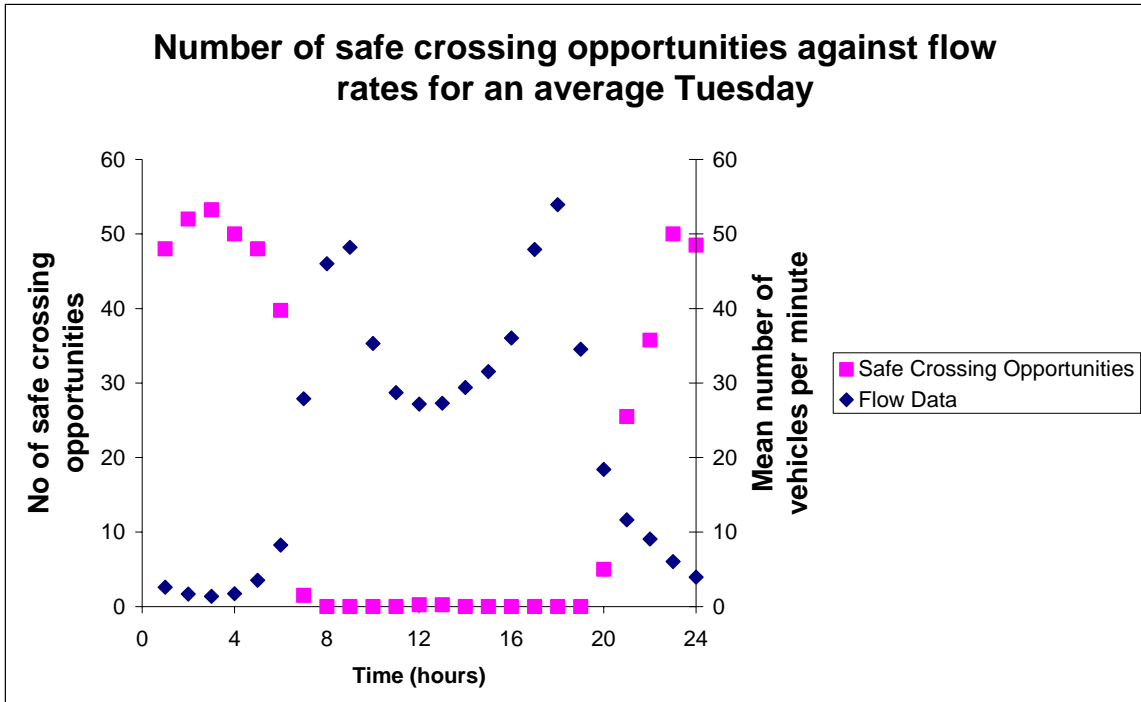


**Figure B14** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Sunday on a 3-lane stretch of the M65

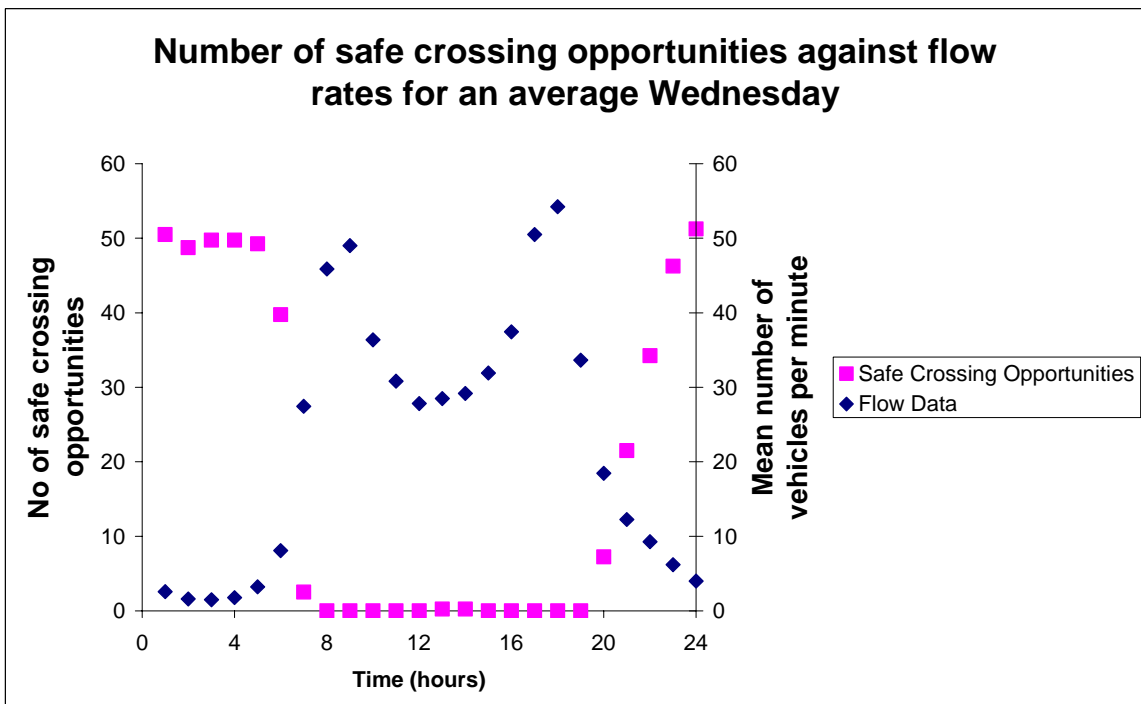
**8.3 M55 3-LANE**



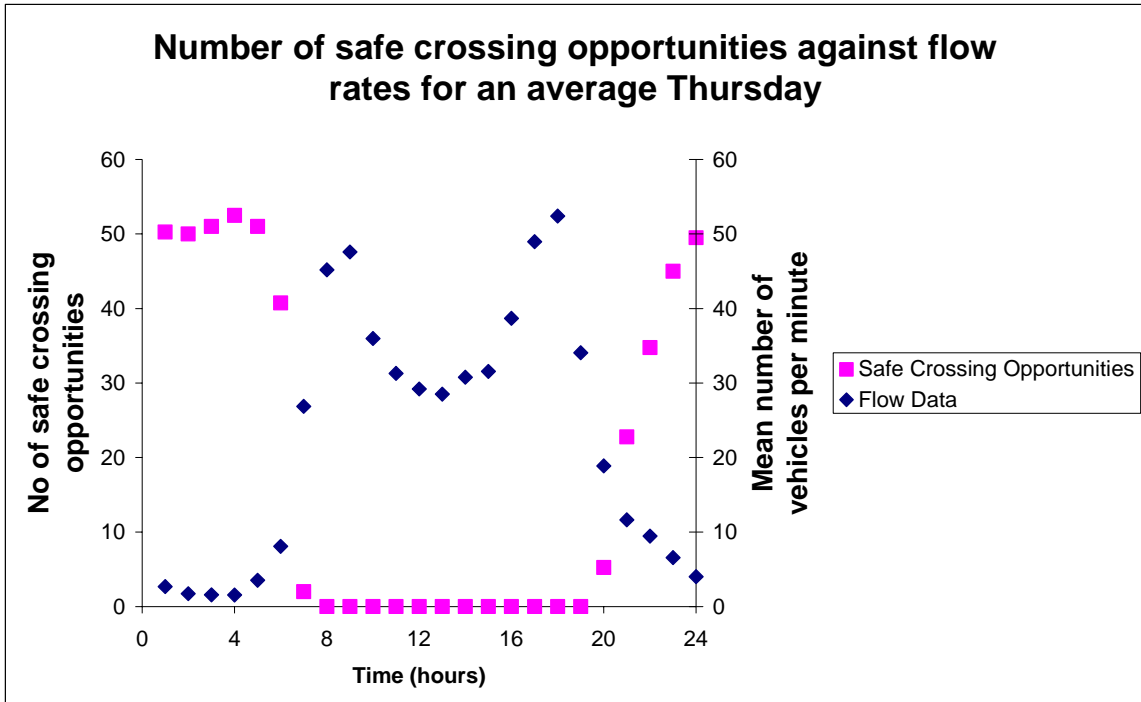
**Figure B15** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Monday on a 3-lane stretch of the M55



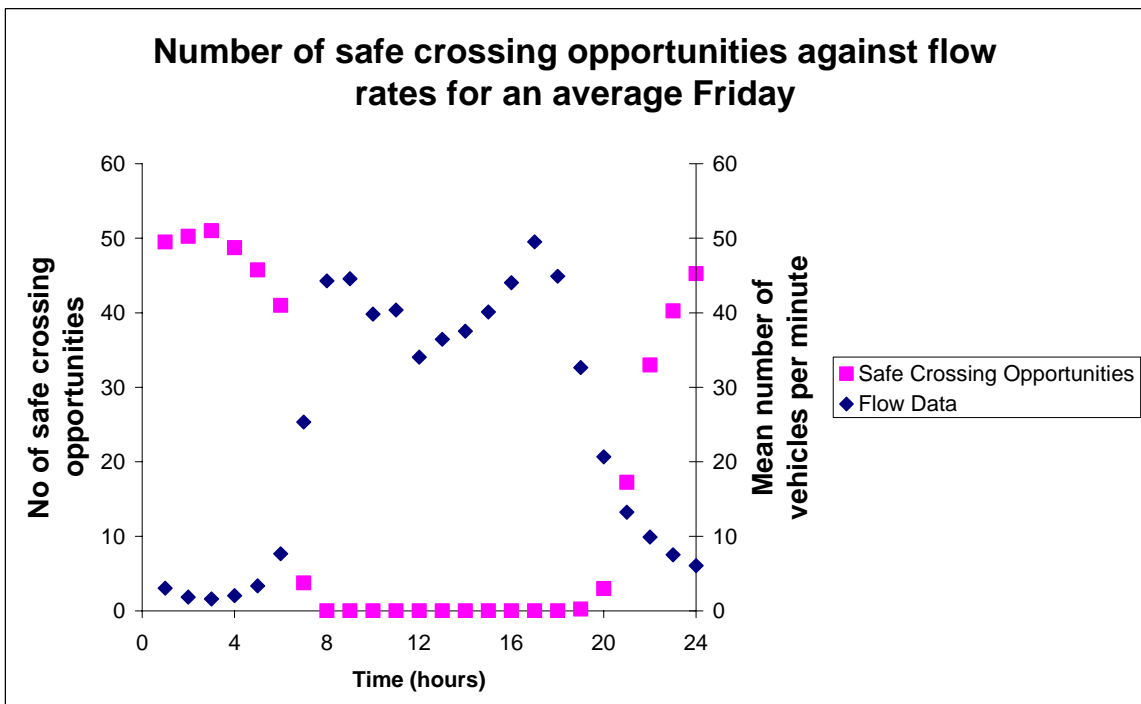
**Figure B16** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Tuesday on a 3-lane stretch of the M55



**Figure B17** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Wednesday on a 3-lane stretch of the M55

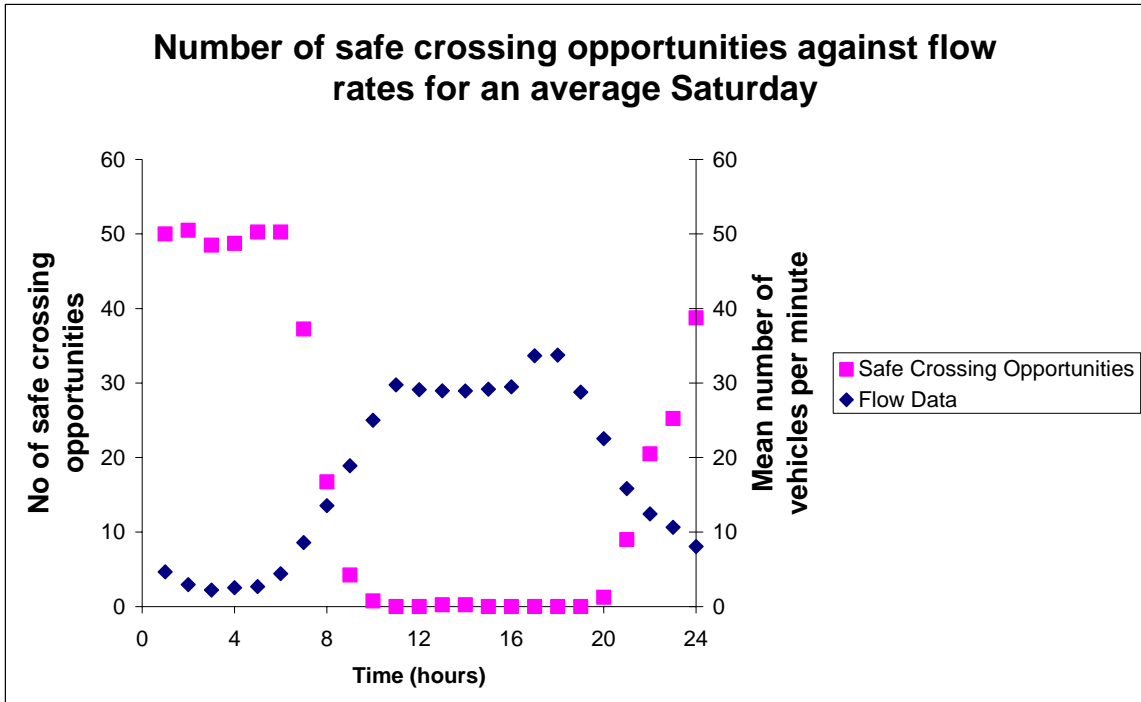


**Figure B18** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Thursday on a 3-lane stretch of the M55

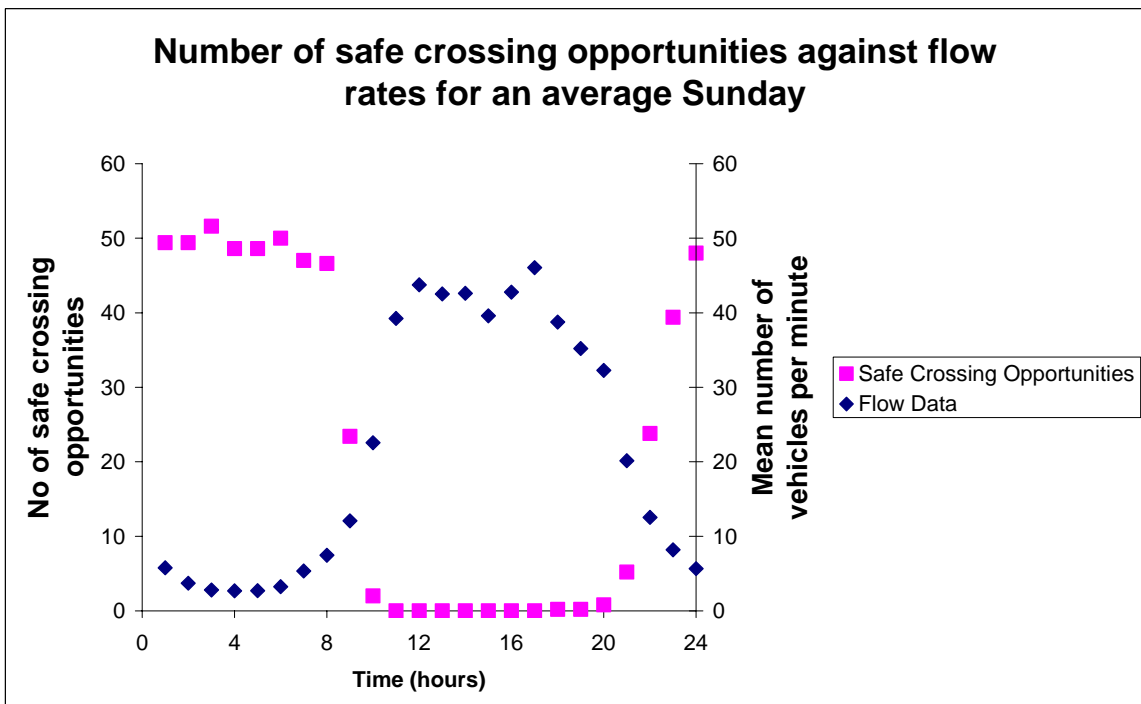


**Figure B19** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Friday on a 3-lane stretch of the M55



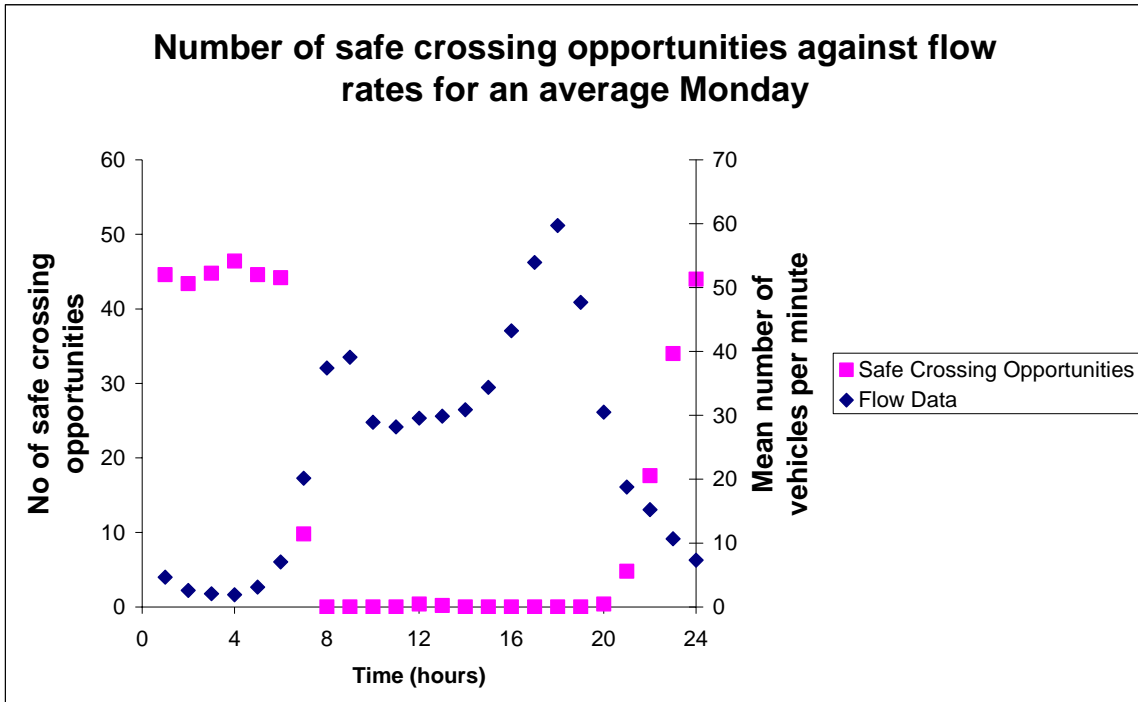


**Figure B20** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Saturday on a 3-lane stretch of the M55

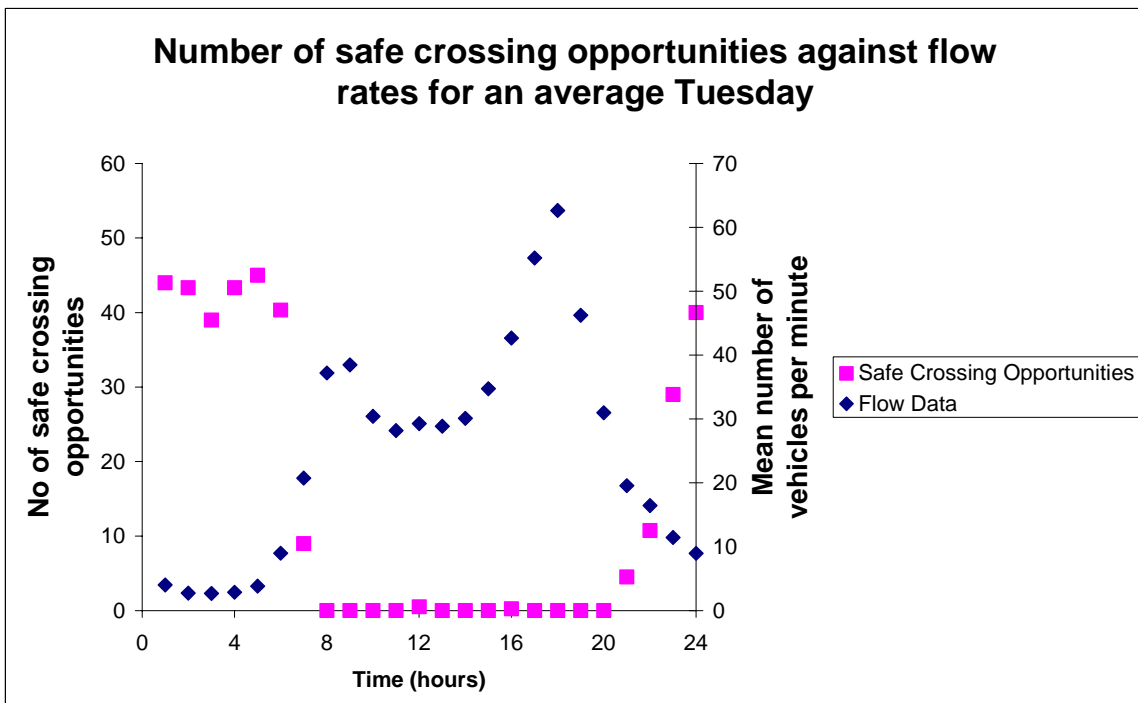


**Figure B21** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Sunday on a 3-lane stretch of the M55

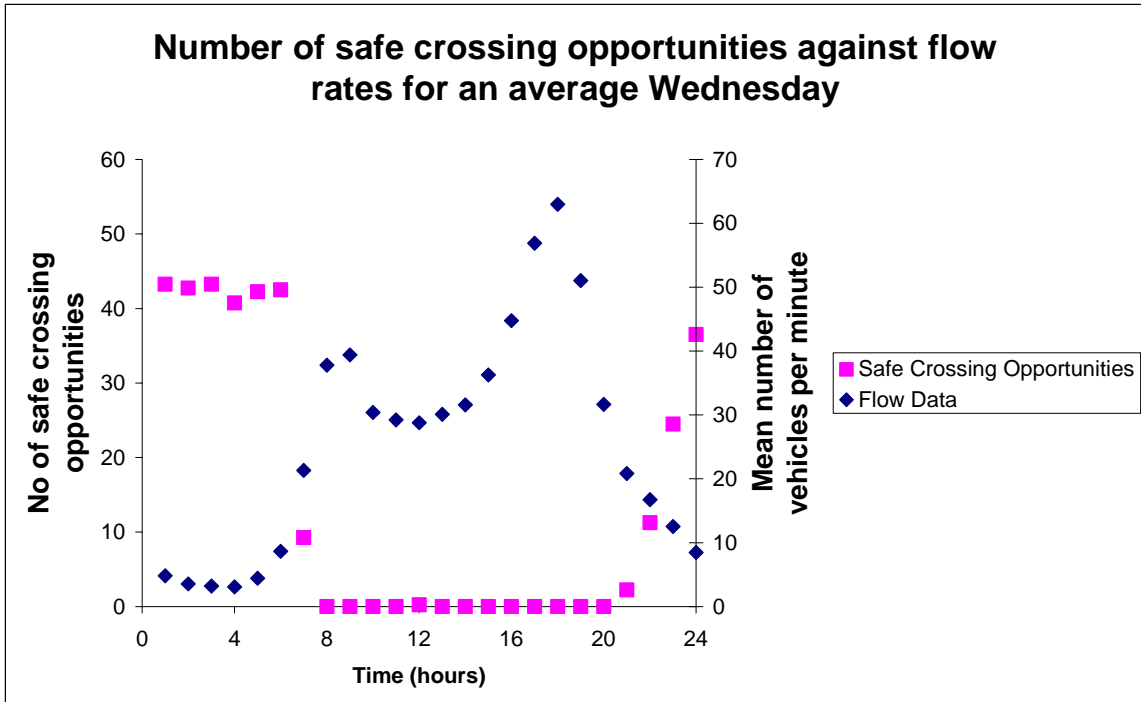
8.4 M2 3-LANE



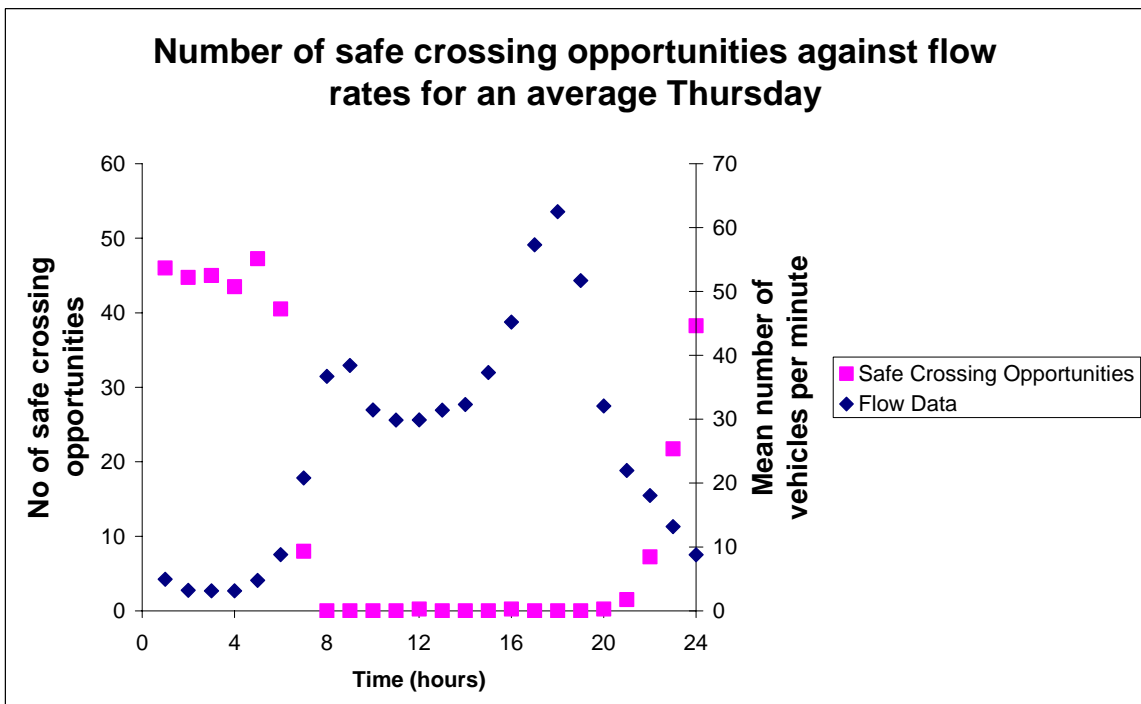
**Figure B22** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Monday on a 3-lane stretch of the M2



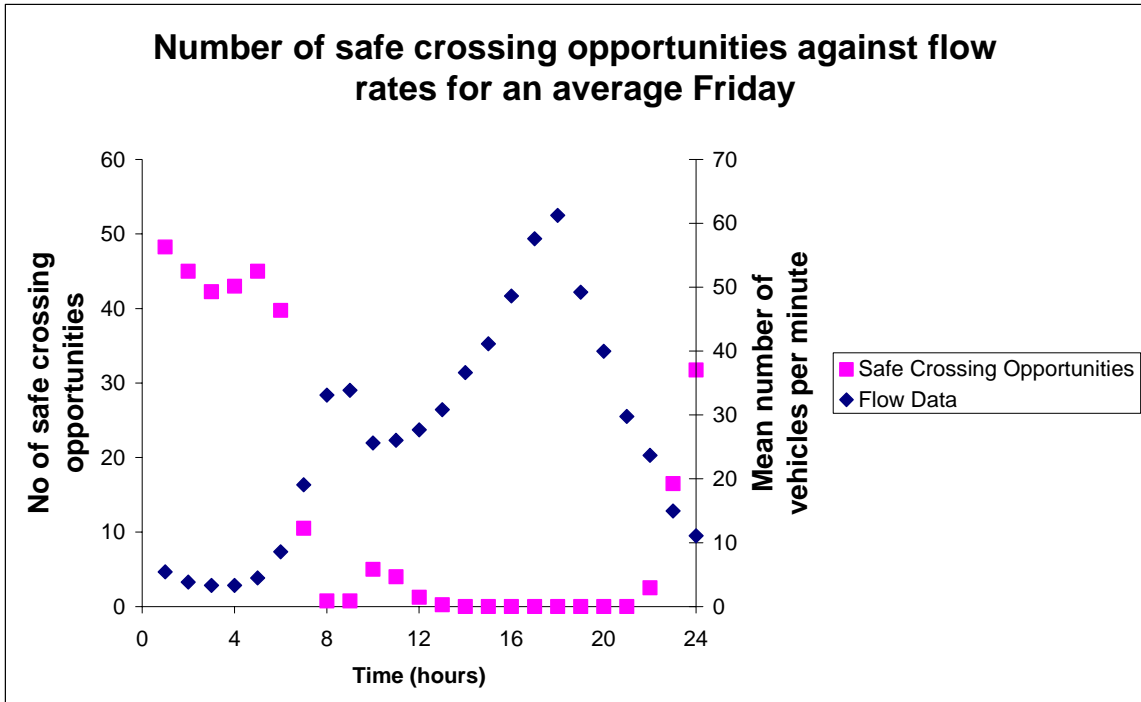
**Figure B23** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Tuesday on a 3-lane stretch of the M2. (No data for first 11 hrs of the 24/6/08 so, for these hours, data was averaged over 3 days, not 4)



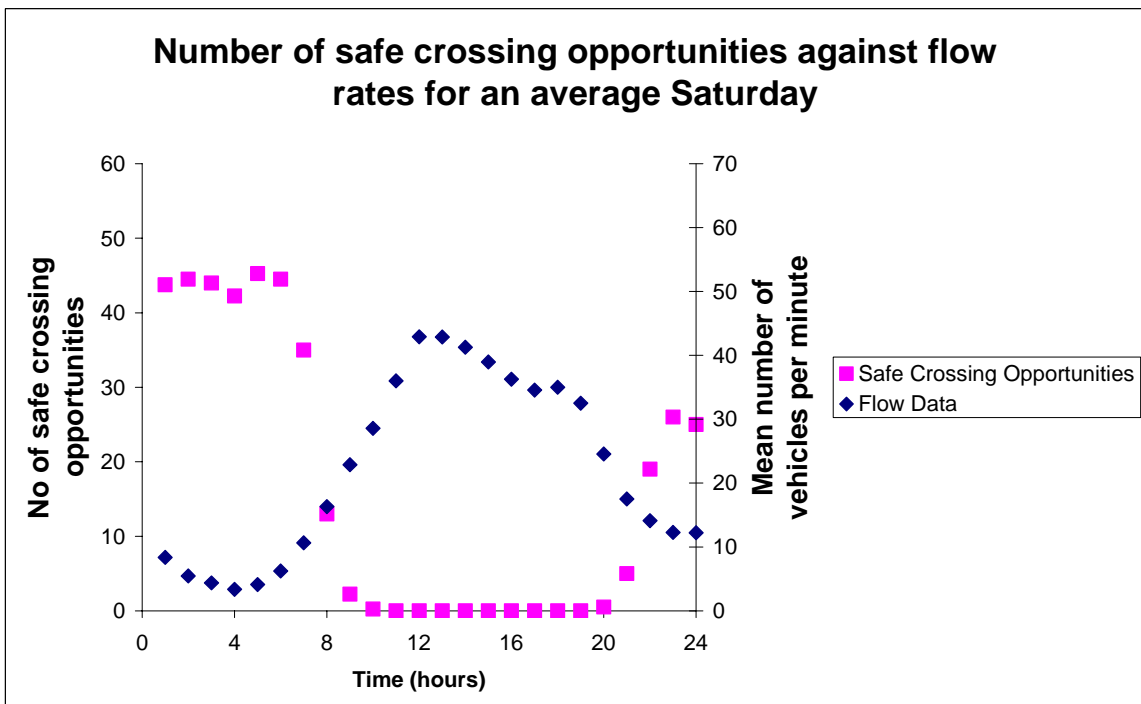
**Figure B24** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Wednesday on a 3-lane stretch of the M2



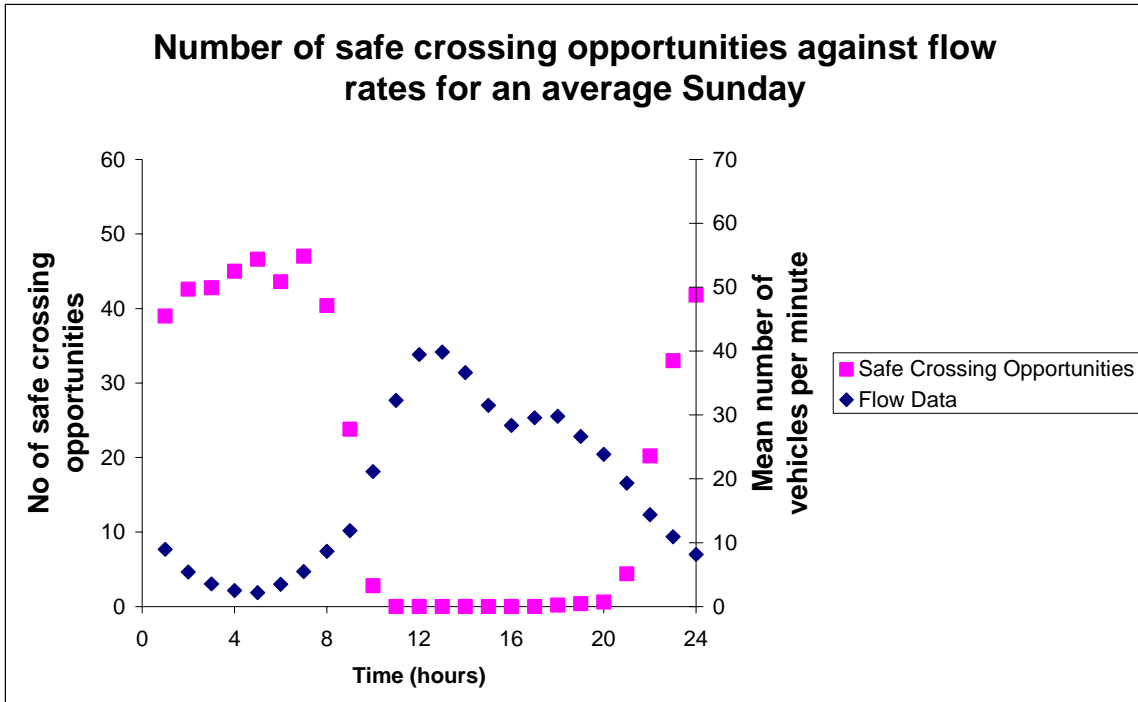
**Figure B25** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Thursday on a 3-lane stretch of the M2



**Figure B26** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Friday on a 3-lane stretch of the M2

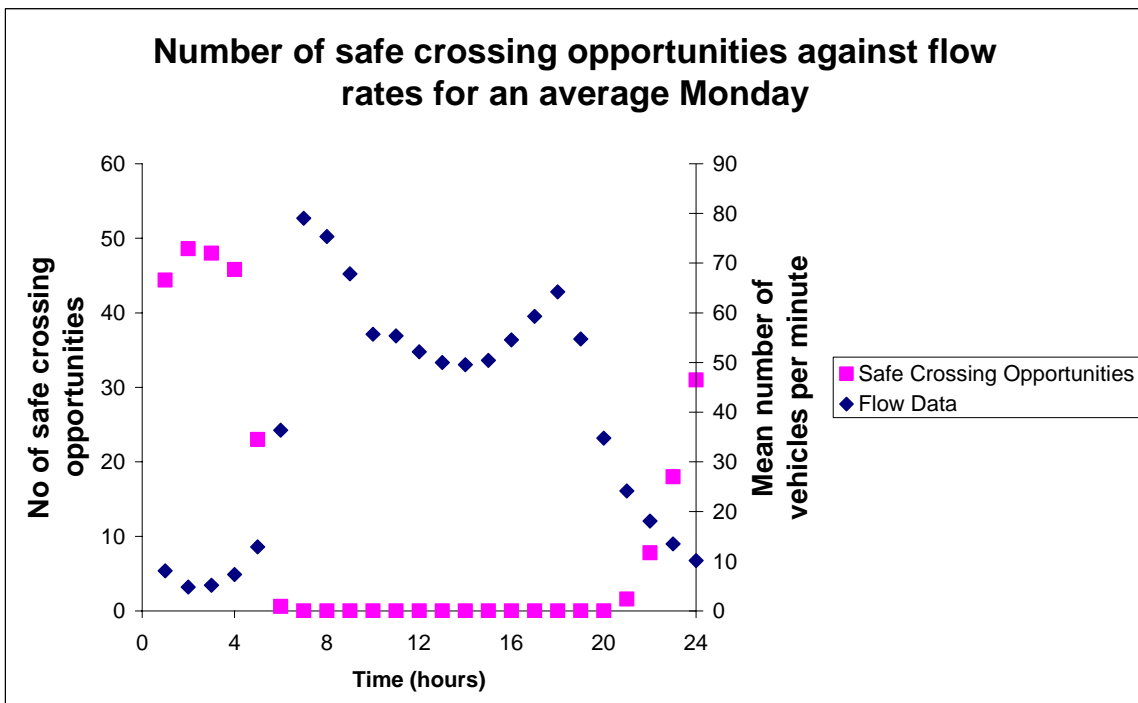


**Figure B27** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Saturday on a 3-lane stretch of the M2

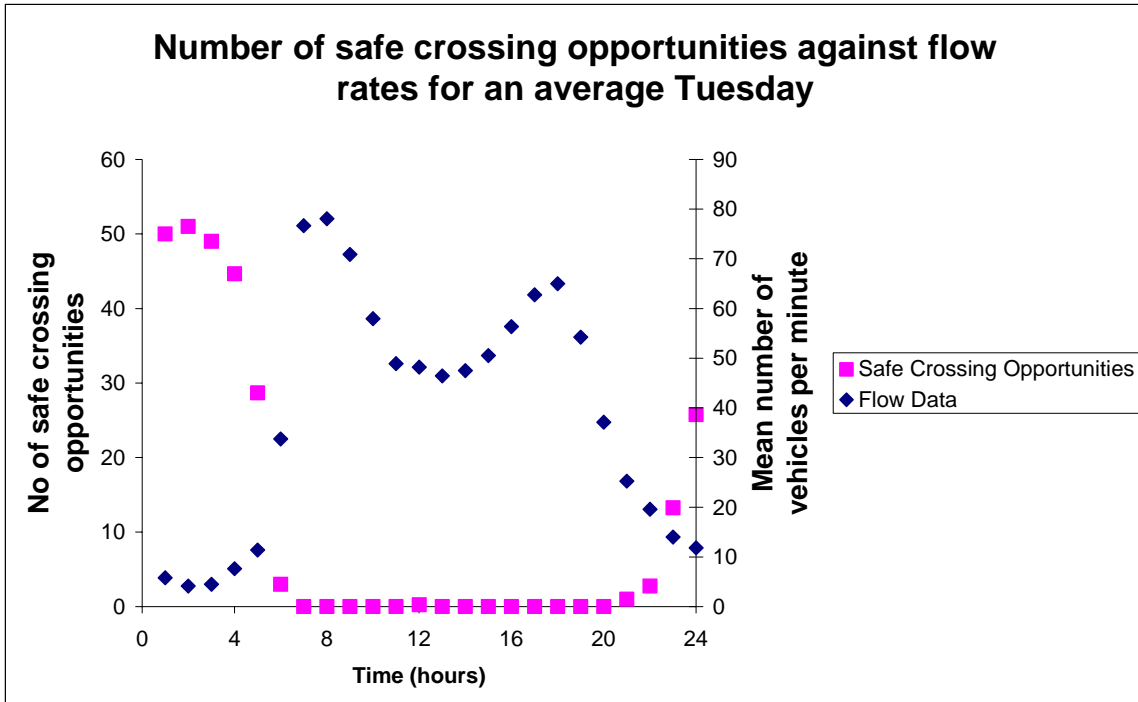


**Figure B28** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Sunday on a 3-lane stretch of the M2

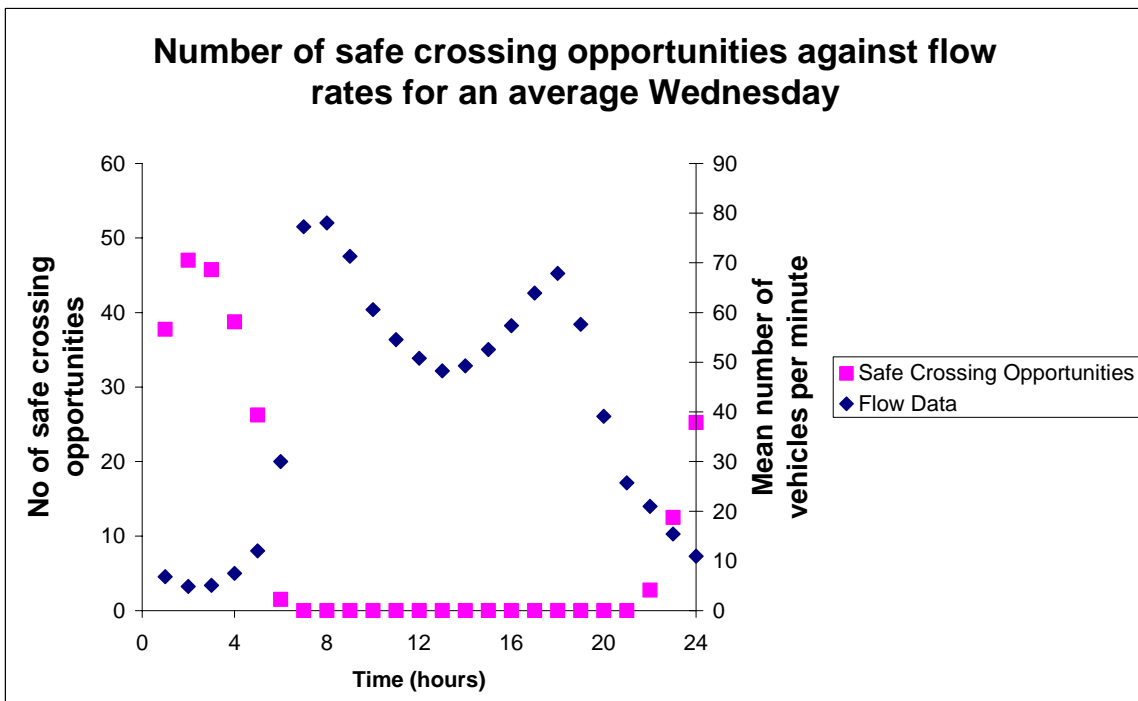
**8.5 M25 3-LANE**



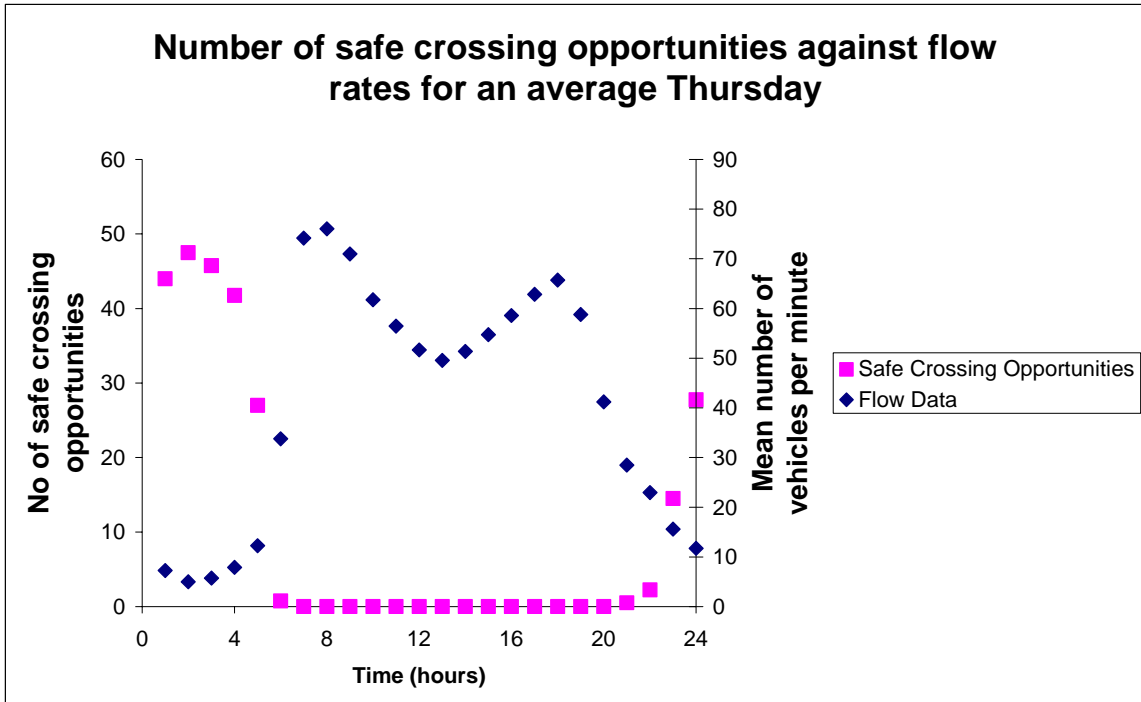
**Figure B29** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Monday on a 3-lane stretch of the M25



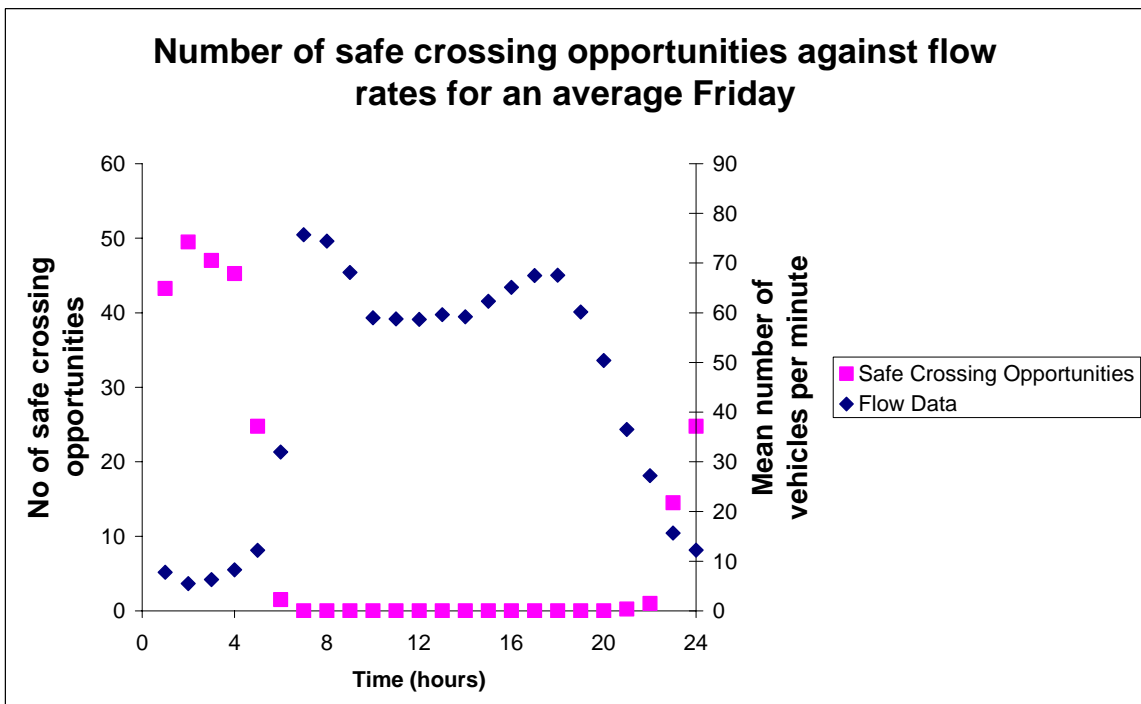
**Figure B30** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Tuesday on a 3-lane stretch of the M25. (No data for first 11 hrs of the 24/6/08 so, for these hours, data was averaged over 3 days, not 4)



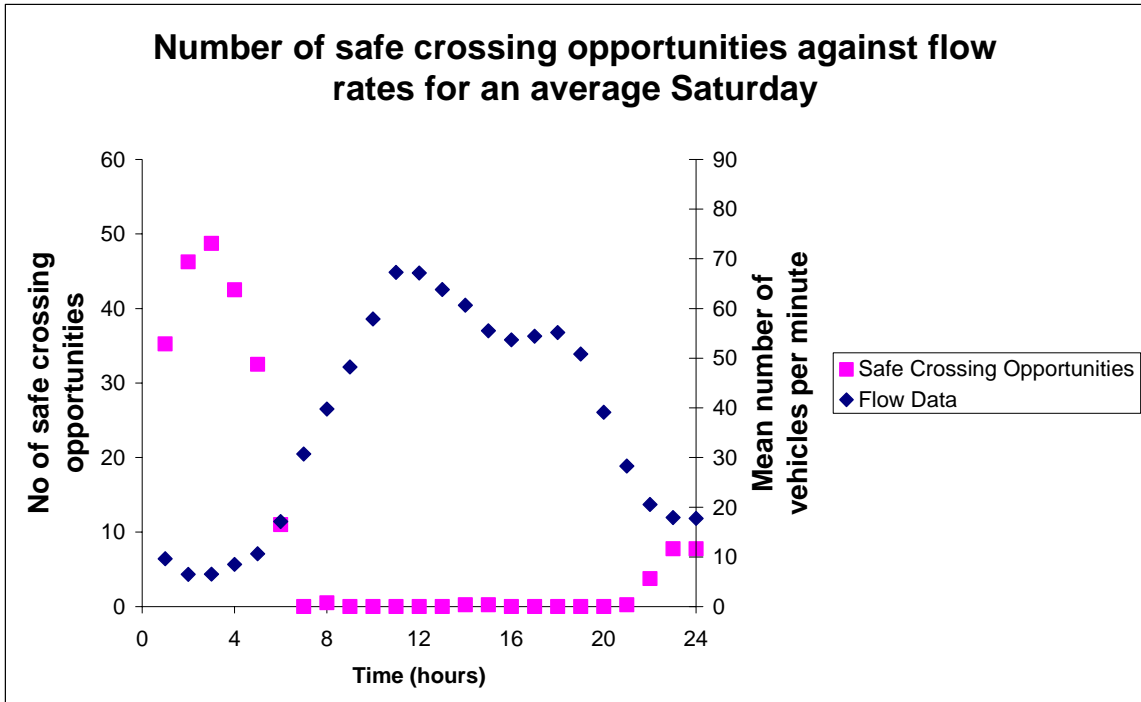
**Figure B31** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Wednesday on a 3-lane stretch of the M25



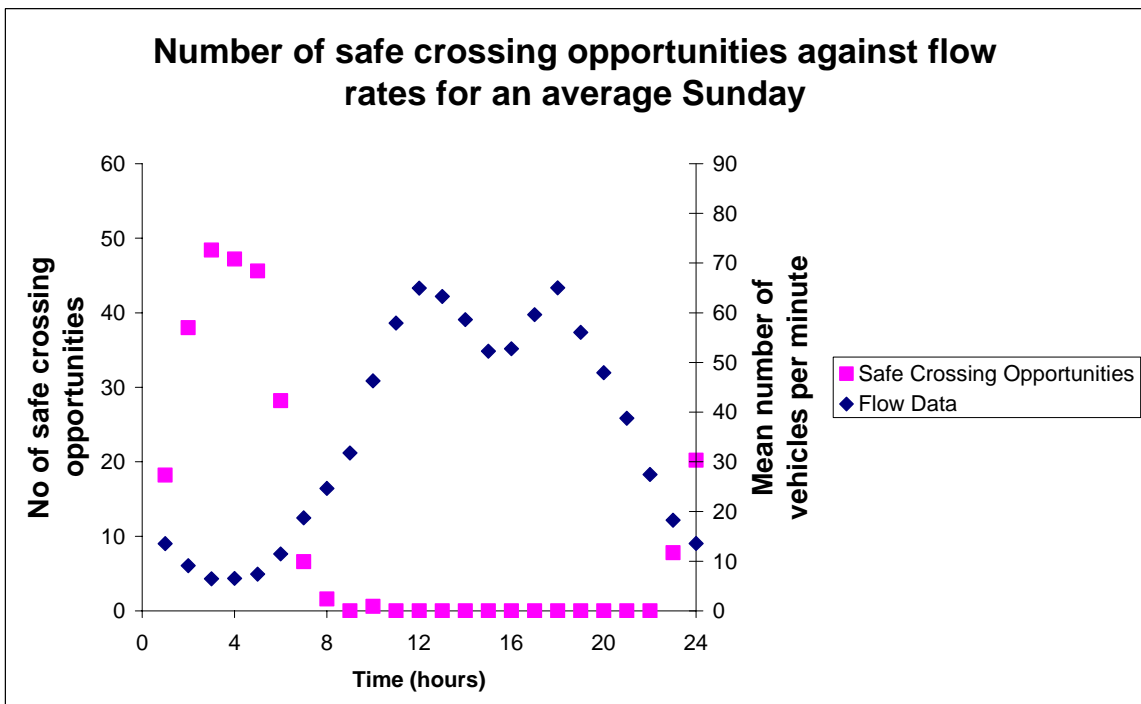
**Figure B32** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Thursday on a 3-lane stretch of the M25



**Figure B33** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Friday on a 3-lane stretch of the M25



**Figure B34** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Saturday on a 3-lane stretch of the M25

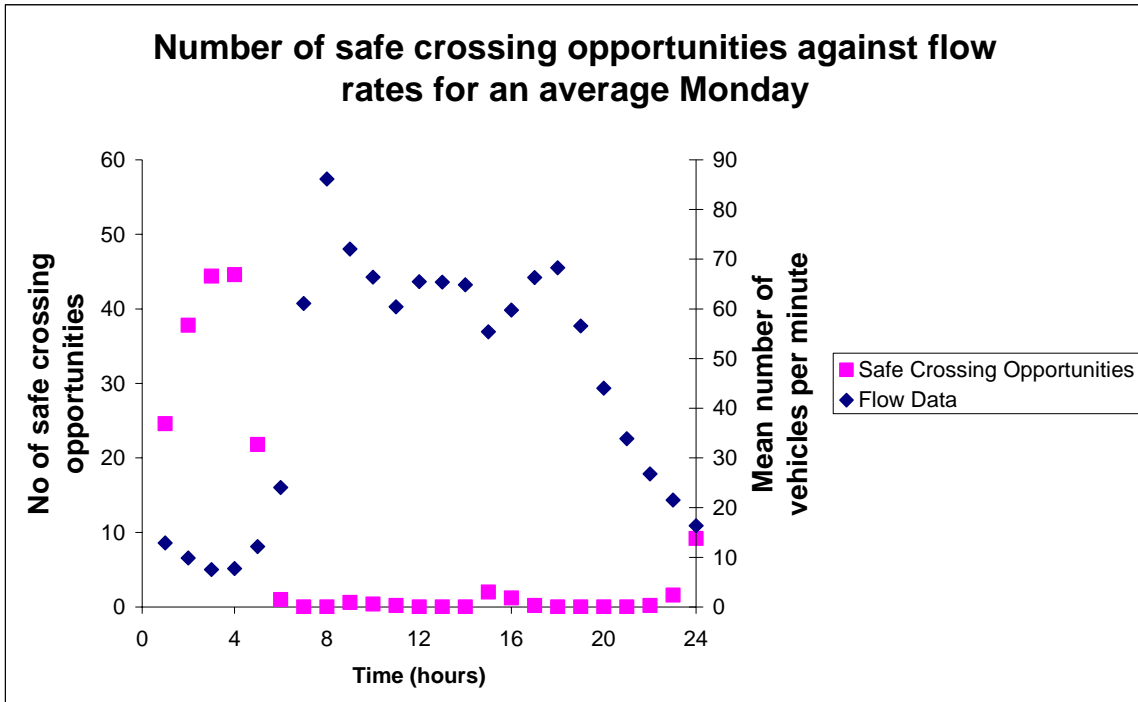


**Figure B35** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Sunday on a 3-lane stretch of the M25



8.6

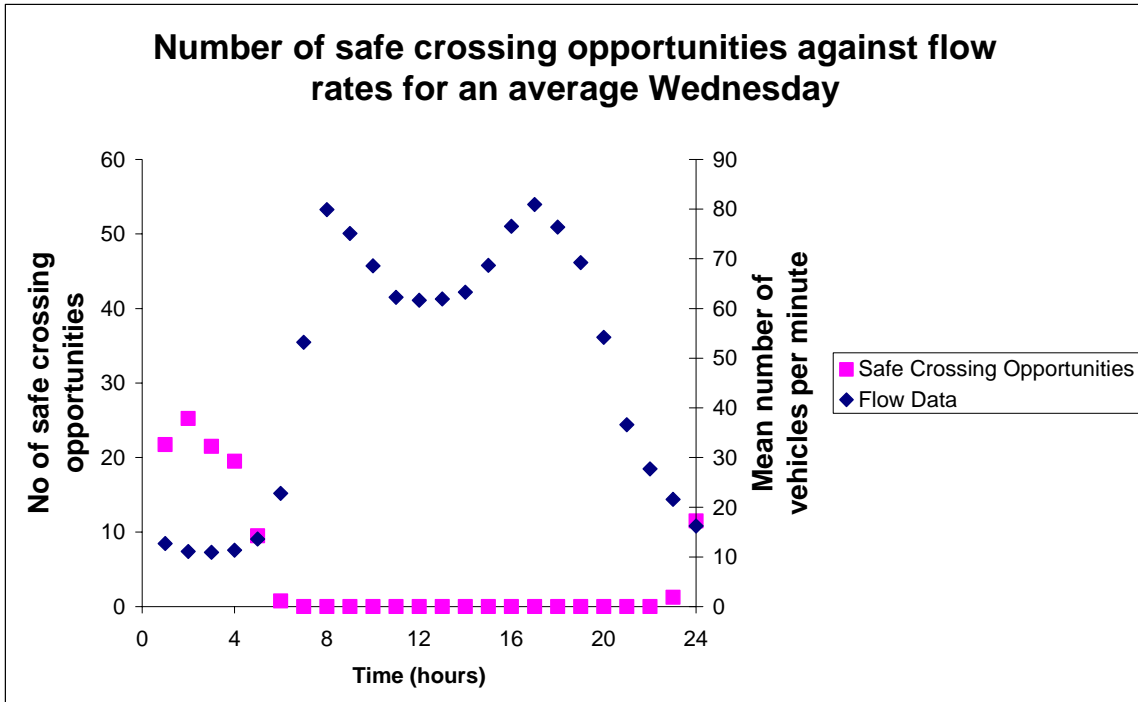
M6 3-LANE



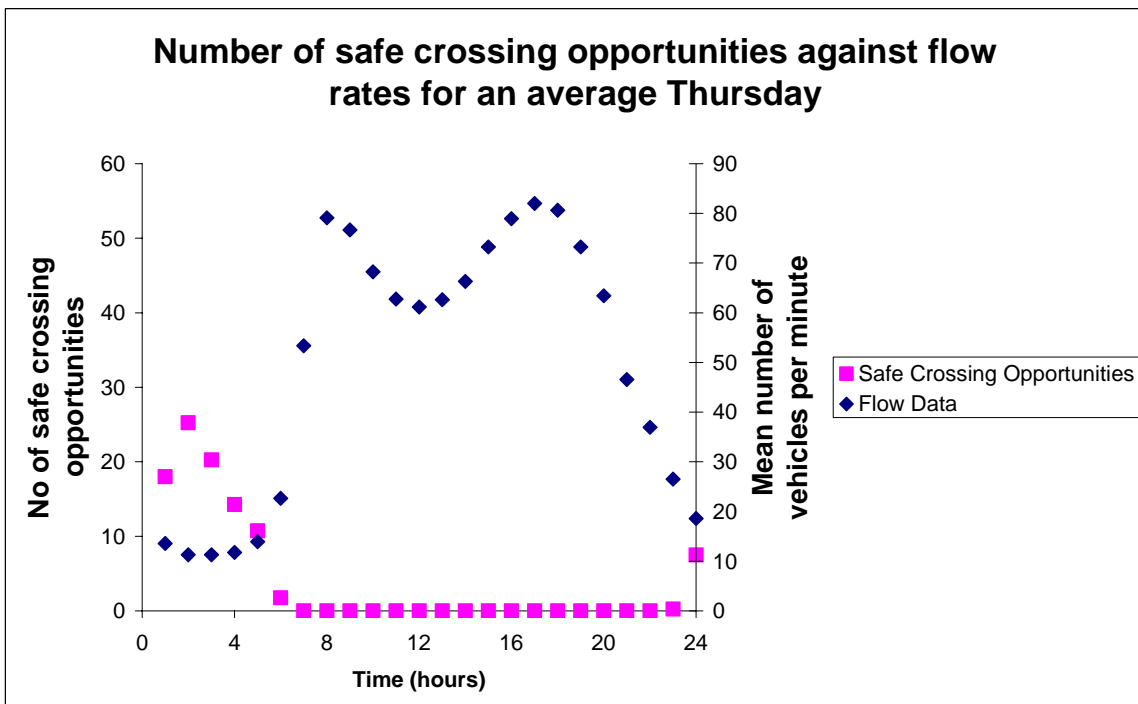
**Figure B36** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Monday on a 3-lane stretch of the M6



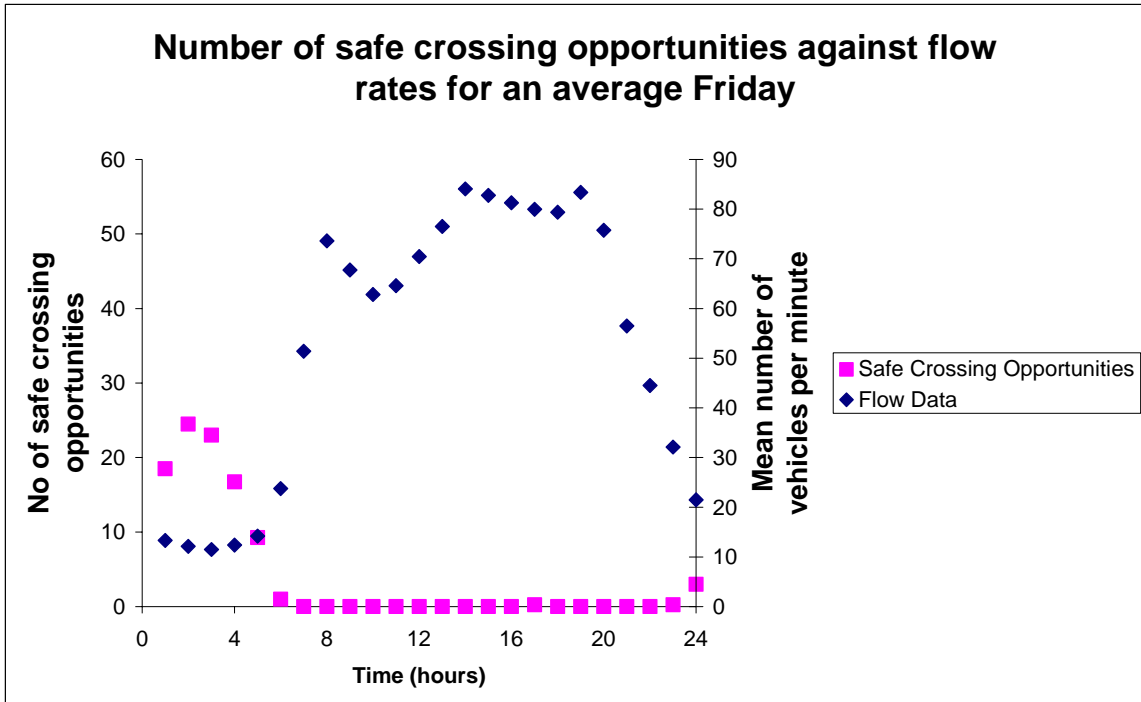
**Figure B37** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Tuesday on a 3-lane stretch of the M6



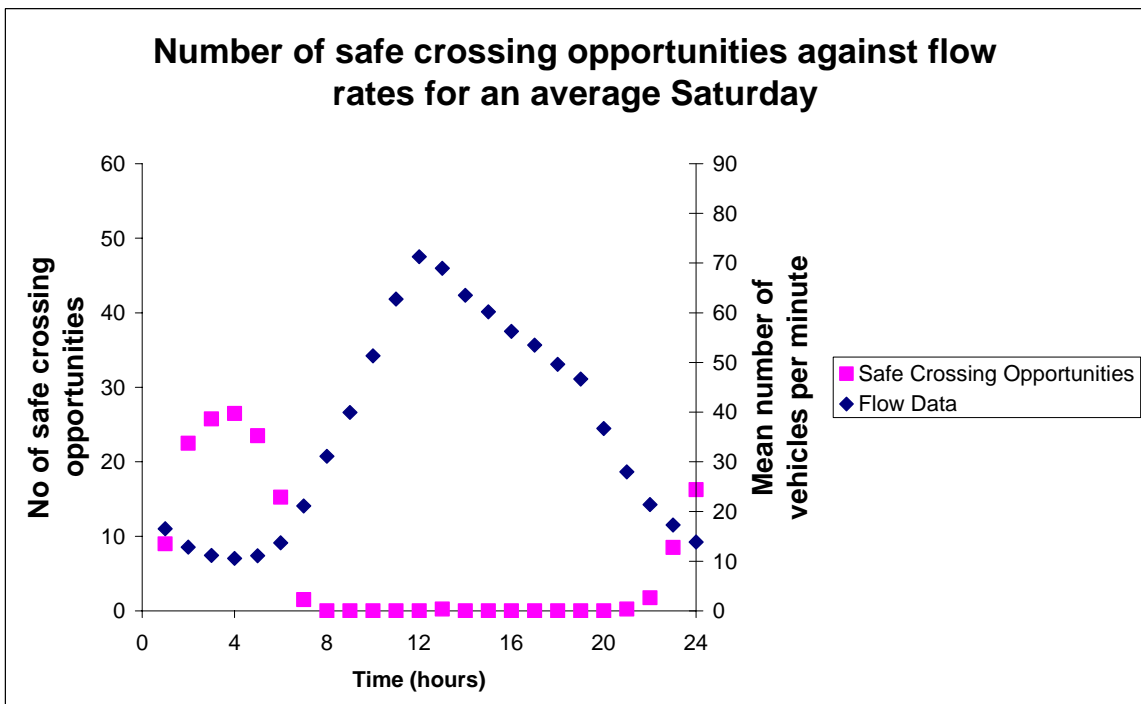
**Figure B38** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Wednesday on a 3-lane stretch of the M6



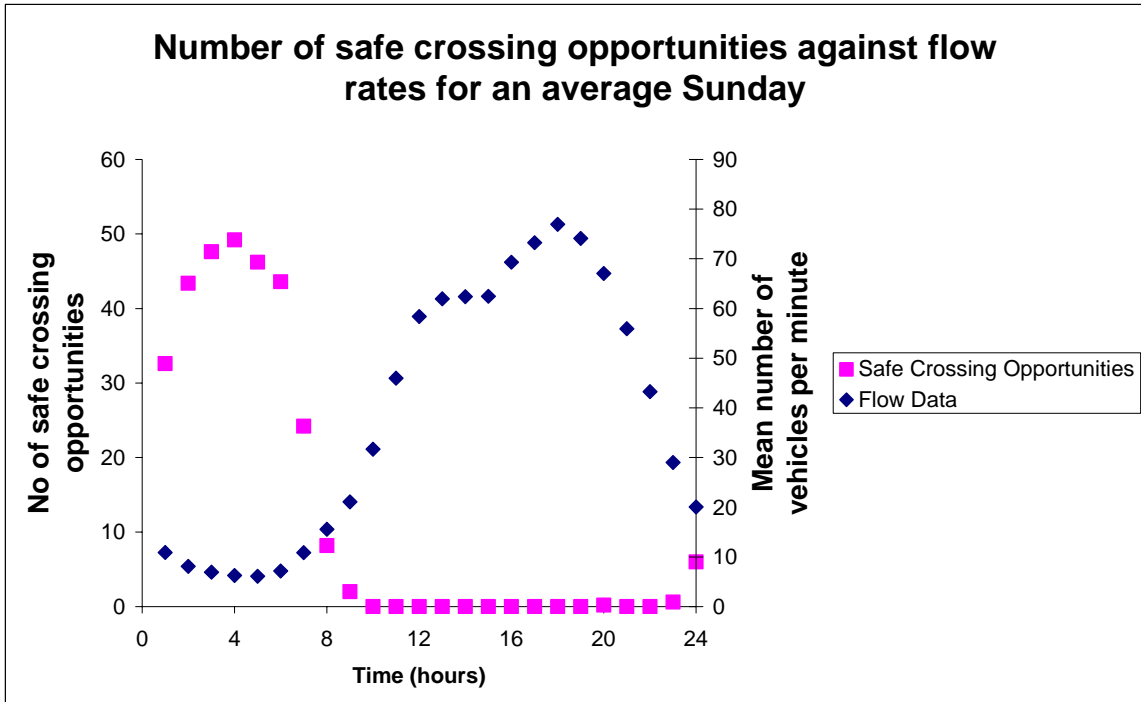
**Figure B39** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Thursday on a 3-lane stretch of the M6



**Figure B40** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Friday on a 3-lane stretch of the M6

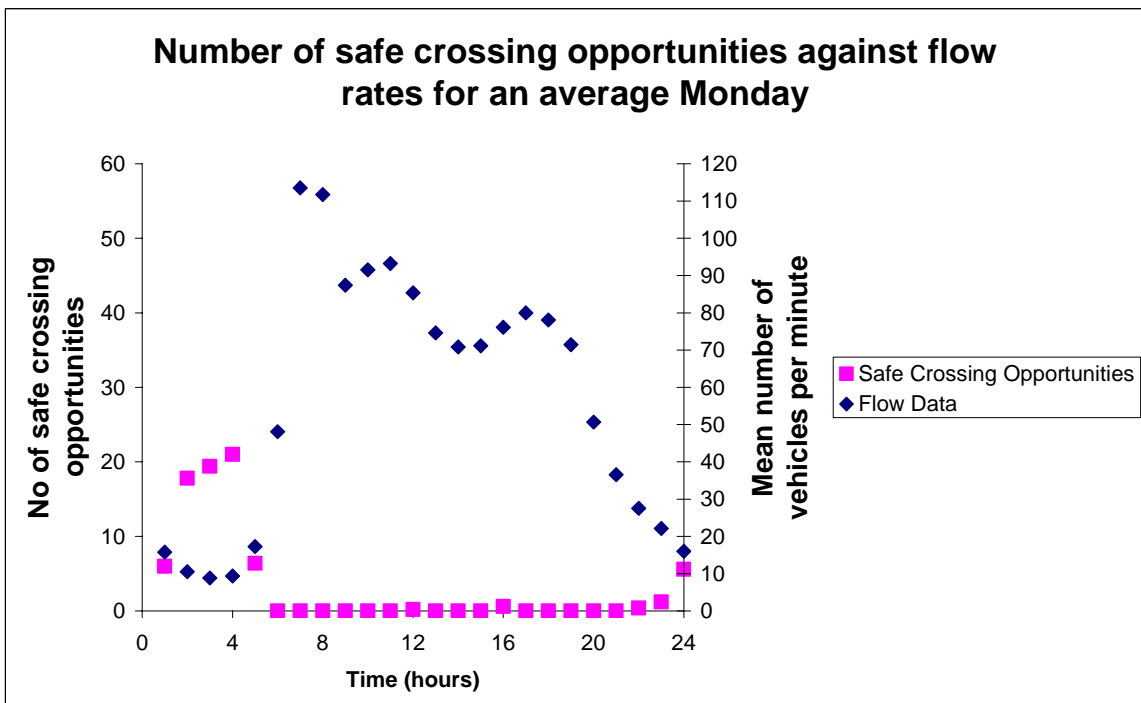


**Figure B41** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Saturday on a 3-lane stretch of the M6

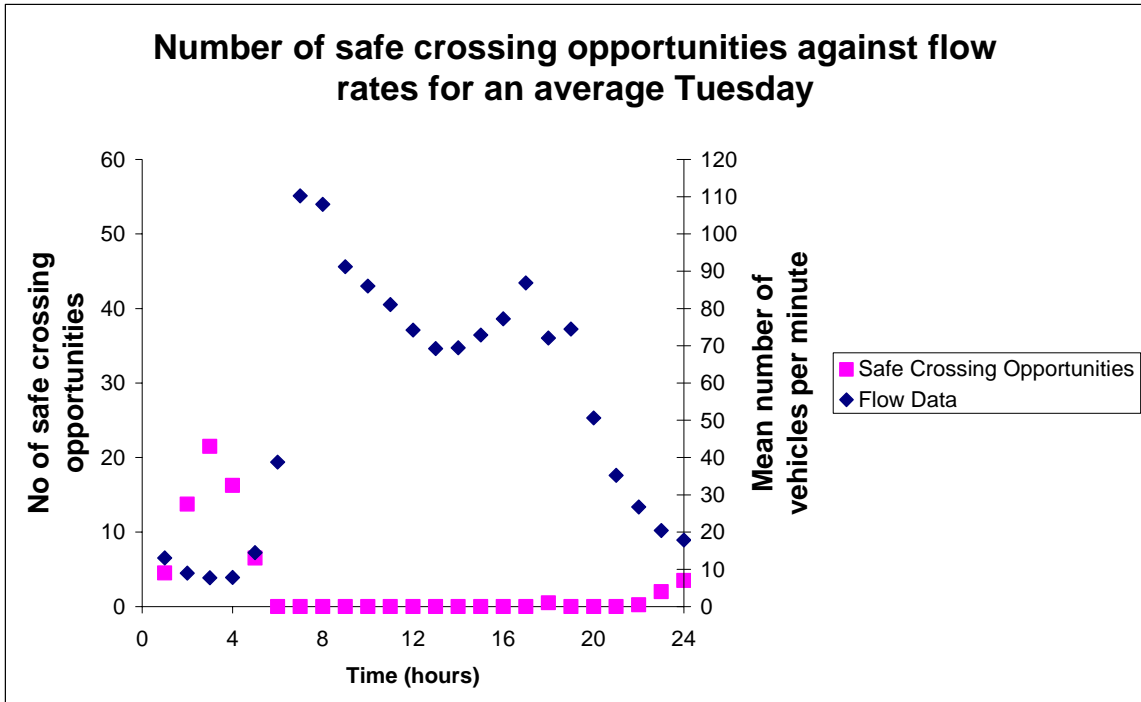


**Figure B42** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Sunday on a 3-lane stretch of the M6

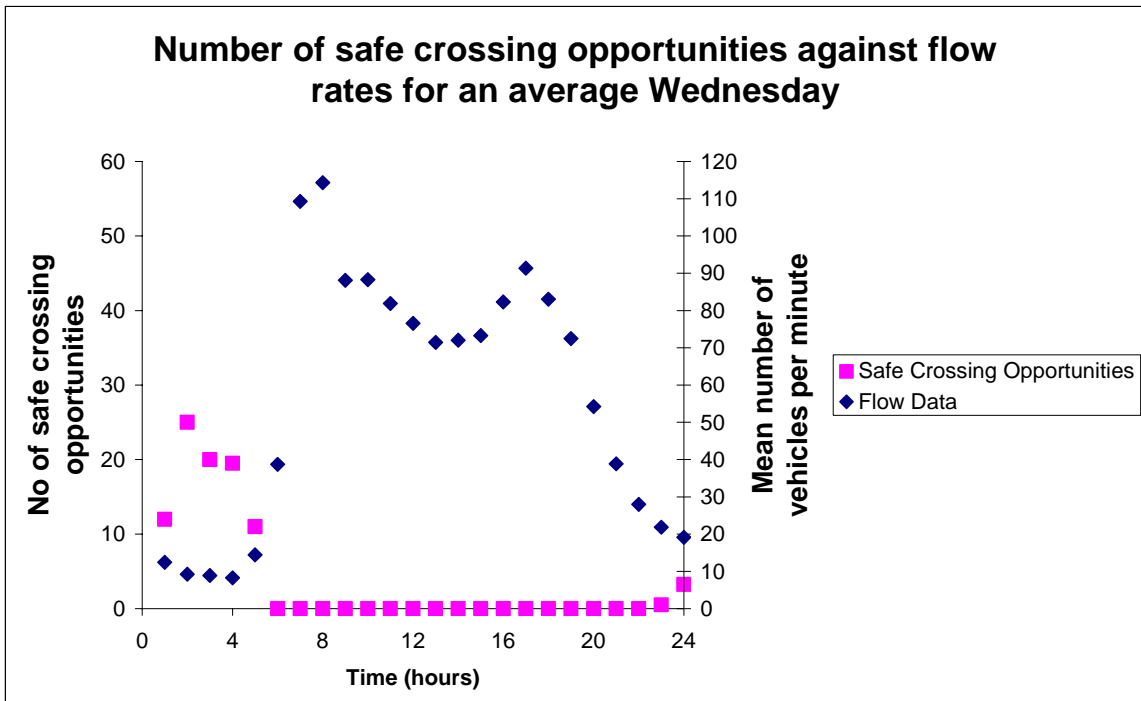
**8.7 M25 4-LANE**



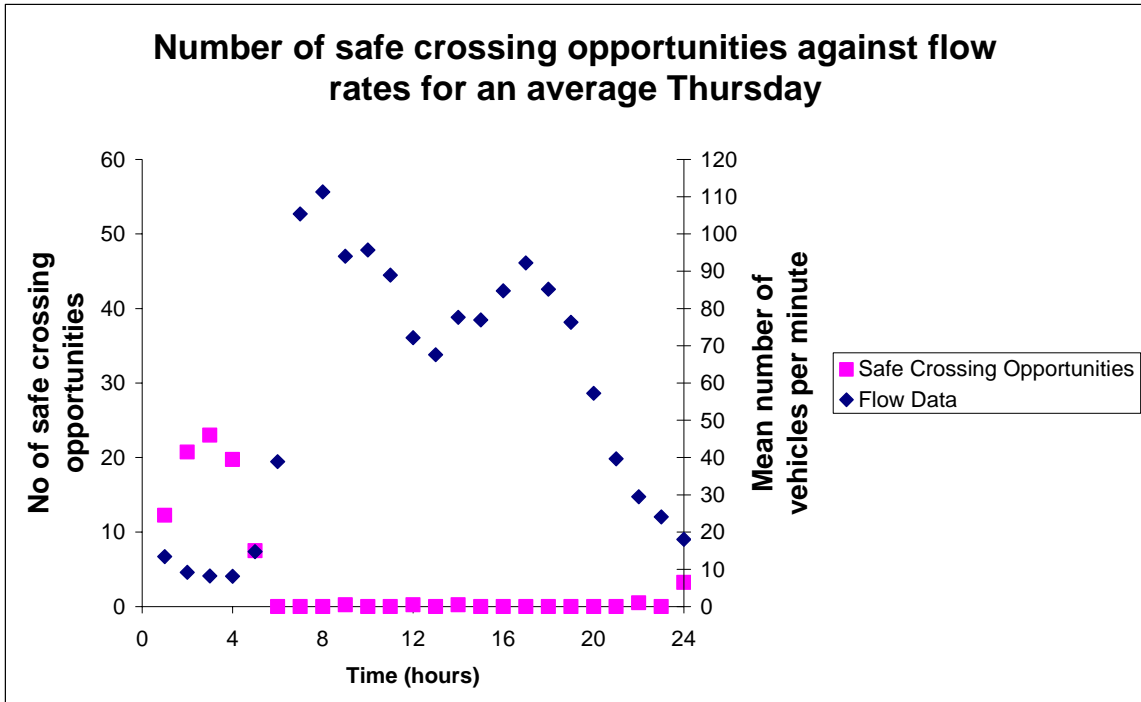
**Figure B43** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Monday on a 4-lane stretch of the M25



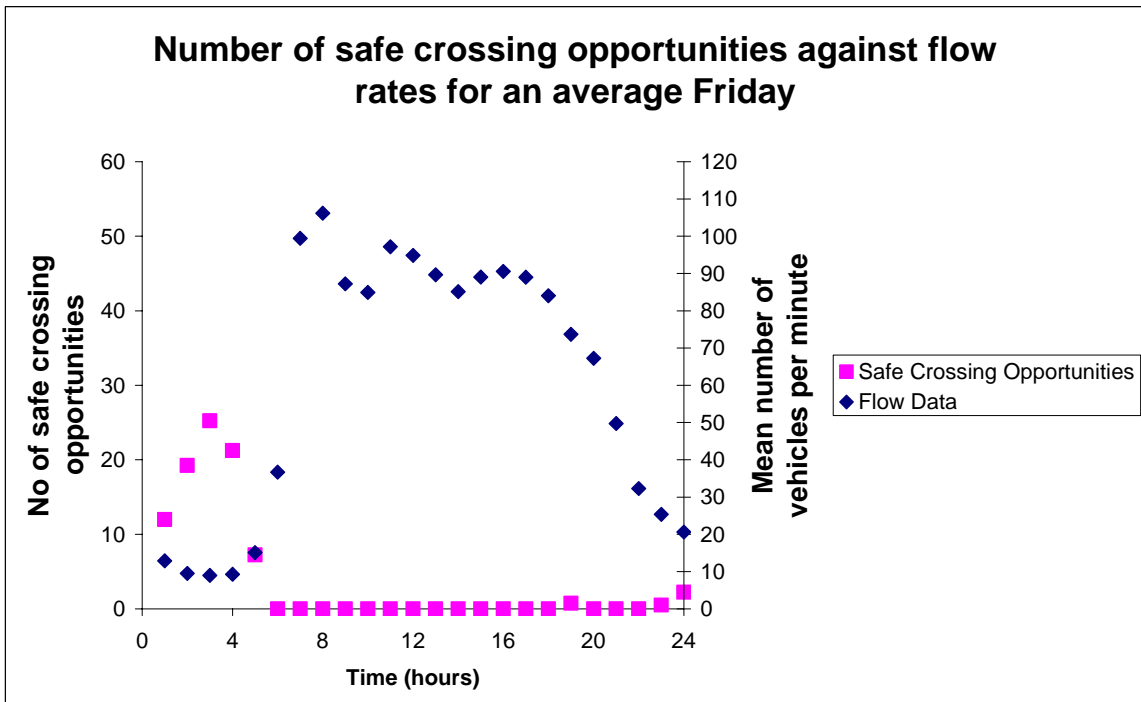
**Figure B44** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Tuesday on a 4-lane stretch of the M25. (No data for first 11 hrs of the 24/6/08 so, for these hours, data was averaged over 3 days, not 4)



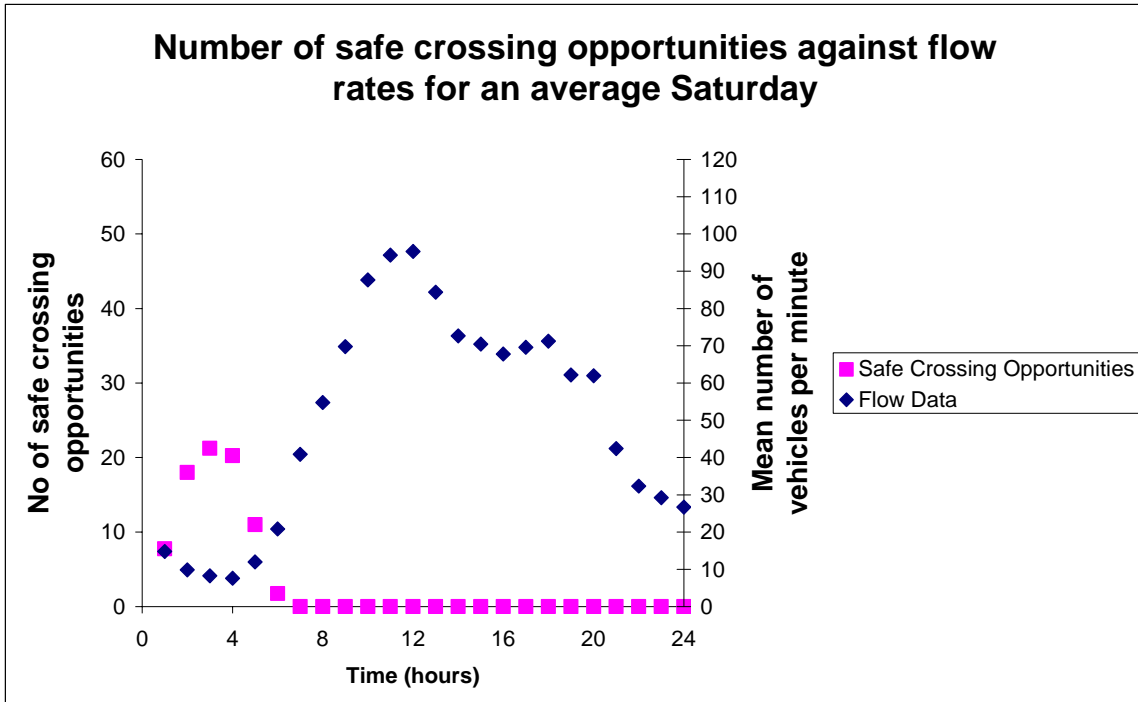
**Figure B45** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Wednesday on a 4-lane stretch of the M25



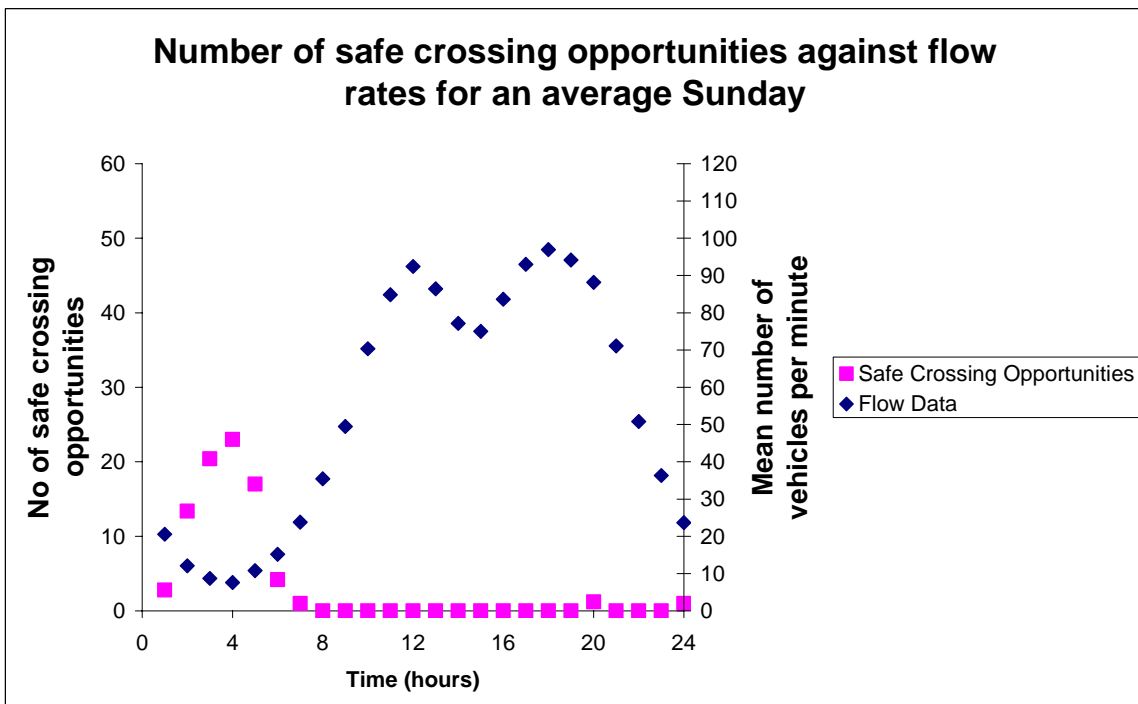
**Figure B46** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Thursday on a 4-lane stretch of the M25



**Figure B47** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Friday on a 4-lane stretch of the M25



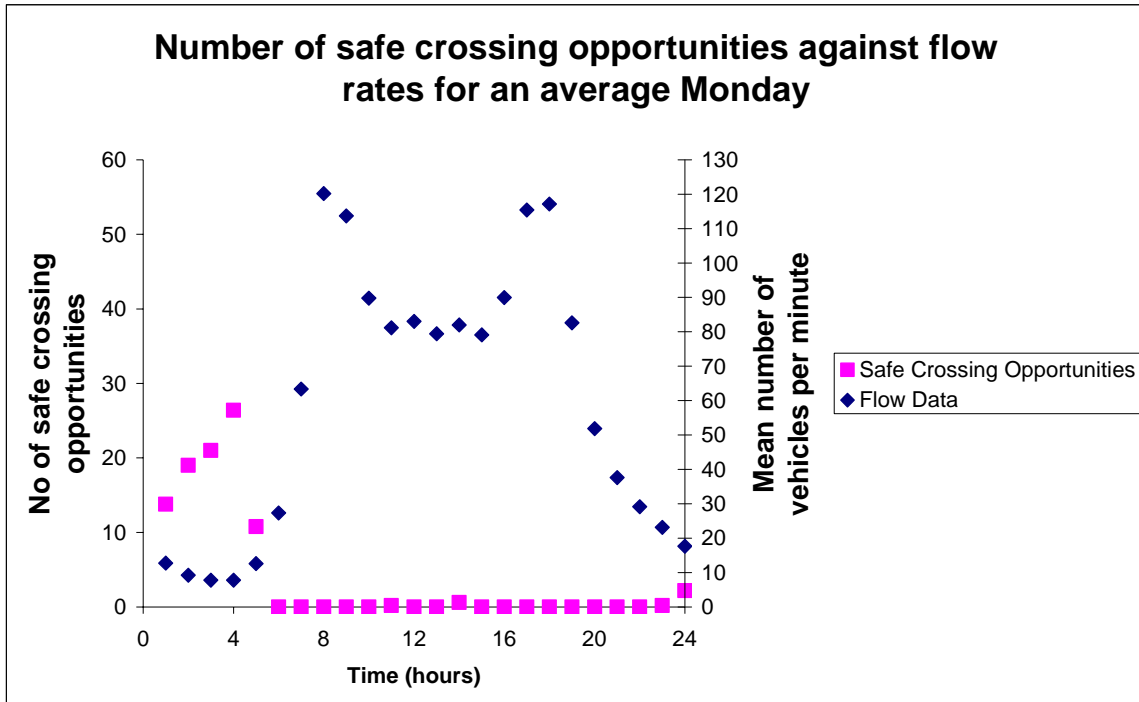
**Figure B48** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Saturday on a 4-lane stretch of the M25



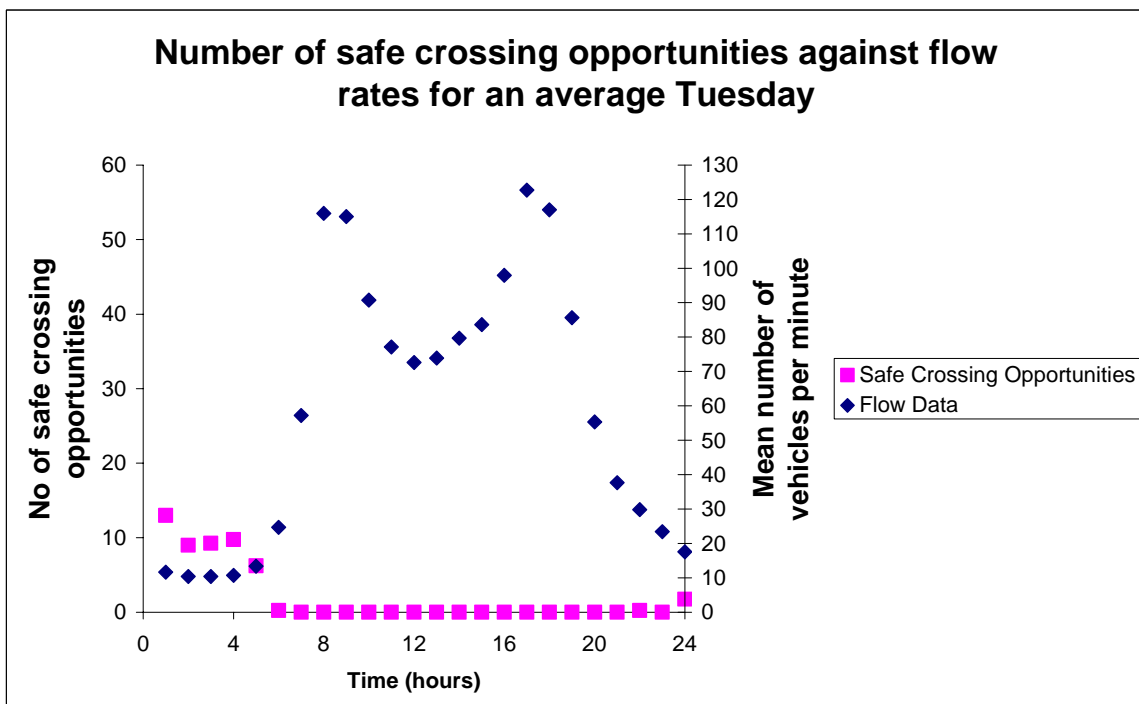
**Figure B49** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Sunday on a 4-lane stretch of the M25

8.8

M6 4-LANE

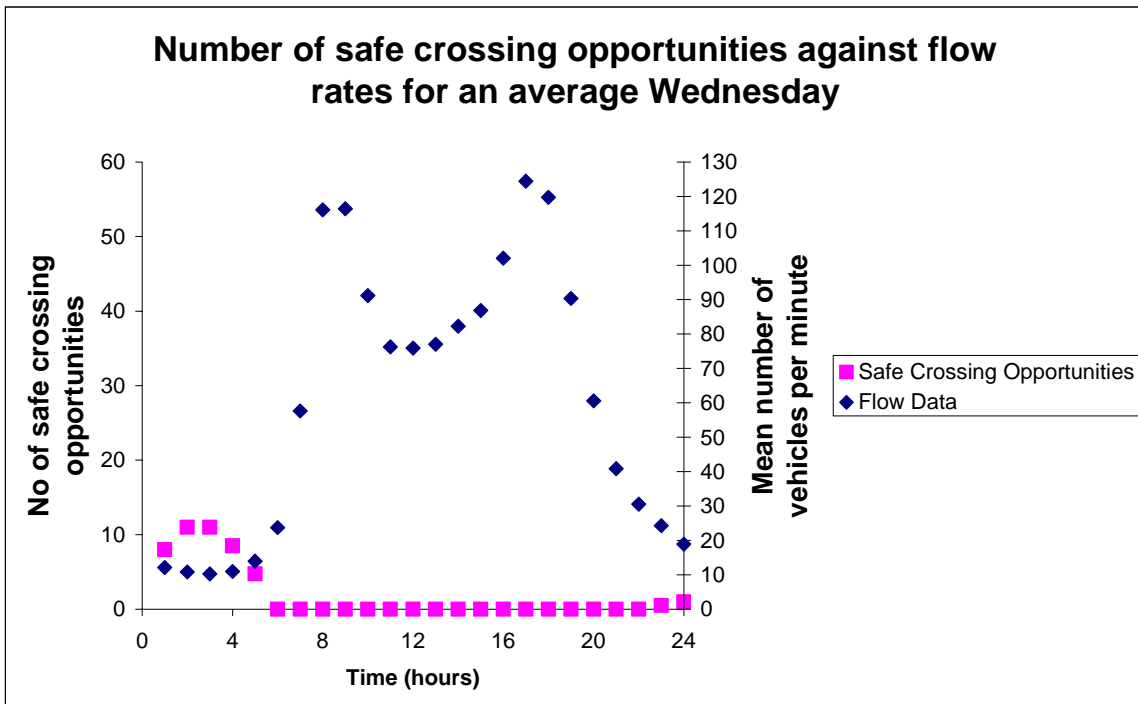


**Figure B50** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Monday on a 4-lane stretch of the M6

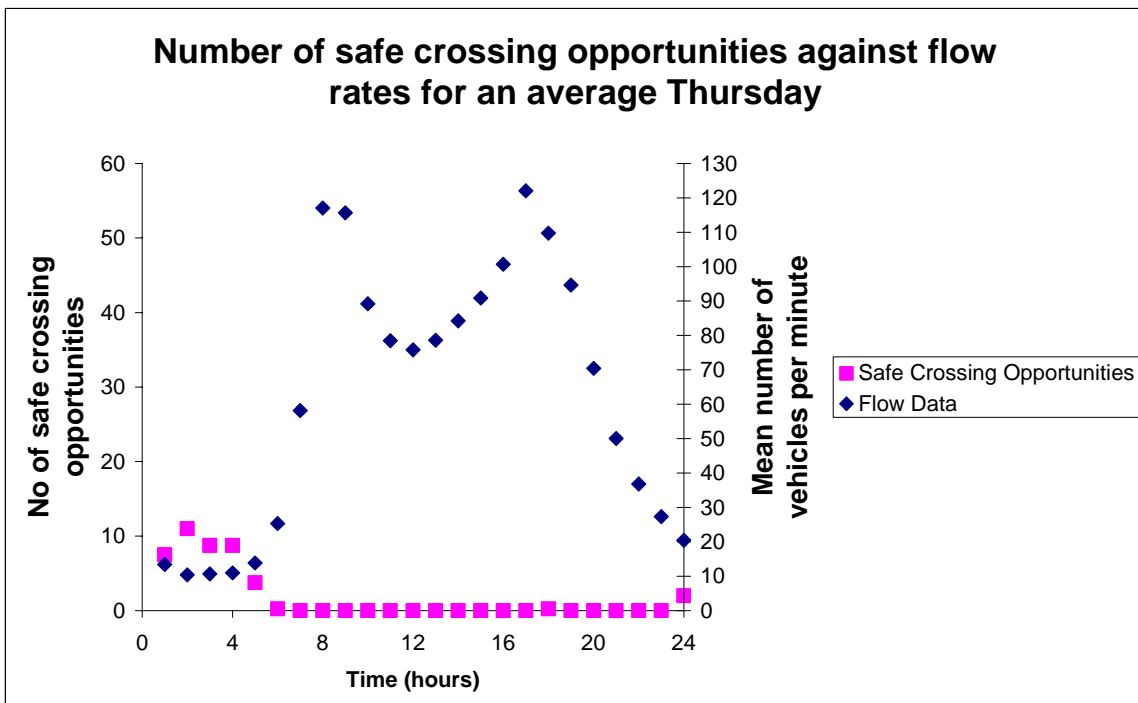


**Figure B51** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Tuesday on a 4-lane stretch of the M6

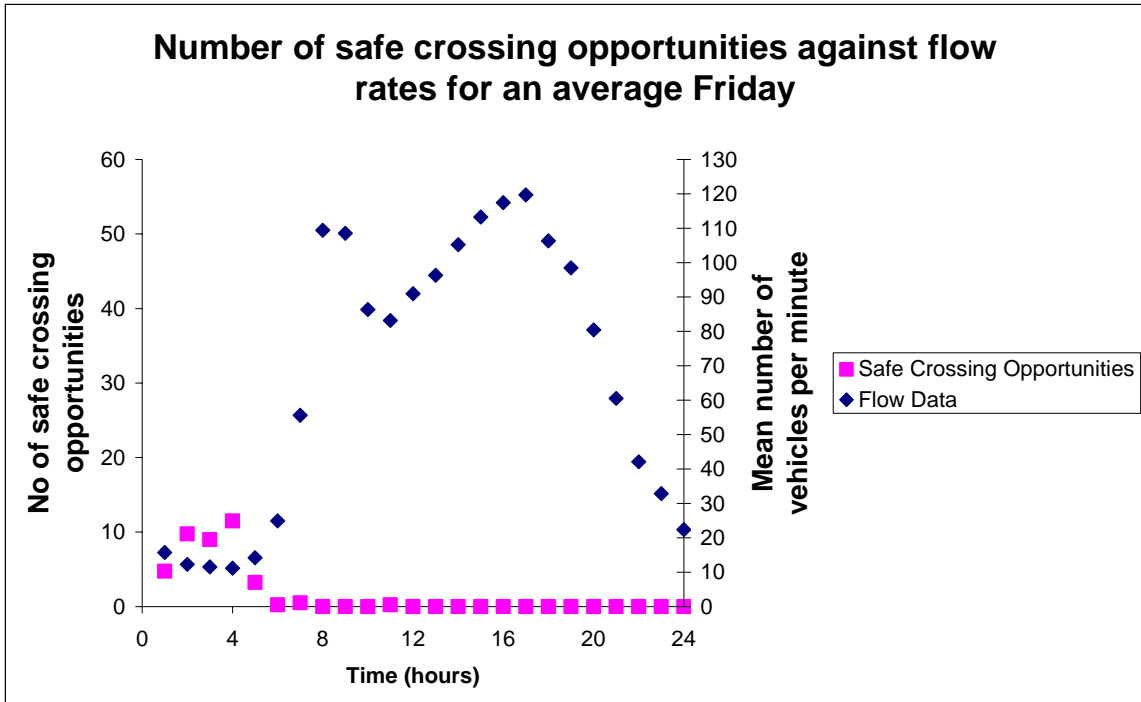




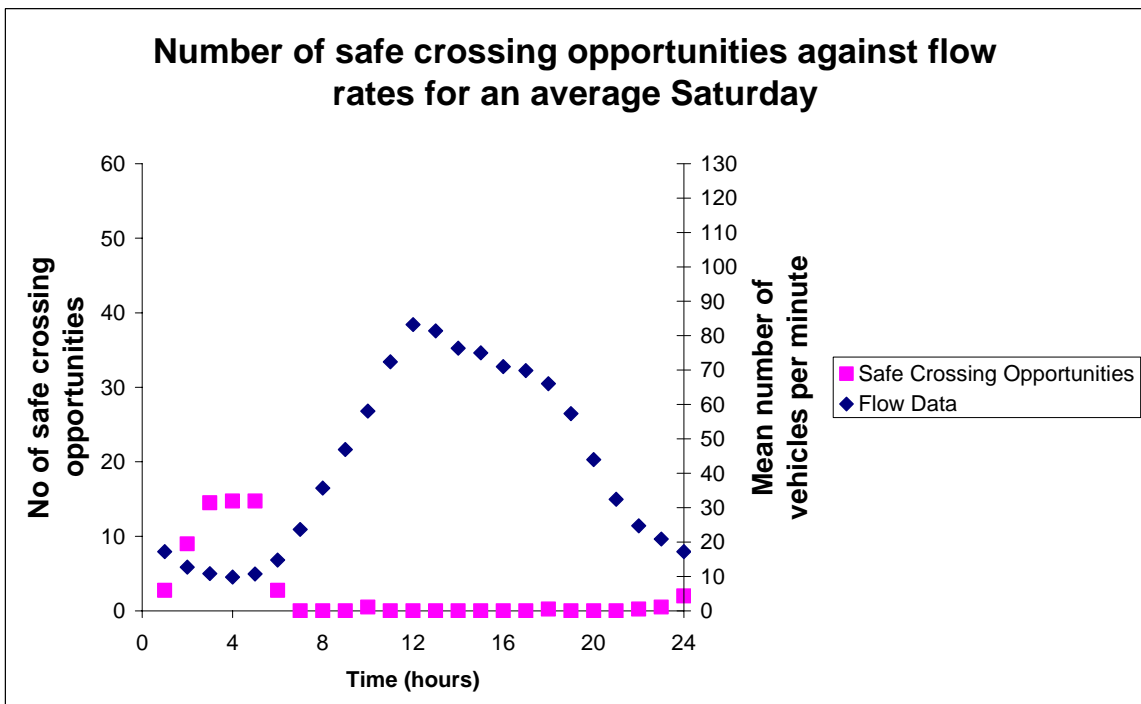
**Figure B52** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Wednesday on a 4-lane stretch of the M6



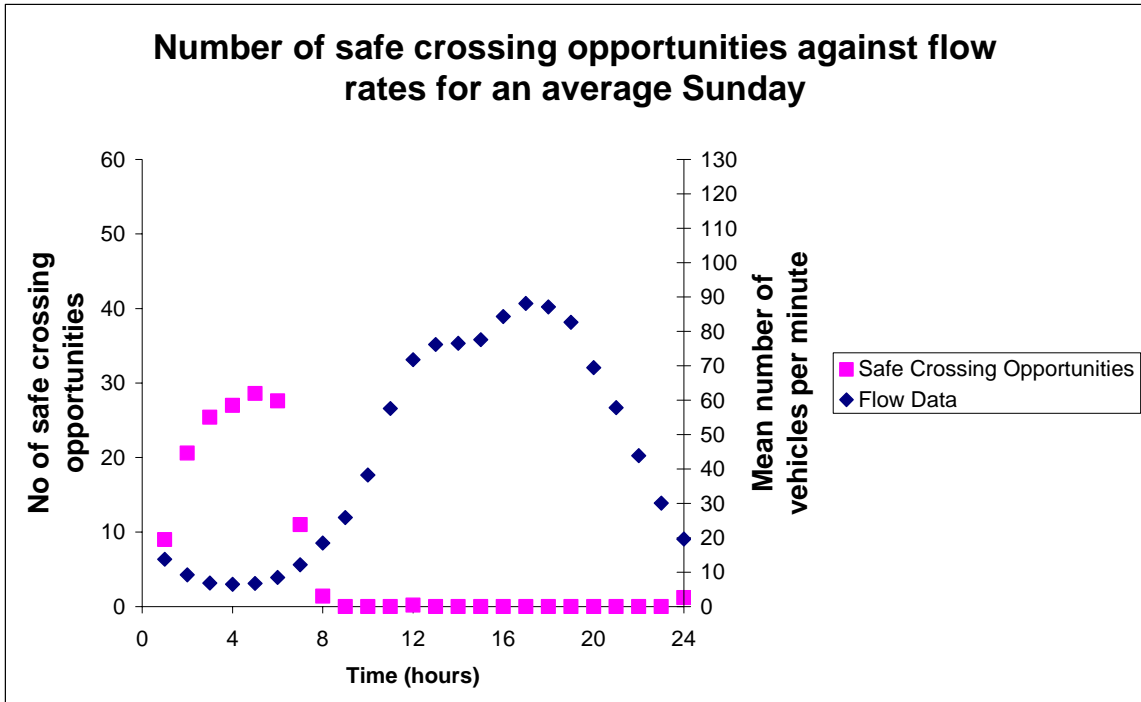
**Figure B53** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Thursday on a 4-lane stretch of the M6



**Figure B54** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Friday on a 4-lane stretch of the M6



**Figure B55** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Saturday on a 4-lane stretch of the M6



**Figure B56** Graph of number of minutes per hour with safe crossing opportunities against flow rate for an average Sunday on a 4-lane stretch of the M6

## **9 APPENDIX C – MISSING DATA**

The tables on the following pages show how much headway data was missing from the extracted traffic counting data files. There is a table for each motorway section analysed and the values are the number of minutes in each hour of each day for which data had to be discarded as there were too many '-1's in the headway data. It should be noted that there appears to be a correlation between the traffic flow and missing data, i.e. more data generally seems to be missing at quieter times of the day and is rarely missing during the busy peak times.

**Table C1** Number of minutes per hour that contained missing data for a 2-lane stretch of the M65

Time (hour)	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	21	18	21	26	27	31	27	17	27	26	26	22	26	24	17	27	24	30	31	28	26	18	29	31	22	23	22	23	22	26	
2	22	32	34	28	27	22	18	25	26	25	33	20	25	22	20	22	28	32	36	28	22	21	28	28	24	24	28	28	24	26	
3	24	26	25	25	30	30	26	31	23	28	24	33	31	27	29	25	28	27	27	23	17	28	22	28	28	24	21	25	28	27	
4	29	22	29	20	28	24	29	28	22	19	25	22	27	22	32	21	25	30	27	23	28	22	28	20	22	17	30	25	35	30	
5	19	18	29	25	33	27	27	31	28	22	29	29	21	23	27	27	29	20	32	28	30	33	28	28	31	26	29	30	24	16	
6	23	21	24	29	21	22	18	27	20	21	23	21	27	23	27	21	21	25	20	24	23	24	25	19	21	20	20	23	24	22	
7	18	10	5	9	7	11	27	16	11	7	3	7	5	26	25	6	10	5	10	9	20	18	10	10	5	11	9	30	17	7	
8	22	0	0	0	0	0	10	21	0	0	0	0	0	14	16	0	1	1	0	0	15	23	0	0	0	1	0	11	18	0	
9	22	0	0	0	0	0	4	22	0	0	0	0	0	4	25	0	1	0	1	0	6	20	0	0	0	0	0	0	9	19	0
10	11	0	0	0	0	0	6	8	1	0	1	0	0	7	14	0	0	0	0	0	5	13	1	1	0	0	0	5	8	0	
11	1	0	0	0	0	0	2	4	0	0	0	0	0	2	0	0	1	0	0	0	0	3	0	0	0	0	0	4	4	1	
12	3	0	0	0	1	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
13	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	1	0	22	0	0	0	1	0	0	
14	0	0	0	1	0	1	0	0	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	
15	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	
16	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	
17	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	
18	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
19	2	0	0	0	0	1	0	2	19	0	0	0	1	0	1	0	1	0	0	0	0	2	0	0	0	0	0	0	0	2	0
20	0	3	0	1	1	1	3	0	7	0	2	0	3	6	2	3	3	0	2	2	0	8	0	3	3	3	2	3	3	3	
21	8	12	9	7	7	13	12	0	7	11	5	4	6	20	7	15	7	8	5	5	18	15	10	12	7	2	5	15	5	12	
22	17	14	16	11	15	11	9	9	17	14	18	15	22	15	13	11	14	13	20	11	21	14	18	15	11	15	18	19	21	12	
23	21	24	26	21	15	15	22	21	25	22	16	24	17	21	19	18	26	15	17	17	19	29	27	18	11	11	19	16	16	13	
24	21	24	20	21	18	12	26	16	26	25	19	21	18	18	24	20	23	26	16	19	19	17	20	16	21	28	20	16	21	21	

**Table C2** Number of minutes per hour that contained missing data for a 3-lane stretch of the M65

Time (hour)	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	14	9	8	6	7	9	13	6	9	7	8	14	12	10	10	11	2	12	10	7	14	10	9	8	5	6	9	5	14	6	
2	14	4	8	2	8	9	8	7	6	11	11	8	14	16	12	7	7	6	6	10	13	11	6	4	5	9	10	16	7	8	
3	6	6	7	4	7	7	8	8	6	8	6	6	8	9	9	2	8	10	10	8	9	3	6	7	9	7	9	8	11	6	
4	7	2	12	9	4	3	11	10	6	9	9	10	6	8	6	4	5	5	9	7	13	4	7	8	5	6	6	7	11	3	
5	4	11	5	9	8	11	13	13	5	15	10	10	8	14	7	9	10	9	7	9	8	9	6	5	12	9	5	6	10	8	
6	8	7	10	10	6	10	12	16	9	9	8	9	10	6	10	7	6	6	7	14	16	8	12	9	11	8	5	9	8	8	
7	13	0	0	1	3	1	11	10	2	1	1	0	0	6	7	2	1	1	0	2	11	4	1	0	0	1	3	9	10	2	
8	15	0	0	0	0	0	7	5	0	0	0	0	0	4	8	0	1	1	0	0	4	7	0	0	0	1	0	7	6	0	
9	7	0	0	0	0	0	0	5	0	0	0	0	0	3	3	0	1	0	1	0	2	7	0	0	0	0	0	3	8	0	
10	1	0	0	0	0	0	0	6	1	0	1	0	0	1	7	0	0	0	0	0	1	2	1	0	0	0	0	1	8	0	
11	1	0	0	0	0	0	1	2	0	0	0	0	1	0	3	0	1	0	0	0	0	2	0	0	0	0	0	0	1	1	
12	0	0	0	0	2	0	0	1	0	0	1	0	0	0	2	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	
13	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	22	0	0	0	1	1	0
14	0	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	
15	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	
16	0	0	0	1	0	0	1	1	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0
18	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
19	1	0	0	0	0	0	3	0	19	0	0	0	1	0	1	0	1	0	0	0	0	2	1	0	0	1	0	1	1	0	
20	4	2	0	3	1	1	3	3	2	1	4	0	3	4	0	3	2	0	1	0	3	1	1	0	0	1	1	2	1	3	
21	5	5	3	4	3	5	0	2	6	3	2	2	5	3	4	4	3	7	3	1	4	8	3	6	2	1	2	7	9	3	
22	9	8	5	6	5	3	12	7	4	5	9	11	7	12	6	7	6	8	1	3	4	5	2	3	1	5	7	5	8	6	
23	9	6	11	12	7	7	8	11	9	8	9	4	5	8	7	5	9	7	6	9	8	15	5	10	8	6	10	12	10	8	
24	14	17	9	13	5	11	7	10	10	10	11	12	8	9	8	7	8	14	11	7	5	7	6	11	7	9	7	8	6	17	

**Table C3** Number of minutes per hour that contained missing data for a 3-lane stretch of the M55

Time (hour)	Date 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	5	9	10	8	10	5	5	8	7	7	12	8	8	3	4	9	7	8	9	11	6	7	7	11	7	10	9	7	3	5
2	5	11	7	14	7	9	9	9	10	7	10	9	8	5	6	6	9	6	13	10	7	6	7	6	12	9	9	12	7	4
3	7	8	4	9	10	8	13	5	4	7	14	2	9	13	11	8	8	9	10	8	8	9	8	5	6	9	5	8	3	8
4	6	12	10	5	9	6	14	6	8	6	16	4	11	11	12	12	9	6	7	15	6	16	13	12	8	9	9	10	7	15
5	9	7	8	6	8	13	7	11	5	10	12	8	11	6	9	7	11	9	7	12	8	10	8	10	9	5	10	13	8	10
6	6	1	3	5	3	2	3	10	1	3	4	1	2	3	8	4	3	4	5	5	6	5	3	1	4	1	3	11	9	2
7	6	2	0	0	0	0	5	4	1	0	3	0	0	2	9	0	1	0	0	1	3	3	0	0	0	0	0	2	5	0
8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4	0	1	1	0	0	0	5	0	0	0	1	0	1	2	0
9	1	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	2	0	0	0	0	0	0	2	0
10	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
12	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	23	0	0	0	1	0	0
14	0	0	0	1	0	1	0	0	0	0	0	47	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	33	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
16	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	1	20	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	1	2	1	0	0	1	1	1	0	1	0	0	1	0	0	1	3	0	0	1	0	0	0	1	0	0	0	1	0
21	0	0	1	0	0	0	1	0	1	1	1	0	1	0	1	3	4	1	2	1	2	1	1	2	1	2	0	0	0	0
22	0	0	1	2	2	2	2	0	3	2	0	2	1	1	0	3	2	3	2	0	0	1	0	1	1	0	3	1	3	2
23	5	4	2	5	5	6	0	4	9	2	0	3	1	2	4	5	2	8	6	4	1	1	8	3	5	2	2	2	0	3
24	5	7	4	7	5	3	3	3	5	13	2	7	3	5	5	3	13	12	5	9	2	2	5	7	5	8	6	3	8	5

**Table C4** Number of minutes per hour that contained missing data for a 3-lane stretch of the M2

Time (hour)	Date 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	7	9	18	19	13	10	4	2	12	10	13	11	7	7	8	14	15	13	13	4	3	5	17	60	6	4	10	2	6	13
2	13	20	13	18	14	15	10	7	15	15	19	16	14	11	11	15	18	16	12	10	13	11	17	60	14	12	12	6	13	13
3	16	16	21	13	19	18	17	16	12	16	15	14	19	20	14	13	20	13	11	12	9	13	11	60	19	11	16	12	17	19
4	13	14	20	16	15	12	17	11	14	10	17	18	17	18	15	13	16	17	14	15	15	13	11	60	17	15	21	17	17	11
5	10	14	17	14	9	11	14	13	15	12	16	13	14	11	10	15	13	18	12	13	16	12	14	60	14	10	14	13	20	13
6	17	8	8	3	7	2	11	12	6	4	3	3	9	9	12	5	2	4	3	6	8	19	8	60	8	11	5	12	12	6
7	12	1	0	0	0	0	1	7	0	1	0	1	0	3	7	0	0	0	1	0	4	10	0	60	0	0	4	3	7	0
8	8	0	1	0	0	0	1	8	0	0	0	1	0	1	2	0	0	0	0	0	1	8	0	60	0	0	0	0	1	0
9	2	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3	0	60	0	0	0	0	1	0
10	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	2	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	2	0	0	0
12	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	2	0	0	1
13	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
21	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	1	1	0
22	1	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	1	2	1	0	0	1	0	0	1	1
23	1	3	1	1	1	1	1	1	1	2	4	0	0	1	2	4	5	2	1	0	2	4	2	1	0	1	0	1	0	0
24	7	7	6	6	5	5	2	2	9	4	4	5	4	1	6	12	6	4	0	3	1	2	3	2	5	4	0	1	11	6



**Table C5** Number of minutes per hour that contained missing data for a 3-lane stretch of the M25

Time (hour)	Date 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
1	0	3	4	1	3	4	2	3	2	3	0	1	1	1	2	1	4	5	1	1	1	0	2	60	2	0	1	2	0	1	
2	3	8	11	8	4	1	4	0	4	2	0	4	6	5	2	4	6	1	5	2	6	2	2	60	5	7	3	2	4	5	
3	2	8	9	5	6	1	4	8	10	4	0	4	4	2	2	2	6	5	3	1	3	3	3	60	2	6	4	4	5	7	
4	5	2	1	2	3	1	4	4	2	3	1	3	1	0	7	4	3	2	0	1	4	2	3	60	3	3	3	3	2	1	
5	5	2	0	1	1	0	3	1	0	1	2	0	0	0	3	0	0	0	2	0	2	1	2	60	0	0	1	2	3	0	
6	2	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	60	0	0	0	2	0	0	
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	1	2	0	
8	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	0	0	0	
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	0	0	0	
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	60	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	0	0	0	
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	
13	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	
15	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	1	
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
17	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	
23	0	0	1	1	1	0	0	0	0	2	0	0	1	0	0	0	0	1	0	0	1	0	0	0	2	0	0	0	2	1	
24	1	2	0	1	0	2	0	3	2	0	1	0	2	0	1	2	0	3	1	0	0	1	0	1	0	1	0	0	0	0	

**Table C6** Number of minutes per hour that contained missing data for a 3-lane stretch of the M6

Time (hour)	Date 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	3	3	5	2	3	3	0	3	1	3	3	3	0	0	4	0	2	3	4	0	1	5	2	0	0	1	0	0	1	0
2	4	5	2	4	3	2	3	4	3	4	7	3	4	1	7	5	5	2	2	3	5	7	4	3	3	3	3	2	6	2
3	5	7	4	6	3	1	1	5	5	4	4	7	2	4	5	7	7	7	4	5	1	7	8	8	1	3	2	3	5	3
4	6	4	5	2	4	6	1	9	2	4	7	10	1	3	3	8	7	2	4	0	4	7	4	3	2	4	3	3	4	4
5	7	1	2	2	1	0	4	5	2	2	8	3	4	5	4	5	5	1	2	2	3	7	3	6	3	2	1	3	7	3
6	5	0	0	0	0	0	1	4	0	0	0	0	0	0	6	0	0	1	0	0	2	9	1	0	0	0	0	2	6	0
7	0	0	0	0	0	0	0	7	0	0	0	0	0	0	4	0	0	0	0	0	0	3	0	0	0	0	0	0	5	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0	1	0	0
14	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
16	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
24	0	1	1	0	1	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	2	0	0	0	1	1	0	0	0	0

**Table C7** Number of minutes per hour that contained missing data for a 4-lane stretch of the M25

Time (hour)	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	1	10	8	11	8	19	10	3	8	12	8	7	10	6	4	8	6	8	6	13	16	0	5	60	8	12	12	7	3	5	
2	8	15	22	13	20	16	17	20	15	23	12	20	14	17	8	14	9	10	21	20	13	14	15	60	14	13	19	15	9	18	
3	18	20	17	18	22	21	22	22	19	14	16	17	20	22	15	26	19	16	24	11	17	18	20	60	13	21	19	20	11	24	
4	19	16	20	26	23	15	22	25	15	16	18	25	20	27	24	18	21	20	20	18	27	24	15	60	22	15	11	17	17	18	
5	9	7	8	8	10	13	7	15	1	8	7	11	8	19	11	4	8	9	11	5	14	17	9	60	11	7	5	11	16	3	
6	6	0	1	0	0	0	2	11	0	0	0	0	0	3	5	0	0	0	0	0	5	11	0	60	0	0	0	3	5	0	
7	2	0	0	0	0	0	0	3	0	1	0	0	0	0	2	0	0	0	0	0	0	2	0	60	0	0	0	0	1	0	
8	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	60	0	0	0	0	1	0	
9	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	60	0	0	0	0	1	0	
10	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	0	0	0	
11	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	1	0	0	0	0	
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0	0	0	0	0	1	
13	1	0	0	1	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	5	0	0	0	0	0	
15	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	1	
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
17	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	
19	1	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
21	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
22	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	2	0	2	0	1	0	0	1	0	1	0	1	0	0	0	
23	0	4	2	1	2	3	0	1	3	0	2	1	3	0	0	2	1	1	0	3	0	1	2	1	1	2	0	0	0	2	
24	4	12	2	2	3	1	1	5	14	5	4	5	3	0	1	3	0	3	3	11	3	2	2	5	3	4	3	0	1	4	

**Table C8** Number of minutes per hour that contained missing data for a 4-lane stretch of the M6

Time (hour)	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	6	10	10	12	3	2	4	7	5	16	12	13	12	3	11	9	12	11	5	7	2	9	9	11	10	10	8	3	8	3	
2	20	18	20	17	9	13	14	18	20	16	17	15	8	8	14	17	20	11	18	6	11	10	22	14	16	14	13	8	13	13	
3	11	23	19	11	6	13	14	25	19	16	16	15	21	11	25	24	16	14	21	15	13	24	23	20	16	12	8	12	21	17	
4	25	16	16	7	15	10	15	18	19	15	15	14	14	20	20	21	12	7	19	14	16	21	13	17	21	19	14	20	20	23	
5	18	11	9	9	9	8	11	20	8	9	4	10	8	12	19	7	7	12	5	9	10	19	8	12	11	17	10	12	17	8	
6	13	3	3	1	0	1	10	12	1	2	4	3	0	8	6	1	3	5	1	0	6	10	1	2	2	2	2	2	11	19	1
7	8	0	0	0	0	0	1	7	0	0	0	0	0	1	9	0	0	0	0	0	3	6	0	0	0	0	0	0	1	9	0
8	2	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	4	0	0	0	1	0	0	5	0	
9	2	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0
10	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0
14	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
17	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
22	0	0	0	2	1	0	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	3	0	0	1	0	3	1	5	1	0	2	0	1	0	0	2	0	2	0	1	0	1	1	1	1	0	0	2	2	1
24	5	4	8	2	4	1	7	4	8	6	6	4	3	2	3	2	7	0	3	2	4	5	4	6	4	3	1	4	3	3	

## 10 APPENDIX D – FLOW RATE WHEN TIME BETWEEN GAPS IS LESS THAN 5 MINUTES

The following tables illustrate what the mean flow per minute in any hour is for each day of the month if the mean time to wait for a safe crossing opportunity in that hour was 5 minutes or less. In other words, if a worker had 12 or more opportunities in any given hour to cross the carriageway, what was the mean number of vehicles passing in any minute within that hour.

There is one table for each motorway of interest and, in each case, the date is the day of June 2008. The values in black give the hourly mean flow when there are sufficient safe crossing opportunities and the values in green show the hourly mean flow when there are not sufficient safe crossing opportunities, i.e. the worker would have to wait longer than 5 minutes for a safe gap

The tables give an estimate of what the maximum flow rate can be in order for there to be safe opportunities to cross. The current industry guidance uses a flow rate of 40 vehicles per minute but these tables indicate that a more realistic figure would, in general, be 20 vehicles per minute.

**Table D1** Flow rate when time between safe gaps is less than 5 minutes (in black) and more than 5 minutes (in green) for a 2-lane stretch of the M65

Time (hour)	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
1		5	3		2	3	3	4	4	2	2	3	2	2	4	5	3	2	2	2	2	4	5	2	2	2	2	2	4	5	3	
2		3	1 <sup>2</sup>		2	2	2	2	3	1	1	2	2	2	3	2	2	1	2	1	2	2	3	1	1	1	2	2	3	2	2	
3		2	1 <sup>1</sup>		1	1	1	2	1	1	1	1	1	1	2	2	1	1	1	1	1	2	2	1	1	1	1	1	1	2	2	1
4		1	1 <sup>2</sup>		1	1	1	2	1	1	1	1	1	1	2	1	1	1	1	1	1	2	2	1	1	1	1	1	2	2	1	
5		1	1 <sup>1</sup>		1	2	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	
6		1	4 <sup>1</sup>		4	4	4	2	2	4	4	4	4	4	2	1	4	4	4	4	4	4	3	2	4	4	4	4	4	2	1	4
7		2	16 <sup>1</sup>	16	17	16	16	5	2	16	16	17	17	15	5	2	16	16	16	16	15	5	2	15	16	16	16	16	15	5	3	15
8		4	53 <sup>4</sup>	49	52	52	50	10	5	52	52	52	52	49	9	4	52	51	48	50	48	9	4	51	50	50	49	49	10	4	51	
9		6	50	52	49	53	51	14	7	51	51	52	52	49	13	5	51	51	53	52	48	12	5	51	51	51	50	45	13	6	49	
10		10	32	35	37	36	33	16	12	32	35	35	34	33	14	11	31	34	35	33	32	15	9	32	34	34	34	32	16	11	30	
11		17	25	28	29	28	29	21	15	26	27	27	27	27	19	16	26	26	27	26	29	18	16	25	25	26	27	27	19	17	26	
12		17	25	27	27	28	29	22	21	25	26	27	27	28	20	20	25	25	28	25	28	21	21	26	26	28	26	26	22	19	25	
13		20	26	27	27	28	29	22	23	26	26	27	27	29	20	23	26	27	28	26	29	23	22	26	25	28	29	31	24	24	26	
14		21	26	28	28	29	32	23	24	27	27	29	27	33	21	25	26	28	28	27	32	23	25	26	28	29	29	31	23	26	28	
15		26	28	30	30	31	35	21	24	29	29	31	32	35	21	25	29	31	30	31	34	24	24	28	30	31	31	35	22	25	28	
16		25	31	34	37	37	43	23	26	35	36	38	35	40	21	25	32	35	35	35	39	24	25	33	35	34	35	39	23	25	30	
17		27	45	48	51	51	49	27	29	47	50	51	49	47	25	30	47	49	49	50	45	35	27	48	49	50	48	44	24	31	43	
18		24	51	53	56	54	48	26	22	53	55	56	56	48	24	29	53	53	53	52	47	34	24	51	55	54	48	47	25	27	49	
19		19	35	33	35	34	31	21	21	31	36	37	36	31	19	24	31	34	35	34	28	26	18	31	34	33	35	32	21	21	35	
20		17	17	18	19	20	20	15	22	17	18	19	20	19	16	19	16	17	17	20	21	20	14	17	17	18	20	20	16	18	19	
21		15	12	13	14	13	13	11	19	12	13	13	14	13	10	15	11	11	13	13	14	10	12	12	12	13	15	15	12	13	13	
22		9	10	9	10	10	10	9	12	9	9	9	9	9	8	10	8	9	9	10	10	7	8	9	9	9	9	10	8	8	8	
23		5	6	7	7	7	8	8	8	6	7	7	7	8	7	7	6	6	7	7	9	7	6	6	7	8	7	8	8	7	7	
24		4	4	4	5	4	5	6	5	3	3	4	5	5	5	4	4	3	4	4	6	6	4	4	4	4	5	6	7	5	4	

**Table D2** Flow rate when time between safe gaps is less than 5 minutes (in black) and more than 5 minutes (in green) for a 3-lane stretch of the M65

Time (hour)	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
1		3	3		2	2	2	3	3	2	1	2	2	2	4	4	2	2	2	2	2	3	3	2	2	1	2	2	3	3	2	
2		2	1		1	1	2	2	2	1	1	2	1	2	2	1	1	1	1	1	2	2	2	1	1	1	2	2	2	2	1	
3		1	1 <sup>2</sup>		1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	2	1
4		1	1 <sup>1</sup>		1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1
5		1	1 <sup>1</sup>		1	1	1	1	1	1	1	2	1	1	2	1	2	1	1	1	1	2	1	1	1	1	2	1	1	1	1	1
6		1	4 <sup>1</sup>		4	4	4	2	2	4	4	5	4	4	2	1	4	4	4	4	4	4	2	1	4	4	5	4	4	2	1	4
7		3	17 <sup>1</sup>	17	18	17	16	5	2	17	17	17	16	16	5	2	17	16	17	17	15	5	2	16	16	17	16	16	4	2	16	
8		3	41 <sup>4</sup>	39	41	41	39	8	4	39	40	39	40	38	7	3	39	40	38	39	37	7	4	40	39	38	38	38	8	4	39	
9		5	35	40	39	39	38	12	5	39	38	40	39	37	11	4	40	39	39	40	37	10	4	39	40	40	39	37	11	5	38	
10		8	25	27	28	27	26	13	9	24	27	28	27	25	10	7	24	26	27	25	25	12	8	25	27	27	27	25	13	8	23	
11		11	20	21	22	21	22	16	12	19	21	20	21	20	16	11	20	20	20	20	22	15	12	19	20	21	21	20	16	12	20	
12		15	19	22	20	21	23	18	16	19	20	21	21	22	16	14	20	19	22	20	22	18	14	19	20	22	20	22	19	15	19	
13		18	21	21	22	22	24	18	17	20	20	20	21	24	19	17	20	20	22	21	24	19	16	21	21	22	23	24	18	16	20	
14		17	21	22	21	22	26	17	16	21	21	23	22	26	18	18	21	22	23	21	25	19	18	20	22	23	22	26	18	17	21	
15		18	23	24	23	24	28	17	16	22	23	24	25	28	17	16	22	23	24	22	27	18	17	22	21	24	24	26	16	17	21	
16		18	23	25	27	28	34	17	16	26	27	30	27	31	17	16	25	27	27	27	31	17	17	25	26	27	27	30	17	20	22	
17		19	36	36	42	39	36	19	17	36	38	40	38	37	17	19	37	39	39	39	35	19	18	38	39	38	37	35	17	20	33	
18		17	42	41	42	41	36	18	19	41	43	42	42	37	17	17	42	42	41	41	36	18	17	40	43	41	38	35	17	17	35	
19		13	27	26	28	27	24	15	17	24	27	29	30	25	14	14	24	27	30	28	23	13	12	24	27	26	26	24	15	13	24	
20		12	13	14	15	15	16	11	15	13	15	15	15	15	10	13	12	13	14	16	16	10	10	13	13	15	16	16	11	12	15	
21		9	9	10	10	10	11	8	10	9	9	10	11	10	7	10	8	8	10	11	11	7	9	9	9	10	12	11	8	8	9	
22		6	6	6	7	7	8	5	7	6	7	6	7	7	5	6	6	7	7	8	7	4	6	6	7	7	7	7	6	6	6	
23		4	5	5	5	5	6	5	5	5	5	5	5	6	4	5	4	4	5	6	5	4	4	4	5	6	6	6	5	5	5	
24		3	2	3	3	3	4	4	3	3	2	3	4	4	3	3	3	2	3	3	5	4	3	3	3	3	4	4	4	3	3	

**Table D3** Flow rate when time between safe gaps is less than 5 minutes (in black) and more than 5 minutes (in green) for a 3-lane stretch of the M55

Time (hour)	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1		6	3	3	2	3	3	5	7	3	2	3	2	3	4	5	3	3	3	3	3	5	5	3	2	2	3	3	4	6	4
2		4	2	2	2	2	2	3	4	2	1	1	2	2	3	3	1	2	1	2	1	3	4	1	2	2	2	2	3	4	2
3		3	2	2	1	1	2	2	3	1	2	2	1	2	2	3	2	1	1	1	1	2	3	2	1	1	2	2	3	3	1
4		3	3	1	2	2	2	3	3	2	2	2	2	2	3	2	2	2	2	1	2	2	3	2	2	2	1	2	2	3	2
5		3	4	4	3	3	3	3	3	4	4	3	4	4	3	3	5	4	3	4	3	2	2	5	3	3	3	3	3	2	5
6		3	11	8	8	8	8	5	3	11	9	8	8	7	5	3	10	8	8	8	8	5	3	10	8	8	8	7	4	3	10
7		6	28	29	28	27	26	9	6	29	28	27	27	25	9	5	29	27	26	27	25	9	5	30	28	28	27	25	8	6	30
8		8	46	47	46	45	44	13	8	47	46	46	46	44	15	7	45	46	45	45	45	13	8	45	46	46	45	44	14	7	46
9		13	47	47	48	46	46	20	14	46	49	50	50	44	19	12	47	48	48	48	43	18	11	47	50	49	47	45	18	11	45
10		23	36	35	36	36	41	26	25	38	36	36	35	40	24	22	38	35	36	36	40	25	21	37	35	37	37	39	25	23	36
11		41	35	29	32	30	41	30	38	38	30	30	31	38	29	37	33	28	30	31	42	29	38	35	28	30	33	41	31	42	34
12		45	32	27	28	28	35	30	42	30	27	28	30	35	26	43	30	26	27	29	34	30	43	31	28	28	30	33	31	46	30
13		42	28	27	27	29	36	30	40	31	27	29	29	36	25	40	29	26	28	27	39	31	46	31	29	29	29	34	29	45	29
14		43	29	29	28	31	38	28	39	31	29	30	31	34	25	38	30	28	29	29	42	33	48	31	31	29	31	36	29	46	31
15		42	31	28	34	32	39	28	39	33	33	32	31	38	25	37	30	31	30	31	42	35	41	29	33	32	32	41	29	39	30
16		42	35	36	40	41	44	30	46	37	37	38	37	42	25	41	33	35	35	37	46	32	40	35	36	37	39	44	31	45	36
17		42	48	47	52	51	52	34	57	49	50	50	48	48	31	45	47	46	50	49	51	33	44	49	48	51	48	47	37	42	46
18		37	53	55	58	56	45	36	34	55	56	53	53	44	31	47	51	52	53	52	48	31	36	50	53	53	49	43	37	39	49
19		30	33	33	37	37	33	31	44	35	36	34	32	31	29	39	33	34	30	34	34	24	28	32	35	34	33	33	31	34	34
20		26	19	18	21	19	22	26	56	20	20	17	20	20	22	32	17	17	16	19	21	19	22	19	19	20	17	20	24	25	20
21		17	13	11	14	13	14	18	29	13	12	12	12	12	16	22	12	11	11	12	14	13	14	12	12	12	10	14	17	18	14
22		10	9	10	10	11	10	14	20	9	9	8	10	9	14	13	8	9	9	9	11	9	10	9	9	10	9	11	14	10	9
23		8	6	6	7	7	8	12	9	6	6	6	7	6	11	8	5	6	5	6	8	10	7	5	6	7	7	8	10	9	6
24		6	4	5	5	4	6	9	5	4	4	4	5	6	8	5	4	3	4	4	6	8	6	4	4	4	4	7	8	6	4



**Table D4** Flow rate when time between safe gaps is less than 5 minutes (in black) and more than 5 minutes (in green) for a 3-lane stretch of the M2.  
 NB. There was missing data for the first 11 hours on the 24<sup>th</sup> June 2008 which has led to the errors in the first few cells for that day

Time (hour)	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	10	6	4	5	6	6	9	10	4	4	4	5	6	7	8	4	4	5	4	4	9	8	5#DIV/0!	6	5	6	8	9	5		
2	7	2	3	3	3	3	6	6	3	3	4	3	4	5	5	3	3	4	3	3	5	5	2#DIV/0!	4	4	4	6	5	4		
3	3	2	2	3	3	3	5	4	2	3	3	3	3	3	4	2	3	3	3	4	5	4	2#DIV/0!	3	4	3	5	3	2		
4	3	2	3	3	3	3	3	3	2	3	3	3	4	3	2	2	3	3	3	3	4	2	2#DIV/0!	3	3	3	4	2	2		
5	2	3	4	4	5	4	4	2	3	4	5	5	5	4	2	3	4	4	5	5	4	2	3#DIV/0!	5	4	4	4	2	3		
6	3	7	9	8	9	9	6	3	7	9	9	9	9	7	4	7	9	9	9	9	6	3	7#DIV/0!	9	9	7	6	4	7		
7	5	19	20	21	21	20	11	6	20	21	21	21	20	11	5	20	21	21	21	22	11	5	21#DIV/0!	22	21	13	11	6	20		
8	8	37	36	37	37	36	16	9	38	37	37	36	38	16	9	36	38	38	37	36	15	8	38#DIV/0!	39	37	22	19	10	39		
9	11	39	37	39	39	39	21	12	39	39	40	39	39	24	11	39	39	40	40	38	20	11	40#DIV/0!	39	36	20	27	15	38		
10	20	29	29	31	31	30	28	22	29	31	32	31	29	30	22	28	31	29	31	30	27	19	29#DIV/0!	30	33	13	30	23	29		
11	28	26	27	29	30	31	36	35	29	29	31	29	29	36	35	28	28	27	30	32	34	29	28#DIV/0!	30	31	13	39	34	30		
12	32	27	28	28	30	32	43	43	31	31	28	30	33	43	46	28	28	28	29	31	41	35	29	30	31	32	15	45	41	33	
13	36	28	27	30	33	34	41	43	30	30	31	31	34	42	43	30	29	29	32	35	41	37	30	30	30	20	47	40	31		
14	35	30	28	31	33	39	40	37	31	31	31	33	39	39	38	31	31	32	31	40	41	36	31	31	32	33	29	45	37	31	
15	32	34	33	37	38	43	38	32	35	37	35	37	43	39	33	33	35	35	36	42	37	30	35	34	38	38	37	42	31	35	
16	30	41	45	44	46	49	36	28	44	43	48	47	50	36	28	44	41	43	43	50	36	28	42	42	44	44	46	37	28	45	
17	29	52	54	57	57	56	34	29	56	56	58	58	59	35	29	55	52	55	57	58	35	29	54	58	57	57	35	31	53		
18	31	55	62	62	62	63	35	29	62	63	63	62	65	36	31	60	62	62	61	62	33	28	63	63	64	65	56	36	31	58	
19	25	45	47	51	56	50	33	25	48	48	48	50	55	33	29	45	43	49	50	51	32	26	49	47	55	52	41	33	28	52	
20	23	35	35	33	35	43	24	22	27	29	31	30	39	25	25	29	31	30	30	43	25	23	29	29	33	34	35	25	25	32	
21	18	19	20	20	22	31	17	20	18	18	21	22	29	17	21	18	19	21	20	29	18	20	19	21	21	23	30	19	18	19	
22	14	14	17	18	19	22	14	15	14	18	17	18	20	15	15	16	15	16	17	22	13	15	16	16	16	18	31	15	13	16	
23	11	10	12	14	12	15	12	11	10	12	12	14	13	12	11	10	10	12	13	15	12	10	11	12	12	14	16	13	11	12	
24	8	7	9	8	8	12	12	8	7	8	8	9	9	11	8	7	9	9	10	11	13	9	9	10	9	9	12	12	8	7	

**Table D5** Flow rate when time between safe gaps is less than 5 minutes (in black) and more than 5 minutes (in green) for a 3-lane stretch of the M25.  
 NB. There was missing data for the first 11 hours on the 24<sup>th</sup> June 2008 which has led to the errors in the first few cells for that day

Time (hour)	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	14	8	6	7	7	7	9	14	7	6	6	7	8	9	12	7	6	7	6	8	11	15	10#DIV/0!	8	8	8	9	13	8		
2	9	5	4	4	5	6	6	8	5	4	5	5	6	7	10	4	4	5	4	5	7	9	5#DIV/0!	5	6	6	6	10	5		
3	6	5	5	5	5	6	6	6	6	5	5	5	6	6	7	7	5	4	5	6	7	7	6	6#DIV/0!	5	6	6	7	7	5	
4	7	7	8	8	8	8	9	6	7	7	7	8	8	8	7	7	8	8	8	8	8	9	6	8#DIV/0!	7	8	9	8	7	8	
5	7	13	11	11	12	13	10	8	13	12	12	12	12	11	7	14	11	12	12	12	11	7	13#DIV/0!	12	12	11	10	7	13		
6	12	37	32	31	34	32	18	12	37	35	22	32	31	18	12	36	34	33	33	32	15	11	37#DIV/0!	34	36	33	17	12	35		
7	19	80	75	77	77	78	31	18	80	78	77	77	75	31	19	76	76	77	77	75	29	18	81#DIV/0!	78	65	75	32	19	78		
8	24	79	75	74	77	74	41	25	78	79	82	77	73	38	25	82	80	77	79	75	38	22	79#DIV/0!	79	71	75	42	27	58		
9	28	68	69	69	71	70	52	37	70	72	73	72	70	47	33	69	72	72	71	66	45	28	66#DIV/0!	71	70	67	49	32	66		
10	38	58	56	61	61	58	65	54	58	58	61	60	57	55	49	56	60	59	60	61	55	43	54#DIV/0!	61	65	60	57	47	53		
11	51	51	45	60	56	59	74	69	56	50	52	52	54	65	64	55	52	53	61	63	64	51	59#DIV/0!	54	57	59	66	55	57		
12	60	49	45	52	50	57	69	71	53	48	50	51	56	67	71	51	49	51	52	61	63	59	52	51	50	54	61	70	64	55	
13	58	48	40	51	50	61	66	68	50	47	46	47	59	60	66	52	50	47	52	60	63	62	49	48	49	50	60	66	61	51	
14	57	47	46	50	53	59	59	61	50	46	47	51	58	62	60	49	50	49	50	58	61	59	54	49	51	52	62	60	56	48	
15	53	48	49	52	54	60	52	50	49	51	51	55	61	53	52	50	50	54	55	63	55	51	53	51	54	55	65	61	55	51	
16	53	54	55	56	57	62	49	49	54	58	56	59	65	55	52	56	55	59	60	68	55	54	53	57	58	59	65	55	55	56	
17	60	54	61	63	65	63	52	54	57	63	63	59	68	56	60	63	63	63	64	70	56	59	62	63	66	64	68	53	66	61	
18	63	60	62	70	64	66	53	59	67	67	69	67	72	55	67	63	65	67	67	67	67	57	65	67	67	65	65	65	56	72	65
19	53	57	59	55	60	64	46	51	50	52	58	60	60	51	59	55	51	57	56	60	53	55	58	55	60	59	57	54	63	53	
20	46	36	41	41	41	51	35	44	32	34	36	40	46	38	51	34	36	38	42	53	41	49	35	37	40	42	51	42	49	36	
21	35	24	28	27	28	34	25	38	23	25	25	28	34	29	43	25	24	25	26	37	29	41	25	25	26	31	42	30	36	24	
22	26	16	19	22	22	28	16	28	18	20	20	23	23	22	30	18	19	20	22	27	21	28	18	20	22	24	31	23	25	19	
23	17	13	14	18	15	17	15	17	13	14	14	15	15	18	19	12	13	16	16	15	18	20	14	16	14	16	16	20	18	15	
24	13	9	12	13	12	11	19	11	9	11	10	10	11	15	13	9	11	10	13	14	21	18	15	14	11	12	12	16	13	9	

**Table D6** Flow rate when time between safe gaps is less than 5 minutes (in black) and more than 5 minutes (in green) for a 3-lane stretch of the M6

Time (hour)	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1		12	12	12	13	14	12	16	10	13	12	13	13	14	17	10	14	13	11	13	12	15	11	12	13	14	14	15	18	11	15
2		8	8	12	11	11	12	13	8	10	11	10	11	13	13	7	10	11	10	12	12	12	8	8	11	13	12	13	14	9	13
3		7	7	11	10	11	11	12	7	8	11	11	11	12	11	7	7	11	11	11	11	11	6	7	11	12	12	12	11	8	9
4		6	7	12	12	12	13	10	7	7	11	12	12	12	10	7	7	11	11	11	12	11	6	7	12	11	12	13	11	7	10
5		6	12	14	13	14	15	11	6	12	13	13	14	13	11	6	12	14	14	14	14	12	6	11	13	14	14	14	10	6	13
6		7	24	23	23	23	24	14	7	24	22	22	22	23	15	7	24	23	23	23	25	13	7	23	23	23	23	23	13	8	25
7		11	61	53	55	54	50	22	11	62	55	53	53	52	22	10	63	50	52	53	53	21	11	60	55	53	54	51	20	10	60
8		16	85	78	81	80	75	31	16	86	81	80	79	72	32	14	87	84	80	78	74	31	16	86	82	79	79	74	30	16	87
9		21	74	72	73	76	68	40	22	77	78	77	76	66	41	20	71	72	73	76	70	39	22	63	81	77	79	67	39	21	75
10		33	65	69	67	65	61	52	32	72	70	71	71	61	47	30	52	74	68	69	64	53	32	75	69	68	68	65	54	32	68
11		45	62	60	62	62	66	64	46	64	60	63	64	63	60	45	63	63	60	63	64	61	46	47	61	64	63	65	66	47	66
12		59	69	57	64	61	69	73	59	59	58	58	62	70	68	56	63	57	63	61	72	68	57	69	57	62	61	71	76	61	69
13		62	68	57	63	62	78	69	62	64	56	61	63	77	62	60	67	56	62	64	78	71	62	63	58	62	62	72	74	64	64
14		65	58	58	64	69	81	62	60	64	63	62	66	88	61	60	68	62	62	66	84	68	61	65	66	65	64	84	64	65	69
15		62	15	67	69	72	85	58	61	59	65	68	73	86	56	60	66	63	69	74	80	65	63	64	68	69	74	80	62	65	73
16		69	20	73	77	81	83	57	66	64	69	76	79	83	53	63	68	73	77	80	79	57	69	71	74	76	76	80	59	80	76
17		79	43	75	81	83	80	52	66	75	73	82	87	69	51	71	71	79	81	86	87	54	72	68	76	80	72	84	56	79	75
18		74	79	66	76	79	85	48	72	64	73	77	85	70	47	75	66	76	77	81	78	53	81	64	73	75	78	84	51	83	69
19		74	55	64	68	73	83	44	78	57	65	72	77	85	50	71	57	66	69	79	86	44	70	56	64	68	64	79	48	77	57
20		65	42	50	52	60	68	36	66	43	50	53	64	84	38	66	43	45	56	61	71	34	70	45	45	56	69	80	38	68	47
21		56	32	32	35	47	50	27	58	31	32	36	45	55	26	47	31	32	37	45	60	28	69	31	36	38	50	60	30	50	44
22		43	24	27	27	37	44	23	44	25	26	26	39	43	20	45	26	26	28	35	45	20	42	26	25	30	38	46	23	43	34
23		27	20	21	22	26	31	18	28	20	21	21	25	31	17	34	20	19	22	27	34	16	28	22	22	22	29	33	19	28	25
24		18	16	16	15	16	23	14	18	16	16	16	21	21	13	20	16	15	17	18	21	14	19	16	17	17	20	21	15	24	18

**Table D7** Flow rate when time between safe gaps is less than 5 minutes (in black) and more than 5 minutes (in green) for a 4-lane stretch of the M25.  
 NB. There was missing data for the first 11 hours on the 24<sup>th</sup> June 2008 which has led to the errors in the first few cells for that day

Time (hour)	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	22	15	14	12	12	12	15	18	16	13	13	14	13	14	18	16	12	11	14	14	15	23	16#DIV/0!	14	14	13	16	22	17		
2	13	11	9	9	10	9	8	10	11	9	9	9	9	10	12	10	10	9	8	10	11	13	10#DIV/0!	10	11	10	10	13	11		
3	10	9	8	9	8	7	7	3	8	9	9	9	9	8	9	9	7	9	7	9	9	10	9#DIV/0!	9	9	10	9	11	9		
4	8	10	7	7	8	8	7	7	8	9	8	8	9	7	7	9	7	8	8	10	8	8	10#DIV/0!	9	9	10	9	8	11		
5	12	17	14	13	14	15	13	9	17	15	15	14	14	11	12	17	14	14	15	15	11	10	16#DIV/0!	16	16	16	13	11	19		
6	16	48	36	37	39	38	21	14	48	41	38	37	36	22	15	48	39	39	38	36	19	15	49#DIV/0!	41	42	38	21	17	47		
7	25	113	102	111	107	96	40	24	117	113	101	102	103	42	24	118	116	114	104	100	39	23	119#DIV/0!	111	109	99	41	23	100		
8	37	114	95	115	103	106	54	36	111	112	118	114	106	55	34	113	117	110	112	106	53	36	110#DIV/0!	114	115	107	57	35	111		
9	48	91	87	85	95	90	66	51	91	94	93	93	81	70	47	89	92	85	93	89	69	51	76#DIV/0!	90	95	90	74	51	89		
10	69	94	79	82	95	83	87	69	93	88	90	96	70	87	67	95	91	87	98	95	83	72	81#DIV/0!	95	94	91	94	75	95		
11	85	86	77	80	87	94	95	82	91	80	82	82	104	92	82	89	86	83	97	102	93	85	101#DIV/0!	83	90	89	98	90	98		
12	93	80	77	77	73	86	90	87	80	72	78	55	94	94	91	80	76	76	82	98	100	92	96	72	76	80	102	97	98	91	
13	92	71	69	69	72	86	79	79	72	68	72	54	81	82	82	75	71	74	73	92	89	85	81	69	70	71	100	87	94	74	
14	81	71	69	71	73	88	72	73	70	65	72	87	83	73	80	72	70	72	76	78	68	74	73	73	73	75	91	77	76	69	
15	78	69	73	71	76	91	68	71	70	71	73	72	86	68	76	72	71	74	77	83	67	74	74	76	75	82	95	79	76	71	
16	87	76	74	79	84	92	68	80	72	78	81	80	88	63	83	80	77	81	86	89	65	81	79	80	87	89	94	74	86	74	
17	94	79	83	88	95	89	70	90	80	90	94	89	90	67	95	80	87	89	92	91	67	91	78	88	94	93	86	74	96	83	
18	94	76	80	83	87	83	69	96	75	78	84	83	81	70	99	83	81	82	86	81	67	95	77	50	83	84	90	79	101	79	
19	91	71	71	71	79	74	43	95	69	68	72	73	75	68	93	73	70	74	77	72	67	96	73	88	73	76	74	71	96	72	
20	78	47	51	54	58	63	79	87	48	51	51	56	64	54	97	51	51	55	56	76	55	84	52	50	57	59	66	60	95	55	
21	62	35	35	44	39	48	44	72	34	35	35	38	48	39	81	40	35	37	39	51	41	65	35	36	40	43	52	45	76	39	
22	48	25	26	29	28	30	31	53	25	28	27	29	30	32	58	28	25	26	29	33	31	47	29	28	29	32	35	36	48	30	
23	34	22	19	22	22	25	29	37	21	21	21	25	26	28	39	23	20	21	24	25	30	34	21	22	24	25	26	30	39	25	
24	22	15	18	21	18	19	25	20	17	17	17	17	20	25	26	13	18	19	18	23	28	25	18	18	20	19	21	28	26	17	

**Table D8** Flow rate when time between safe gaps is less than 5 minutes (in black) and more than 5 minutes (in green) for a 4-lane stretch of the M6

Time (hour)	Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1		13	11	11	12	14	18	17	13	12	12	13	14	14	18	15	14	11	11	13	16	17	14	12	12	12	13	15	17	14	15
2		9	8	10	10	11	11	12	9	10	11	10	10	11	12	9	9	10	11	10	14	13	9	8	10	12	11	12	14	10	11
3		8	7	10	10	10	11	11	7	8	11	11	11	11	11	7	7	10	10	11	13	10	6	8	10	10	10	11	11	7	9
4		6	7	11	11	12	11	9	8	8	11	11	11	11	10	7	8	10	11	10	11	10	6	8	11	11	11	12	10	6	8
5		7	12	13	14	14	15	11	6	13	13	15	14	14	11	7	13	14	13	14	15	11	7	12	13	14	14	14	10	7	13
6		9	28	25	25	25	26	14	9	26	25	23	26	25	15	8	27	25	24	25	25	15	9	27	24	24	25	24	14	8	28
7		12	63	56	59	59	56	24	13	64	59	59	58	55	24	11	63	56	56	58	57	24	13	63	58	57	58	55	23	11	64
8		18	121	112	118	117	109	35	20	120	119	118	118	108	38	18	122	117	111	117	111	35	20	122	116	118	116	109	34	17	116
9		25	113	115	113	110	108	47	27	121	114	121	116	107	49	25	101	113	114	118	110	45	27	114	118	118	118	108	47	26	120
10		38	83	87	88	85	84	62	40	93	94	94	90	87	51	38	86	94	91	88	85	59	37	97	89	93	93	89	61	39	90
11		57	77	76	75	78	83	75	58	81	75	77	79	80	67	56	90	77	76	79	82	70	57	75	80	77	78	88	78	59	82
12		73	83	73	76	75	91	85	70	77	73	74	76	88	79	71	88	71	75	75	89	83	71	85	73	79	77	96	86	75	83
13		79	78	74	77	77	96	81	75	82	74	76	81	97	75	76	81	73	76	80	102	85	74	76	74	79	77	91	85	78	81
14		79	76	78	82	85	105	77	73	81	78	81	85	107	73	77	85	79	83	84	102	79	75	84	83	83	83	107	77	80	85
15		80	58	81	84	90	113	70	73	81	84	87	92	115	71	78	86	83	87	92	112	83	76	81	85	89	89	113	77	80	90
16		87	68	96	103	105	121	69	83	92	96	99	102	118	66	82	94	97	105	108	112	72	81	100	103	101	89	119	77	90	97
17		93	104	121	126	128	123	70	85	121	121	125	128	114	66	86	115	128	126	120	123	70	86	117	120	121	112	119	74	91	121
18		90	131	106	121	108	120	62	82	112	118	121	126	115	65	87	114	123	125	114	81	68	86	113	121	112	90	109	69	89	116
19		83	92	78	91	93	98	55	86	80	85	88	94	100	59	82	80	94	96	107	93	56	77	80	85	86	85	103	60	85	82
20		70	51	56	57	65	74	43	75	51	56	61	68	82	47	70	51	55	63	69	82	40	62	52	54	61	81	83	46	70	55
21		56	35	37	40	47	54	32	63	36	39	40	49	61	33	55	37	36	41	47	62	30	62	37	39	42	57	65	34	54	43
22		44	28	29	30	34	40	24	47	29	31	29	39	42	26	45	29	29	30	34	42	23	43	28	30	32	39	44	27	41	32
23		28	22	23	24	26	31	21	29	22	27	24	28	32	21	34	23	21	24	26	33	20	28	23	23	26	30	36	22	31	26
24		18	16	17	20	21	23	17	19	17	19	19	21	22	18	21	17	16	18	18	22	17	18	17	18	18	21	22	18	23	21

# 11 APPENDIX E – MINIMUM HEADWAY

The following graphs take the first Tuesday of June 2008 and show the hourly mean minimum headway across all the lanes in the motorway. There are error bars showing the standard deviation to illustrate the variation in the data across each hour.

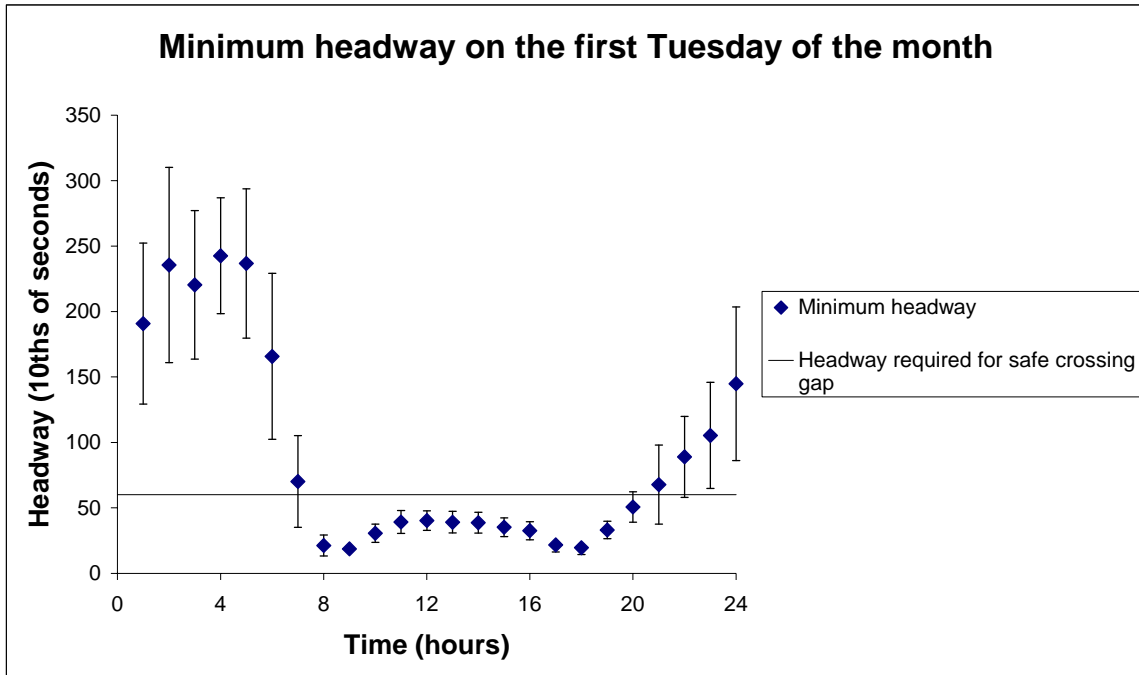


Figure E1 Minimum headway for a 2-lane stretch of the M65

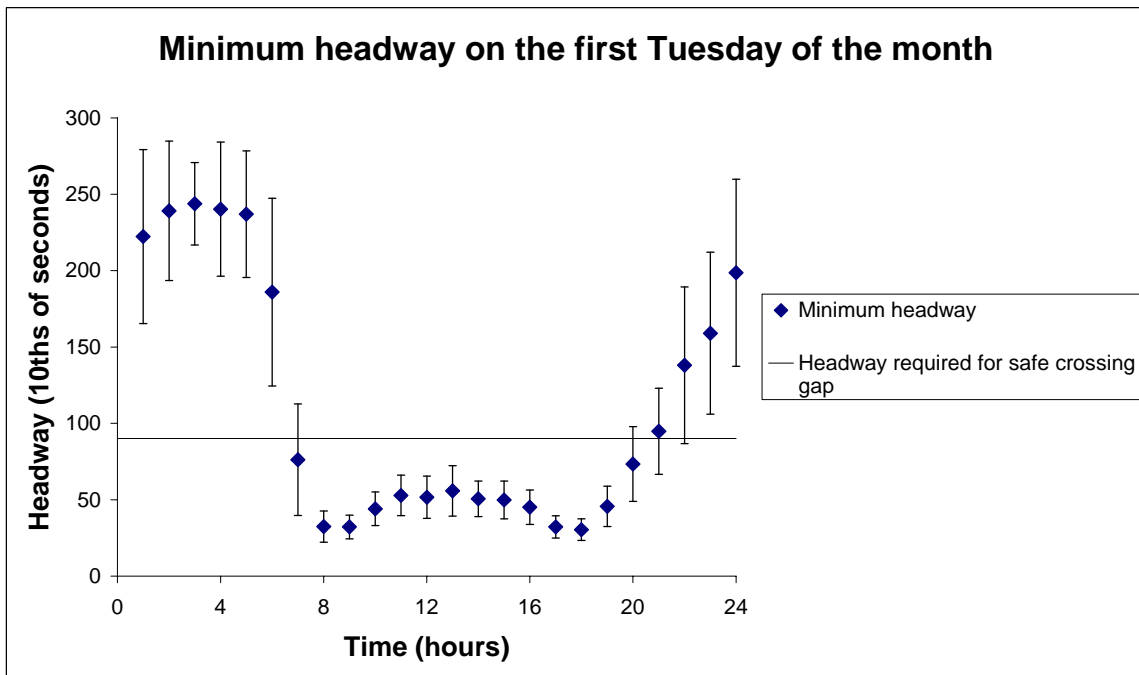
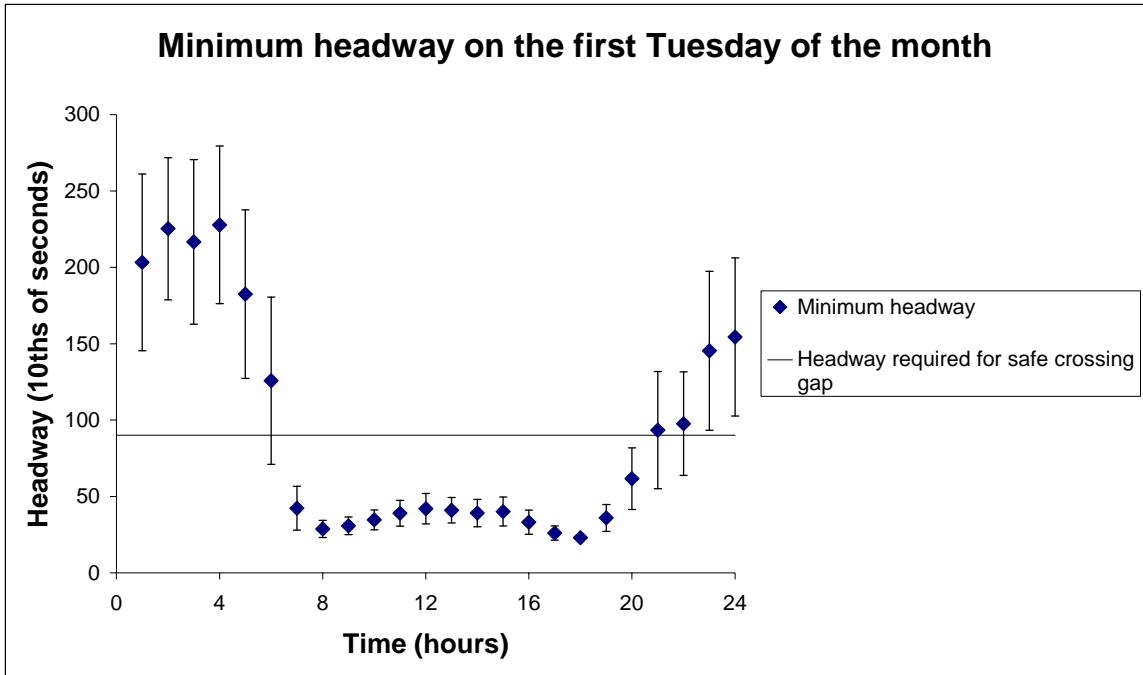
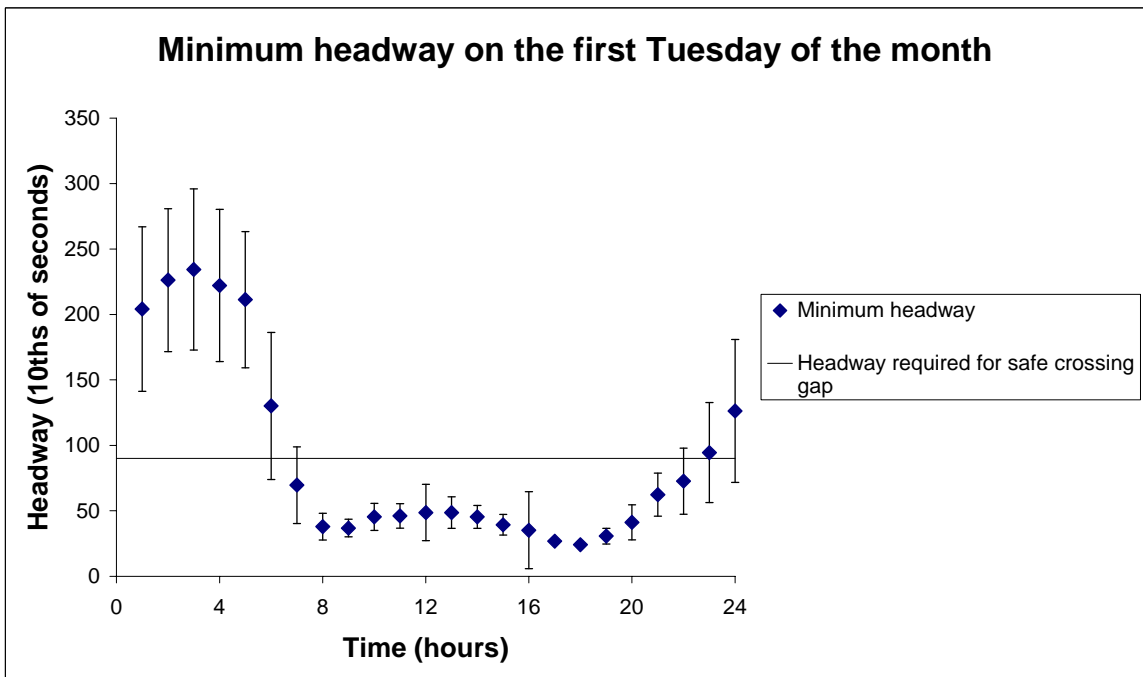


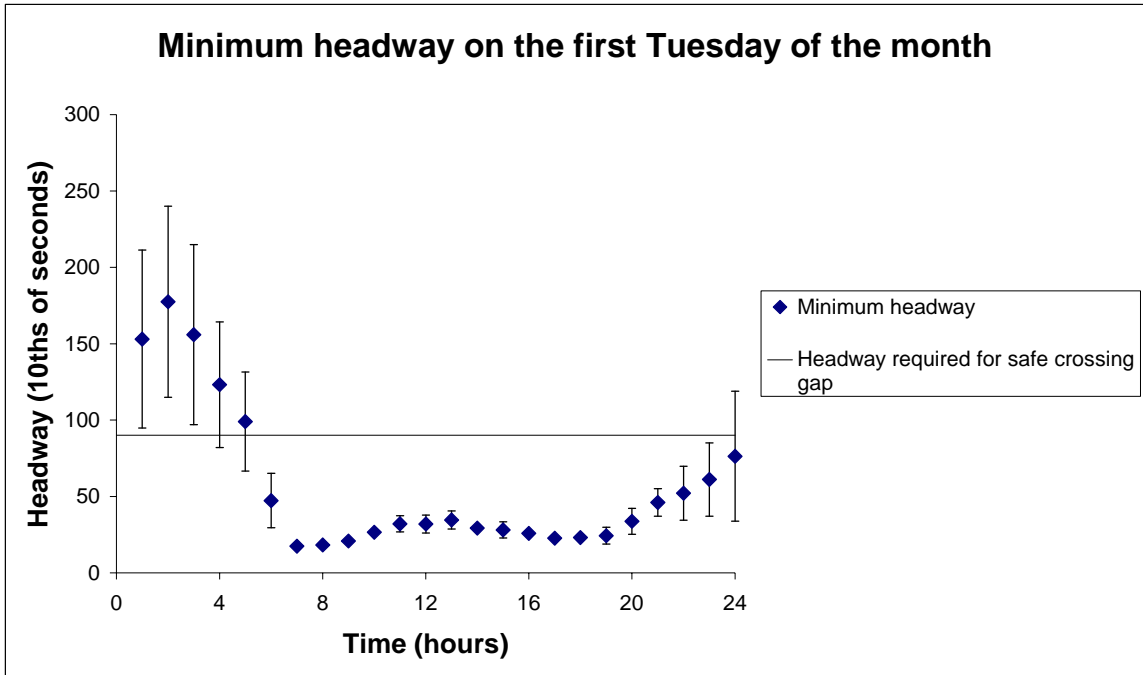
Figure E2 Minimum headway a 3-lane stretch of the M65



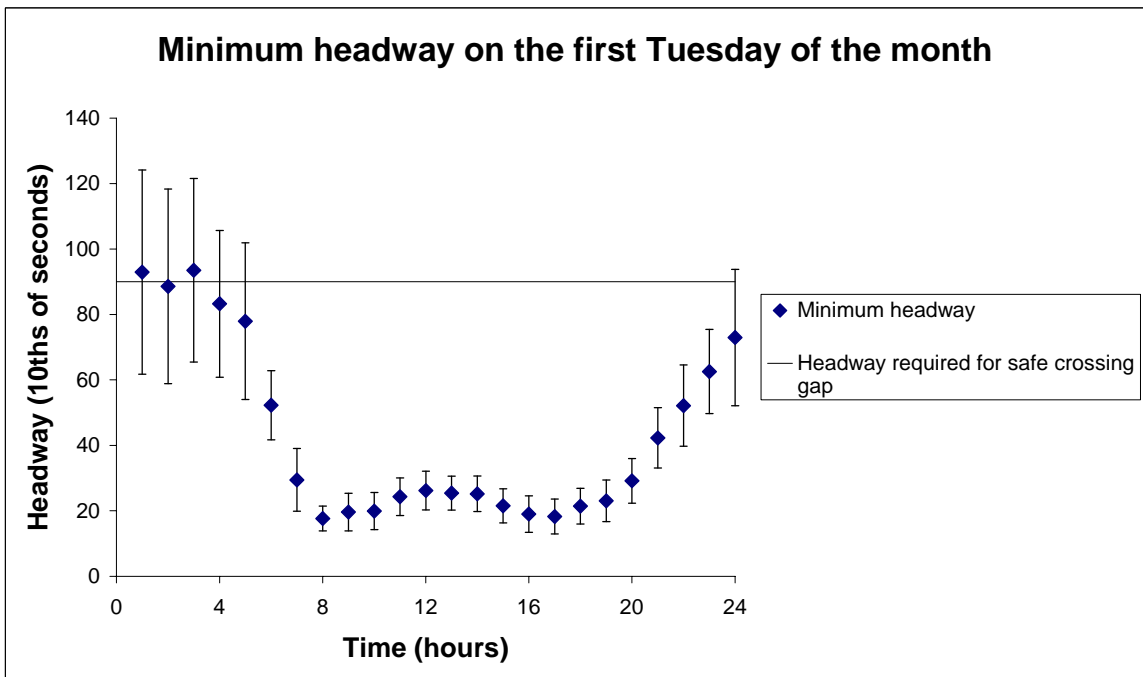
**Figure E3** Minimum headway for a 3-lane stretch of the M55



**Figure E4** Minimum headway for a 3-lane stretch of the M2

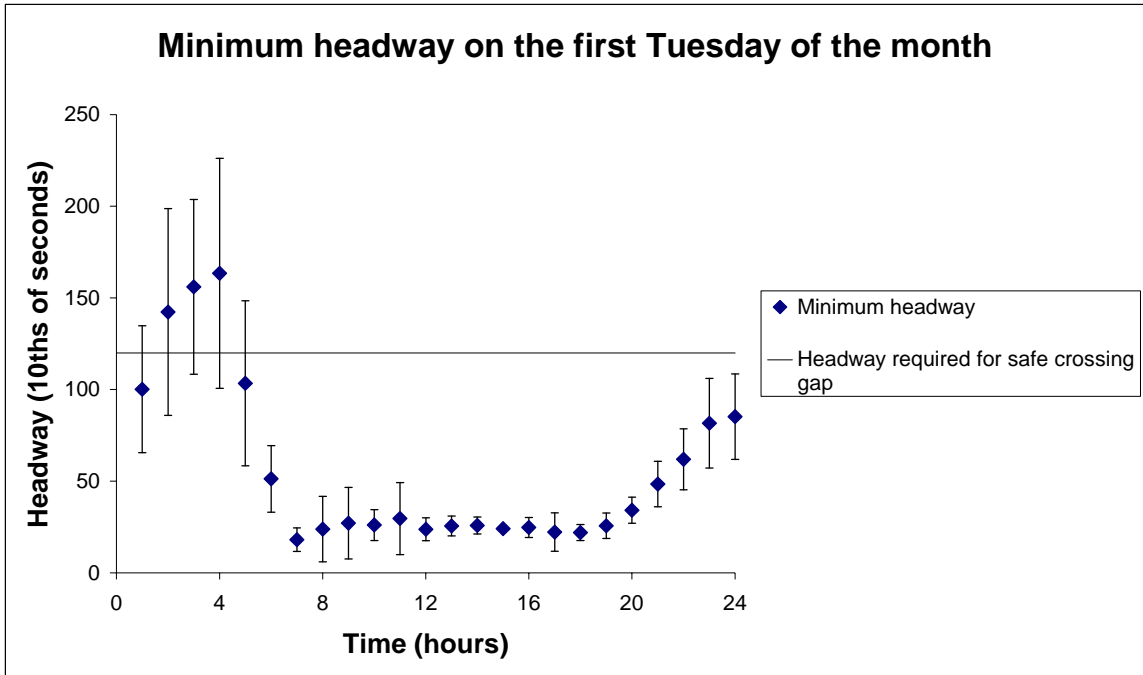


**Figure E5** Minimum headway for a 3-lane stretch of the M25

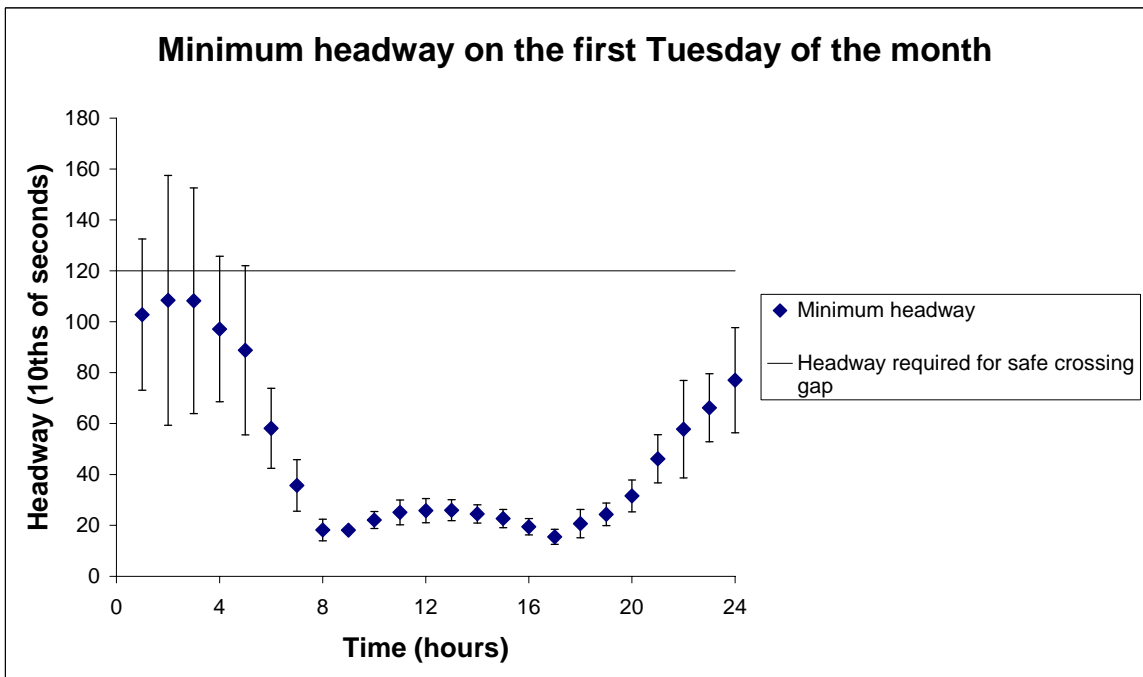


**Figure E6** Minimum headway for a 3-lane stretch of the M6





**Figure E7** Minimum headway for a 4-lane stretch of the M25



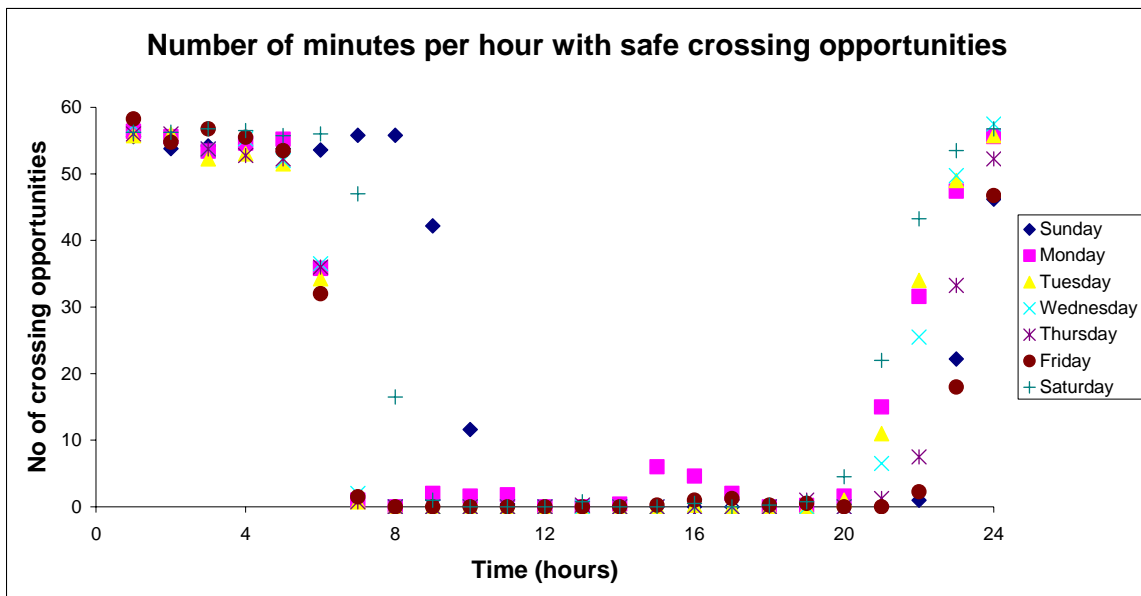
**Figure E8** Minimum headway for a 4-lane stretch of the M6

## 12 APPENDIX F – SENSITIVITY TEST

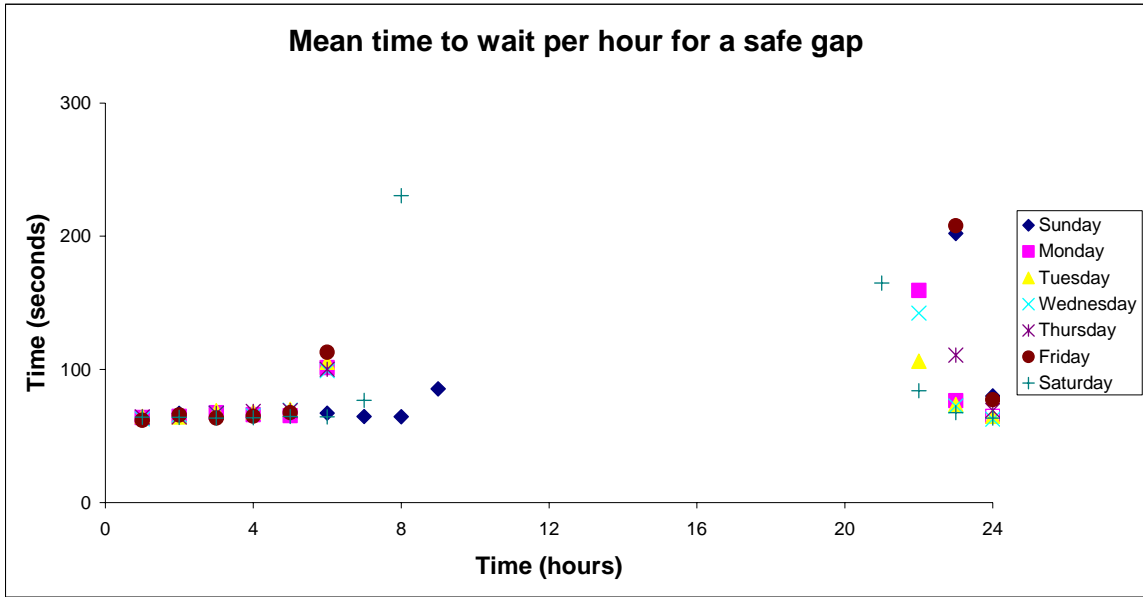
In order to ascertain the effect of using average headway data rather than IVD, calculations were performed for two 3-lane motorways assuming that the time to cross the carriageway was 5 seconds, rather than 9 seconds. If the data was sensitive to the use of averaged headway data then it would be anticipated that this would substantially increase the number of hours in a day when a person could cross the motorway. A small change in the number of hours that it is safe to cross would indicate that there really are very few crossing opportunities at certain times of the day and that this is relatively unaffected by the use of average headway data.

The figures below show the number of minutes with safe crossing opportunities and the mean time to wait for a safe gap for two motorways assuming it takes 5 seconds to cross the motorway.

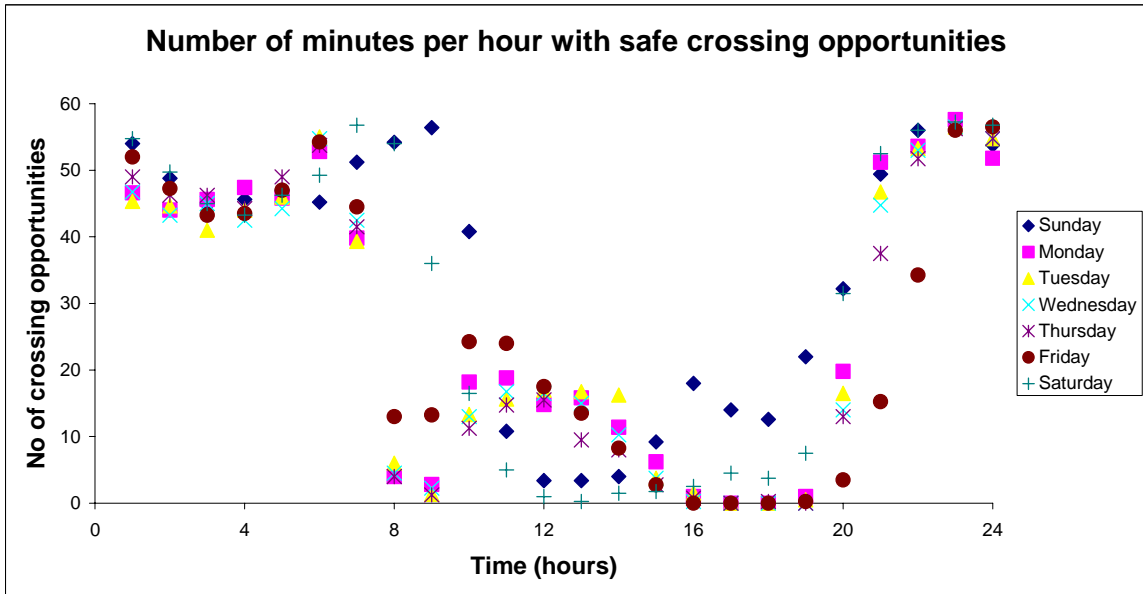
The graphs and the tables, when compared to those in the main body of the report, show that there is not a significant increase in the number of safe crossing opportunities. In the case of the three-lane stretch of the M6, there are an extra couple of hours in the morning and late at night when it would be safe to cross. For the 3-lane stretch of the M2, there are now a few hours in the middle of the day with safe crossing opportunities but there are still very few opportunities during the morning and evening peaks and the maximum 5 minute wait rule does not apply at these times. The data is therefore showing very little sensitivity to the use of average headway data and hence it can be concluded that the results shown in the main body of the report are robust.



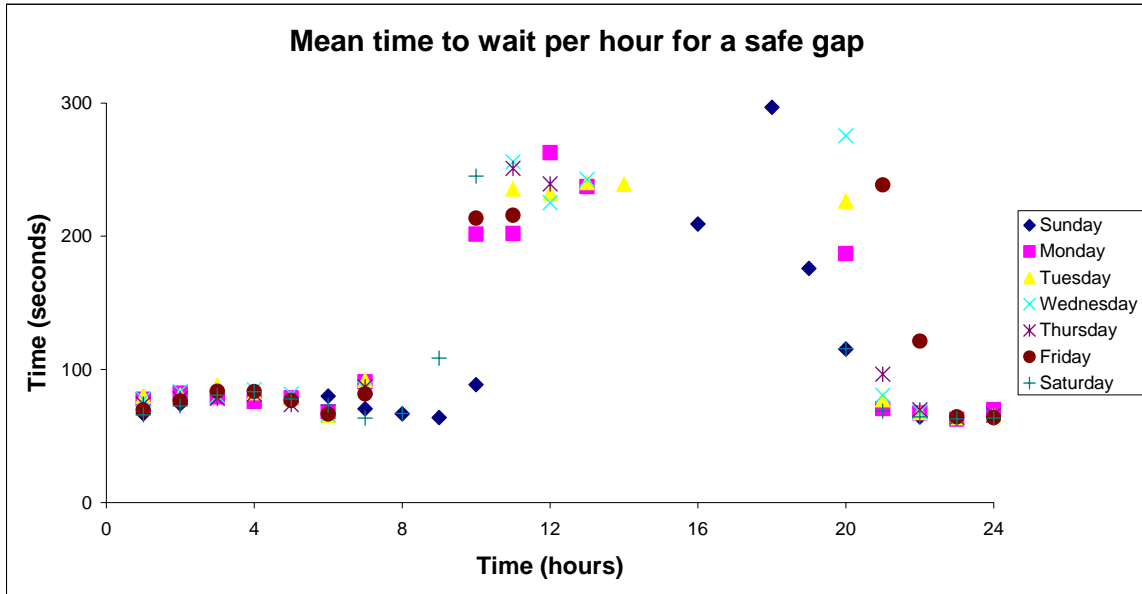
**Figure F1** Graph showing number of minutes per hour with safe crossing opportunities for each day of the week for a 3-lane stretch of the M6



**Figure F2** Graph showing the mean time to wait per hour for a safe crossing opportunity for a 3-lane stretch of the M6. The graph is capped at 5 minutes as this is the accepted maximum waiting time that a worker should have to wait for a safe gap



**Figure F3** Graph showing number of minutes per hour with safe crossing opportunities for each day of the week for a 3-lane stretch of the M2



**Figure F4** Graph showing the mean time to wait per hour for a safe crossing opportunity for a 3-lane stretch of the M2. The graph is capped at 5 minutes as this is the accepted maximum waiting time that a worker should have to wait for a safe gap

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# Assessment of current guidance in relation to Safe Carriageway Crossing (CIS53) on high speed roads

This work has assessed the adequacy of current guidance - HSE Construction Information Sheet 53 (CIS53) - aimed at clients, designers and workers involved in road works on motorways/high speed dual carriageways (50mph or greater). The work has comprised of: a literature review; observing workers setting up temporary traffic management; and analysis of traffic flow data. The findings broadly support the present rules set out in CIS53 for crossing a carriageway on foot, but have indicated that traffic flows for many motorways make crossing impossible in practice for much of the day. Potentially safe gaps can be assessed by measuring the traffic flow in terms of vehicles per minute. At less than 20 vehicles per minute across all lanes, it is likely that sufficient safe gaps occur so that workers would not have to wait more than 5 minutes to cross. Between 20 and 40 vehicles per minute, it is suggested that site specific assessment is undertaken to determine if sufficient safe gaps exist. At greater than 40 vehicles per minute it is very unlikely that the carriageway can be crossed safely on foot. These flow rates are intended to be used as a guide and are not to be treated as absolute.

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