TRL Limited

PUBLISHED PROJECT REPORT PPR033

SPEED-CONTROL AND INCIDENT-DETECTION ON THE M25 CONTROLLED MOTORWAY (SUMMARY OF RESULTS 1995-2002)

Version: Final

by Tim Rees (TRL), Brian Harbord (HA), Carole Dixon (TRL) and Nabil Abou-Rahme (TRL)

Prepared for: Project Record:	**T020 – M25 Controlled Motorway Monitoring**
Client:	**Safety Standards and Research Directorate, Highways Agency**

	Approvals
Project Manager	**T Rees**
Quality Reviewed	**P Baguley**

CONTENTS

Executive summary

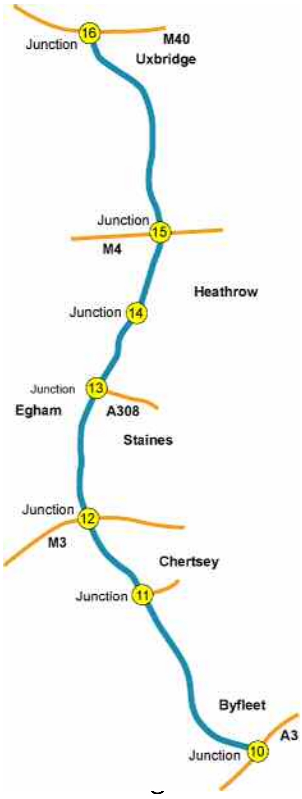
INTRODUCTION

A Controlled Motorways scheme was introduced on to the M25 in August 1995. The M25 Controlled Motorways section originally ran from Junction 11 (Chertsey) to Junction 15 (the M4) along the south-western quadrant in both directions. In November 1995, the scheme was extended to include Junction 10 (the A3) to Junction 11. The scheme was then extended to cover Junctions 15 and 16 of the M25 in March 2002 (see Figure 1).

The objective of this report is to present an overview of the monitoring work undertaken by TRL Limited for the Highways Agency between 1995 and 2002. As well as describing the history of the project, the report presents key results for performance indicators, a variety of traffic behaviour and trends, and a number of specific studies carried out alongside regular monitoring work.

The primary objective of the Controlled Motorways scheme is to smooth vehicle speeds progressively to minimise the risk of flow breakdown, creating a safer, 'better' environment, and therefore maximising the motorway's potential.

The Controlled Motorways system uses variable, mandatory speed limits to control and equalise speeds in all lanes when traffic flow is heavy. The speed limits are set automatically using Motorway Incident Detection and Automatic Signalling (MIDAS) loop data. The aims of the scheme are to:



The Controlled Motorway on the M25 Junctions 10-16

- smooth traffic flow
- improve journey times and journey time reliability
- improve lane utilisation
- reduce the incidence of stop-start driving
- improve safety
- reduce the stress of driving.

The Controlled Motorways system displays 60mph and 50mph congestion signal settings in response to the traffic conditions on the motorway. The congestion signal settings respond to the number of vehicles per minute passing over the MIDAS loop detectors (the traffic flow). At calculated thresholds, the speed limit displayed to drivers is reduced and increased as required.

Several enhancements have been made to the scheme since its introduction. In 1997, the HIgh OCCupancy (HIOCC) incident detection algorithm was implemented on the M25, to provide protection for backs of traffic queues. In 1998, automatic setting of the Enhanced Message Signs (EMS) was implemented to provide drivers with information about the reasons for the signal settings.

The Controlled Motorways monitoring consists of two major activities:

- Traffic and signal data are graphically analysed using the Motorway Traffic Viewer (MTV) facility. This facility was developed as an aid to visualising and interpreting the traffic conditions and signal settings. It enables the traffic conditions over the whole section for a whole day to be viewed, and allows the relationships between the traffic conditions, the signal settings and the messages to be studied. It has been used to support the 'tuning' of system parameters, to optimise the performance of the system.
- The effects on the scheme on traffic are analysed by monitoring traffic trends and traffic behaviour using pre-defined performance indicators. An assessment of the effects of the

variable speed limits on accidents was carried out as part of the monitoring work, as well as an investigation into the effects on noise levels and air pollution. Also, a driver opinion survey provided valuable feedback on how the scheme was being received by its primary users.

SYSTEM HISTORY

A trial of mandatory speed limits on the M25 was announced in 1990 in the Department of Transport’s M25 Action Plan. The simplest method of reducing the speed limits would have been to introduce a fixed speed limit. The effects of introducing a fixed 50mph speed limit were predicted and proved to be strongly negative. As a more complex system was required, the concept of Controlled Motorways was developed during 1993 and 1994 by the Highways Agency. The limited traffic data available from the M25 prior to initial operation was analysed in order to derive the initial parameters and thresholds for the system.

In August 1995, the Controlled Motorways system was introduced between Junctions 11 and 15 using a fixed time plan (setting mandatory speed limits at certain times of day, regardless of current traffic conditions) to control speeds. The fixed time plan was derived using historical traffic data to establish when flow thresholds were likely to be exceeded. It was intended that the fixed time plan would operate for a 3-month period while drivers became accustomed to the system, after which a new system driven by actual traffic flows would be introduced.

During the first two weeks of operation, the fixed time system was monitored in detail by the Highways Agency. It was discovered that the signals were not always suitable for the traffic conditions; this was confirmed by the number of complaints from drivers using this section of the M25. In response to this, the HA introduced automatic flow-based operation earlier then anticipated, in September 1995.

During the early operation of the system, various enhancements were made to the control parameters. Parameters such as the flow levels at which the signals are activated and the minimum time between signal changes were systematically changed. The effects of the changes on the signal setting sequences and on traffic behaviour were studied in detail as part of the on-going monitoring programme. This tuning optimised the signal settings, so that they were appropriate to the changing traffic conditions, and so that drivers saw a consistent sequence of logical signal settings. In order to avoid the signals switching on and off too frequently, the traffic data driving the signal system was smoothed by taking a continuous moving average (the level of smoothing being varied and optimised appropriately).

In November 1995, the system was enabled for the section between Junctions 10 and 11 (where works to widen the motorway to four lanes had just been completed) using the control parameters deployed between Junctions 11 and 15. Subsequent parameters changes were deployed over the whole section.

In April 1996, an optimal set of control parameters was determined. Because traffic conditions change over the years, tuning continues to be performed to improve the operation of the system. The tuning is carried out on a site-by-site basis, to allow for differences in traffic behaviour at various locations (e.g. motorway-to-motorway junctions are given different parameters to other junctions).

Analysis of the traffic signals during congested conditions showed that the signals were switching off in the presence of queues, because the flow level fell below the switch off threshold. The flow-based algorithm was unable to distinguish between free-flowing traffic conditions and low flows during heavy congestion. Drivers were complaining that the speed limits were increasing while the drivers were stuck in a queue. As a result, in February 1997 the HA modified the control algorithm to run on both flow and speed information. This prevented the signals switching off in the presence of queues.

In October 1997, the HIOCC incident detection algorithm was introduced. This detects queueing or slow-moving traffic and protects this traffic by automatically setting lower speed limits (40mph, with 60mph and 50mph settings further upstream to provide drivers with advance warning of the queues). The algorithm works in parallel with the Controlled Motorway system and offers greater scope to reduce accidents and consequential delays. The signal settings were monitored to ensure that drivers continued to see a consistent sequence of logical signal settings. Early feedback from drivers, following the introduction of HIOCC, indicated that many thought the 40mph limit caused the queue. As a result, the HA introduced a publicity campaign to explain the queue protection system.

In order to provide drivers with appropriate and relevant information, the setting of Enhanced Message Signs (EMS) was coordinated with the setting of the signals. This feature was introduced between Junctions 10 and 13 in October 1998, and between Junctions 13 and 15 in July 1999. The EMS messages provide drivers with information about the reasons for the signal settings, and provide warnings of queues or congestion ahead. The message settings were monitored to ensure that they were consistent with the signal settings.

During 2000, work started to extend the Controlled Motorways scheme to cover Junctions 15 (M4) to 16 (M40) of the M25; this scheme became operational in March 2002.

SYSTEM OPERATION

One of the HA objectives in installing the scheme was to prove the technology, i.e. to show that signals could be set using real-time traffic data. In addition, for the system to have an effect, it was necessary to show that drivers responded to the signals.

The monitoring has shown that the Controlled Motorways system is reliable and that it sets consistent and coherent sequences of speed limits that are appropriate to the traffic conditions, and that are generally obeyed by drivers.

The performance of the Controlled Motorways system depends on the availability of accurate MIDAS data. A faulty loop site can cause inappropriate signal settings to be displayed, and loop faults at three consecutive sites can result in HIOCC queue protection signal settings not being displayed at some signal gantries. It is therefore essential that the availability and the accuracy of the traffic data is checked at regular intervals and that any faults are repaired without delay.

SUMMARY OF MONITORING RESULTS

Core performance indicators have been calculated since the implementation of the Controlled Motorways system in 1995, and trends have been analysed. The core performance indicators (journey times, throughputs and lane utilisation) show how the traffic conditions have varied over the period. In addition, studies have been carried out into the underlying traffic behaviour. These provide the reasons behind the changes in traffic conditions. Also, driver opinions have been analysed and studies have been carried out into the effects of the system on accidents and the environment.

The performance indicators and most of the changes to traffic conditions have been analysed for the period since Controlled Motorways was implemented. This is due to a lack of good quality data prior to the introduction of Controlled Motorways, which meant it was not possible to carry out an impact assessment as part of a “before and after” study for the system. Some data on speed compliance and headways was collected prior to the introduction of Controlled Motorways; this has been used to analyse the effects of Controlled Motorways on these aspects of traffic behaviour.

Traffic Conditions on the M25

The development of the Motorway Traffic Viewer (MTV) has enabled all aspects of traffic conditions to be assessed. As well as the performance of the system, the performance of the motorway can be assessed. The effects of traffic management, traffic trends, demand hotspots, driver behaviour and MIDAS availability have been studied. MTV has enabled the identification of locations where congestion first occurs (called “seed points”), and the study of shockwaves of slow moving traffic propagating back from these seed points.

On the M25, there are several seed points on each carriageway. The seed points that cause the most congestion are:

- on the clockwise carriageway at Junction 14. Traffic that joins the motorway at Junction 14 conflicts with traffic preparing to leave at Junction 15.
- on the anticlockwise carriageway between Junctions 12 and 11. Traffic that joins the motorway at Junction 12 has to change lanes prior to the lane drop at Junction 11.

During peak periods, shockwaves propagate back from both of these seed points on a regular basis.

During the system tuning following the introduction of Controlled Motorways, the thresholds for the signal settings were raised in the vicinity of the seed points. It was found that locations of the seed points and the resulting shockwaves remained unchanged. This showed that the system itself was not causing the congestion.

The passage of a slow vehicle outside of the peak period (often accompanied by a police escort) can act as a moving seed point. The behaviour of drivers following at slow speed leads to the propagation of a number of shockwaves in the wake of the slow vehicle. The delays arising from the passage of a slow vehicle can be of the same magnitude as the delays arising during a peak period.

Whilst rubbernecking (drivers slowing to look at an event on the opposite carriageway) does not occur very frequently, when it does occur it can lead to almost double the amount of congestion for the same incident. Analysis has shown that the flow levels need to be sufficiently high before a disturbance due to a distraction on the opposite carriageway will actually lead to flow breakdown.

Effects on Traffic

Following the introduction of Controlled Motorways, it was established that speed limit compliance was good, lane utilisation and headway distribution had been improved and the driver response had been favourable. The lane utilisation became more balanced, thereby making better use of the available road space. There was a reduction in the occurrence of very short headways, which has led to smoother traffic flows.

Throughout the monitoring period a variety of traffic trends and behaviour have been identified. A comparison of data from year to year showed evidence of peak shifting, with the rise in traffic flow associated with the start of the morning peak period moving forward by a few minutes for the first two years of operation. Since 1998, the time at which the traffic flow increases has remained consistent.

The year-to-year trends in journey times show that journey times have been reducing on the clockwise carriageway during the mornings. This is the period when there is most congestion. It is believed that drivers have become accustomed to the Controlled Motorways system, and have learnt to drive more smoothly to prevent or reduce the effect of flow breakdown (see the section on Traffic Behaviour). The year-to-year trends in journey times also show that congestion during the evenings has risen slightly, due to the increased flows. During the evenings, the performance of the road is more susceptible to changes in flow levels than it is during the mornings, when the flow profile is more compressed.

Observations of the changes in shockwave characteristics have shown that whilst the general profile of the shockwaves has remained the same throughout the duration of the monitoring period, the number of shockwaves during the 3-hour morning peak period has reduced. In 1995, there were typically seven shockwaves during the morning peak; by 2002, the number of shockwaves during the morning peak had dropped to five. As there are fewer shockwaves, there will be fewer delays, as shown by the journey times.

Traffic Behaviour

Traffic conditions have been analysed to identify underlying trends and to determine the effect of the system on traffic behaviour. Performance indicators have been produced to measure demand flows, peak throughputs, journey times and flow breakdown on the Controlled section. There have been standard seasonal trends throughout the seven years of monitoring. This has enabled the underlying year-to-year trend to be identified.

During the 5-hour morning peak period, the total throughput has increased by 1.5% per year, and the peak 1-hour throughputs have reduced by 1% per year. Despite this, journey times and the amount of flow breakdown remained unchanged during 2001 and reduced during 2002. The signal activity provides confirmation of the observed trends. The traffic levels (as measured by the flow-based signal activity) have increased, and the amount of queueing (as measured by the HIOCC signal activity) has reduced.

Additional studies into traffic behaviour during 2000 and 2002 have provided some possible reasons for an improvement in performance, despite the increased total throughput and the reduction in peak throughput. These reasons include:

- Drivers are leaving shorter headways during 2002 than they were during 2000, at all speeds up to 50mph. The reduction in average headway implies a more efficient use of road space, and suggests that more vehicles will travel through the section in a given period than was previously the case. Although the proportion of vehicle headways below one second has marginally risen, this does not seem to have affected accidents, possibly because there are fewer very short headways (less than 0.8 seconds) and possibly because of the HIOCC queue protection. The shorter headways observed during 2002 are longer than they were before the system was introduced in 1995.
- There has been a reduction in the frequency of shockwaves. Typically, there were seven shockwaves during a morning peak period; now there are five. The characteristics of a typical shockwave are unchanged, i.e. the same number of vehicles are delayed for the same length of time. Since there are fewer shockwaves, fewer vehicles overall are affected by the shockwaves.
- There has been a reduction in compliance with the speed limits, possibly due to a reduction in levels of speed enforcement. If vehicles travel faster than they did before, then journey times reduce.

The factors described above can all have contributed to the change in performance. In general, it is believed that drivers are becoming accustomed to the system, and are learning to drive more smoothly which has had the effect of preventing or reducing the effect of flow breakdown. The drivers are likely to be using the information provided by the system to modify their behaviour. For example, if a 60mph or 50mph setting is displayed, then the drivers can be confident that there is no queueing traffic before the next gantry. The shorter headways may be a result of increasing driver confidence with the system. However, in the absence of comparable data from similar locations on other motorways, this cannot be proven.

The benefits from the smoother driving regime are being realised towards the end of the peak periods, when the demand flows are close to or lower than the capacity. It appears that there is no benefit during the period immediately before flow breakdown (when the peak throughput occurs). At this time, the demand flow is much greater than the capacity of the section (especially during the morning peak period). This suggests that it is not always necessary to increase the peak throughput or capacity of a section of road in order to improve its performance.

During the evening peak period, there has been little change in traffic behaviour over the last two years. The total evening throughputs have stabilised, and are now decreasing slightly. There are no noticeable long-term trends in performance. There are large differences in journey times and flow breakdown from day to day and month to month, primarily due to the variable effect of the seed point between Junctions 12 and 11.

Driver Opinion Survey

During the first year of operation, a driver opinion survey was carried out to determine the impact of the Controlled Motorways scheme on drivers who use it. Valid responses were received from over 1,600 drivers, with over 800 respondents providing contact details for a repeat survey. Ninety-five per cent of drivers reported that they had noticed the speed camera signs on their most recent trip along the section. Of these, three-quarters reported that the signs affected the speed at which they drove. (An analysis of speed profiles showed that the signs had little effect, with speeds only reducing when the speed cameras started to flash.) More than half the respondents said the system had resulted in an overall improvement, and over two-thirds said they would like to see the system extended in some way to other stretches of motorway. The Controlled Motorways scheme has therefore been well received by its primary users.

Safety Studies

Several safety studies have been carried out during the life of the project. The studies have concentrated on injury accidents; as there are relatively few of these, data from several years is required before any conclusions can be drawn. Each study used all of the accident data that was available at that time, and allowed for external changes to the section, e.g. changes in flow levels. The studies provide different estimates of the effects on safety, as different amounts of data were available for each study. The more recent studies provide the more accurate estimates, as more data was available. The latest study will separate the estimated benefits of the queue protection system and the Controlled Motorways system.

The initial study on the effect that the Controlled Motorways scheme might have had on injury accidents compared accident statistics from five years before and two years after the introduction of the scheme. Regression analysis showed a net reduction in injury accidents on the Controlled section of around 12% during the period of signal operation.

Further research on the safety aspects was carried out using a second technique. The study period was for five years before and five years after the introduction of the scheme. Different accident rates were obtained for the two Police forces patrolling the area. (The section between J10 and J13 is patrolled by the Surrey Police and that between J13 and J15 is patrolled by the Metropolitan Police.) On average, there was a reduction in injury accidents of 10%.

Further work is being conducted on safety aspects of the M25 Controlled Motorways section as part of the Business Case for Controlled Motorways, based on the extension of the scheme between Junctions 15 and 16. Initial results indicate that there was a combined benefit of 30% in reduction of injury accidents following the introduction of the HIOCC (queue protection) system and the Controlled Motorways system (congestion signal settings). Work is in progress to separate the estimated benefits of the two systems.

Environmental Studies

Benefits from the reduction in noise levels and air pollution are attributable to the effects of the enforcement of the speed limits, a key characteristic of the Controlled Motorways section. Both noise levels and air pollution levels have decreased as a result of the introduction of Controlled Motorways.

Research indicates that further benefits are likely to occur at the shoulders of the peak period or during periods when the signs are set and flow breakdown has not yet occurred.

HIOCC Queue Protection

The HIOCC system has performed well, detecting, tracking and protecting the back of queues during both peak and off-peak periods. The signal sequences provide adequate protection for shockwaves and for traffic queuing due to an incident downstream.

Comparison of speed profiles during similar periods in consecutive years suggests that the 40mph settings have restricted traffic speeds as drivers leave a shockwave. This can be interpreted as a reduction in the amount of braking and over-accelerating, and the perception of drivers passing through the section will be that of a smoother journey. In addition to this, the applied speed limits are more appropriate to the traffic conditions thus maintaining the credibility of the system.

Studies suggest that drivers are generally complying with the mandatory HIOCC speed limits as well as the original 60mph and 50mph settings. This supports the findings observed from the performance indicators, that improved driver behaviour in response to Controlled Motorways may be responsible for the improvements in terms of more uniform headways, smoother speeds and more predictable journey times. The Controlled Motorways environment has also helped increase compliance with the national speed limit, even when no signals are displayed.

The Controlled Motorways system has performed well and the performance has continued to improve with time, due to positive changes in driver behaviour, providing optimum conditions to reduce the potential for congestion to occur. The flow-based settings switch on and off at appropriate times to control the traffic, and the HIOCC signal settings track the backs of queues, providing protection from faster-moving upstream traffic. The text messages on Enhanced Message Signs (EMS) inform drivers of the reasons for the displayed speed limits. The introduction of the ‘Queue Ahead’ message warned drivers of conditions downstream and communicated that the system was not causing the queues.

Signal Study

A study has been carried out into the relationship between the different speed limit settings. It shows that the duration of 60mph and 50mph (congestion) settings are increasing from year to year at about the same rate, whilst the duration of 40mph (queue protection) settings is increasing less rapidly.

This effect is most pronounced in the shoulders of the periods of heaviest congestion, when fewer 40mph signals are being set despite an increase in throughput. Although the flows are increasing, there is less queueing. This suggests that one effect of control on the section, over an extended time period, is to reduce the risk of flow breakdown occurring.

Traffic Demand

The underlying traffic demand (i.e. the total throughput during a peak period) should be taken into account when considering any changes to the performance of the motorway. If the demand increases, then the congestion levels would also be expected to increase. If there has been an increase in demand during peak periods, but little or no increase in congestion, this can represent an improvement in performance.

The total throughput during the 5-hour morning and evening peak periods has continued to rise on both carriageways, with each year showing the same seasonal patterns. The total throughput during off-peak periods has also continued to rise.

Since September 1997, when the widening work between Junctions 8 and 10 of the M25 was completed, the demand at the southern end of the section (Junctions 10 to 12) has increased more rapidly than at the northern end, for both carriageways.

The total throughput on all sections is increasing, especially in the evening peak period, with the overall increase in demand being about 2.5% in 1995 and then slowing to about 1.5% per year by 2002.

CONCLUSIONS AND FUTURE WORK

The Controlled Motorways system has provided a beneficial environment for drivers using the M25 between Junctions 10 and 16. The system sets consistent and coherent sequences of speed limits that are appropriate to the traffic conditions, and that are generally obeyed by drivers.

Although limited information is available about the direct effects of introducing the system, the Controlled Motorways section has absorbed an increase in throughput over 5-hour peak periods from year to year, without a detectable increase in congestion levels. Although journey times increased during the first few years of operation, there have been improvements in journey times and changes in headway distribution and shockwave behaviour in the last few years (since 2000). These improvements suggest that there may be long-term benefits from installing a Controlled Motorways system, with drivers using the information provided by the system to drive more smoothly to reduce the effects of flow breakdown. However, in the absence of comparable data from similar locations on other motorways, this cannot be proven as being attributable to the Controlled Motorways system.

Since the implementation of the HIOCC automatic incident detection system during October 1997, the system has detected, tracked and protected the back of queues during both peak and off-peak periods. The Enhanced Message Signs (EMS) serve to provide additional information to drivers regarding the reason for a particular signal display.

The performance of the incident-detection algorithm needs continued monitoring in order to ensure that the full benefits are being achieved. Regular monitoring will also allow the continued identification of locations along the Controlled section from which shockwaves appear to propagate. It will also ensure that the system remains operational and reliable, so that the full benefits of Controlled Motorways are achieved. In addition to this, the ability of the control system to adapt and respond to a variety of traffic patterns and trends can be highlighted through monitoring. This in turn will help identify specific areas where further research is required, particularly for traffic behaviour.

The scheme was extended to cover Junctions 15 to 16 of the M25 in March 2002 and the specific monitoring of this section will be used as a Business Case for further roll-out of MIDAS Controlled Motorways schemes across the English network. The results of this study will be published during 2004.

During 2004 and 2005, the section of the M25 between Junctions 12 and 15 will be widened, prior to the opening of Heathrow Terminal 5. The Controlled Motorways system will continue to operate during the period of the roadworks. The parameters will be modified to allow for changes to traffic conditions, and the section will continue to be monitored.

Glossary of Terms

These definitions explain some technical terms, and some non-technical terms, which have a special or particular meaning in the context of the M25 monitoring.

'A' Carriageway — The clockwise carriageway of the M25 (northbound on the Controlled Section).

AADT — Average Annual Daily Traffic, 24-hour flows averaged over the whole year.

AAWT — Average Annual Weekday Traffic, 24-hour flows averaged over weekdays only for the whole year.

Accident — An incident resulting in damage or injury.

'After' — After switching on the variable speed limit system and while the system remains in operation.

Alert — An event in the MIDAS system that signifies that a certain condition has occurred, e.g. passing a flow threshold.

Algorithm — A method embodied in a software program for setting variable speed limits or other signs in response to traffic data or other alerts generated by the MIDAS system.

'B' Carriageway — The anti-clockwise carriageway of the M25 (southbound on the Controlled Section).

'Before' — Prior to switching on the variable speed limit system (August 1995).

Capacity — A measure of the maximum possible throughput of a road section, normally expressed as the number of vehicles which can be handled in a given time period. On motorways, it is not well defined due to flow breakdown.

Compliance — Conformity with speed limits.

Controlled Motorway or Controlled Section — Section of motorway with variable speed limits, extending from Junction 10 to Junction 16 on both carriageways of the M25.

Demand Flow — The number of vehicles that desire to travel on a particular section of road at a particular time. Within this report, the total throughput during a 5-hour peak period is the demand flow for that period.

EMS — Enhanced Message Signs, used to provide additional information in conjunction with the variable speed limits.

Flow-based — Using only traffic flow information.

Flow breakdown — A condition in which heavy traffic flow ceases to be smooth, associated with a sharp fall in speed and a reduction in effective road capacity.

Godstone	A small town near Junction 6 of the M25 in Surrey, near where the Surrey Police Control Centre is situated.
Headway	The time separation between the front of one vehicle and the front of the next vehicle.
Heston	A district near the M4, east of Junction 15 with the M25, where the Metropolitan Police Control Centre is situated.
HIOCC	HIgh OCCupancy incident detection algorithm implemented on the Controlled Section during October 1997 and used to protect the backs of queues from faster traffic upstream.
ISDN	Integrated Services Digital Network, a communications network used for high-speed data transfer.
IPL	Information Processing Limited, Bath, United Kingdom.
IVD	Individual Vehicle Data. Raw traffic data collected for selected sites and periods by linking portable PCs to MIDAS outstation units.
Loop	A detector in the form of a loop of wire buried in the road surface, which produces an electrical response when a metal object such as a vehicle passes overhead.
MIDAS	Motorway Incident Detection and Automatic Signalling system, which processes traffic information collected through loops and determines the most appropriate speed limit to be displayed on local gantries.
Mode	The value of a variable quantity most frequently observed.
MTV	Motorway Traffic Viewer - a suite of graphical analysis programs developed by TRL for the study of motorway traffic data.
Northern end	The part of the M25 Controlled Motorway section between Junctions 12 and 16.
Parameters	In the present context, a set of numbers which control the behaviour of the algorithm, and include minimum signal On and Off times, a smoothing constant, and flow/speed alert thresholds.
Peak 15-minute	The highest value, usually of throughput, measured in any 15-minute period.
Peak 1-hour	The highest value, usually of throughput, measured in any one-hour period.
Performance Indicator (PI)	A numerical measure of traffic behaviour on the motorway which has implications for assessing the performance of the Controlled Motorways system.
Rubbernecking	Drivers slowing to observe an event, often on the opposite carriageway. An accident can cause congestion on both carriageways due to rubbernecking.

Seed point A point on the motorway where flow breakdown first occurs.

Shockwave A wave of flow breakdown which propagates upstream through a column of moving traffic. A flow-breakdown shockwave is characterised by a constant speed of propagation, and by an increasingly large and abrupt drop in the speed of traffic as it passes, which can lead eventually to stop-start driving.

Significance The probability that an observation occurred by chance, assuming some underlying probability structure (e.g. a Normal distribution). Significance is usually expressed as a percentage, and the smaller it is the better. 5% or less is usually taken to indicate a significant observation or result.

Significant Unlikely to have occurred by chance.

Site A marked point along the motorway near where a loop detector or variable speed limit gantry may be located.

Site numbering A numbering scheme with intervals of 100m. For example, on the M25, site 4902A is at kilometre position 90.2 midway between Junctions 13 and 14 on the A carriageway. Site numbers run from 4727 at Junction 10, to 5010 at Junction 16. The initial digit (4 or 5) identifies the motorway (the M25 in this case).

Smoother In terms of traffic, a more balanced distribution of vehicles on the motorway. This can be within a lane (more uniform headways) or across lanes (a more balanced lane utilisation).

Smoothing A mathematical technique for reducing the variability of data.

Southern end The part of the M25 Controlled Motorway section between Junctions 10 and 12.

SSR Safety Standards and Research, a Directorate of the Highways Agency.

Stop-start Driving conditions in which some vehicles temporarily come to a halt or move at a very low speed.

Swooping Drivers moving late from the offside lanes onto a diverge lane, typically crossing more than one lane in a single manoeuvre are said to be ‘swooping’ onto the junction.

Threshold A value (of traffic flow in the present context) which when passed (either upward or downward depending on its purpose) causes an event, such as a flow alert.

Throughput The amount of traffic passing through a given road section in a certain period of time.

Total peak The value, usually of throughput, measured in a fixed peak period (in the present context usually a 5-hour a.m. or p.m. peak).

TSS Traffic Systems and Signing, a former name of the SSR Directorate of the Highways Agency.

Tuning	The process of adjusting parameters to produce a desired change or improvement in system performance, usually in the light of monitoring results.
'Typical' day	A representative weekday excluding holidays, bad weather and incidents.
Utilisation	Usually the proportion of traffic using a given lane.
Variable speed limit	Gantry mounted mandatory speed limit signs displaying speed restrictions in response to traffic conditions on a MIDAS Controlled Motorway.
Vehicle Hour Delay (VHD)	A summation of the delay experienced by drivers who are not able to travel at a speed of 50 mph. Used as a means of evaluating congestion.

PART I - HISTORICAL SUMMARY

1 Introduction

1.1 Controlled Motorways

The Road Traffic Act of 1991 introduced the legislative framework necessary for variable mandatory speed limits on motorways and the use of photographic evidence for speed enforcement. Using the Motorway Incident Detection and Automatic Signalling (MIDAS) system deployed on the M25 as the basic infrastructure for the new scheme, the Highways Agency developed an automatic speed-control environment known as “Controlled Motorways”. The key feature that differentiates this road environment from a conventional motorway is the use of mandatory speed limit signals (see Figure 1.1.1) rather than the advisory speed limits displayed on traditional motorway signals.

Figure 1.1.1 - The Controlled Motorways Environment

The primary objective of the Controlled Motorways scheme is to smooth vehicle speeds progressively to minimise the risk of flow breakdown, creating a safer, ‘better’ environment, and therefore maximising the motorway’s potential. The Controlled Motorways system uses variable, mandatory speed limits to control and equalise speeds in all lanes when traffic flow is heavy. The speed limits are set automatically using MIDAS loop data. The aims of the scheme are to:

- smooth traffic flow
- improve journey times and journey time reliability
- improve lane utilisation
- reduce the incidence of stop-start driving
- improve safety, and
- reduce the stress of driving.

The Controlled Motorways scheme covers the south-western quadrant of the M25, now extending from Junction 10 (A3) to Junction 16 (M40), a total of around 30km. This section of the M25 is one of the busiest motorways in Europe, with flows that regularly exceed 200,000 vehicles per day.

1.2 Monitoring the M25 Controlled Motorway Section

In February 1995 the Highways Agency commissioned TRL to undertake a programme of monitoring of the Controlled Motorways pilot. The pilot was implemented initially between Junctions 11 and 15 of the M25 in August 1995 and then extended to Junction 10 in November 1995. An initial report for the HA was completed in May 1996 (Rees *et al*, 1996) that described the results of the first seven months of Controlled Motorways operation (August 1995 to March 1996). The next report (Taylor *et al*, 1997) described the first year of monitoring (August 1995 to August 1996). A supplement to that report was produced (Rees and Taylor, 1997) that described the results of the monitoring up to February 1997.

Harbord (1998) provides an overview of the M25 Controlled Motorways scheme, and a summary of the technical assessment involved has been provided by Eastman and Harbord (1997) and Harbord (1997).

The performance of the HIgh OCCupancy (HIOCC) incident detection system for protecting the backs of queues has been monitored since it became operational in October 1997. The performance of the EMS message system has been monitored since it was introduced in October 1998.

A further report (Abou-Rahme *et al*, 1998) described the continuation of the monitoring, in particular for the period between March 1997 and March 1998, including an analysis of the implementation of HIOCC on the section. More recently a report has been issued (Dixon *et al*, 2002) describing the results of the last two years of monitoring.

MIDAS data along with signal setting archives have been collected on a weekly basis. The traffic data includes 1-minute lane-by-lane information on flows, speeds and occupancies, collected for both carriageways with their slip roads, comprising over 63 sites separated typically by 500m. The signal setting databases log the details of all signal events at the Godstone and Heston control centres. The signal logs differentiate between congestion alerts, incident alerts and manual settings and are time stamped, allowing synchronisation with the traffic data.

The Controlled Motorways Monitoring work consists of two major activities:

- Traffic and signal data are graphically analysed using the Motorway Traffic Viewer (MTV) facility. This facility was developed as an aid to visualising and interpreting the traffic conditions and signal settings. It enables the traffic conditions over the whole section for a whole day to be viewed, and allows the relationships between the traffic conditions, the signal settings and the messages to be studied. It has been used to support the 'tuning' of system parameters, to optimise the performance of the system.
- The effects on the scheme on traffic are analysed by monitoring traffic trends and traffic behaviour using pre-defined performance indicators. An assessment of the effects of the variable speed limits on accidents was carried out as part of the monitoring work, as well as an investigation into the effects on noise levels and air pollution. Also, a driver opinion survey provided valuable feedback on how the scheme was being received by its primary users.

MTV provides a graphical representation of traffic and signal setting data by both time and location along the Controlled Motorways section. The plots are designed to be either site-specific (allowing analysis of the data from a particular loop), junction-specific (focusing on traffic data in the vicinity of a junction), or for the whole control section (providing a global view).

Plots can show data for the peak periods, a whole day or a sequence of days, allowing detailed comparisons to be made and patterns to be observed. Throughout the monitoring period, certain days that exhibit anomalous or interesting behaviour are identified. The ability to examine the broader picture has (for example) provided insights into the effects of slow vehicles passing through the sections and flow breakdown arising from drivers observing an incident on the opposite carriageway (rubbernecking), as well as the characteristics of flow breakdown during the peak periods.

Figure 1.1.2 is an example of the daily speed plot for the clockwise carriageway during the morning peak period. It consists of a grey-scale background representing speeds and coloured bars representing signal settings. Shockwaves can be seen as light grey streaks running diagonally downwards (from left to right), whilst traffic itself is moving diagonally upwards (from left to right). Various examples of MTV plots are used throughout this report in order to present the traffic data and illustrate performance and behaviour. Examples of the plots most commonly used for monitoring work have been included in Appendix B.

The visual representation of the shockwaves on the MTV plots enabled the characteristics of the shockwaves to be analysed. It was established that the critical speed was 25mph; if the average speed dropped below this, traffic was likely to come to a standstill. 25mph was therefore selected as the threshold for the flow breakdown performance indicator, and also for identifying slow moving traffic on MTV plots.

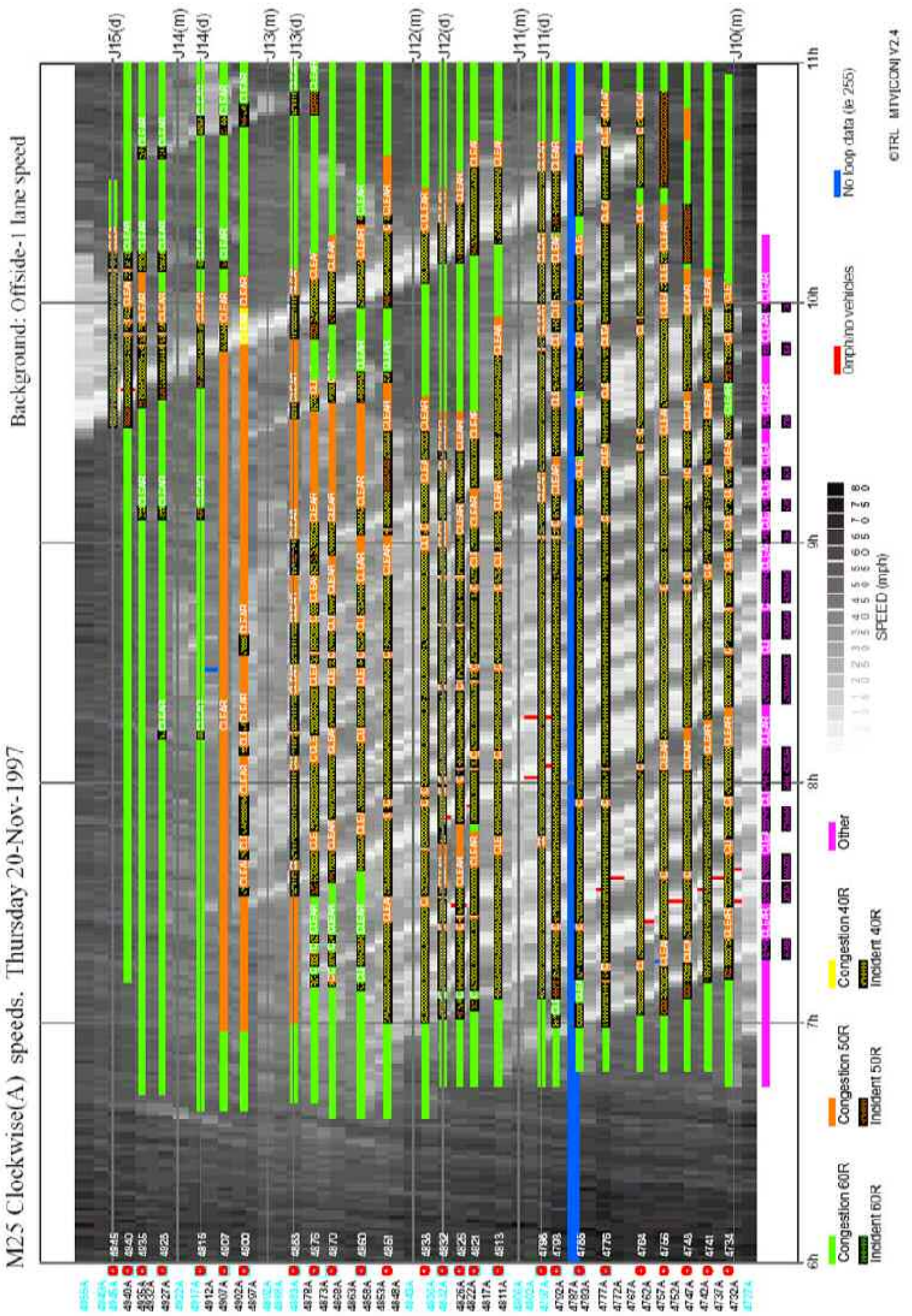


Figure 1.1.2 - An Example of the Daily Speed Plot from MTV

1.3 Report Scope and Objectives

The objective of this report is to present an overview of the monitoring work undertaken by TRL for the HA between 1995 and 2002. As well as describing the history of the project, the report presents key results for performance indicators, a variety of traffic trends and behaviour, and a number of specific studies carried out alongside regular monitoring work.

The majority of this report examines changes in traffic conditions once Controlled Motorways was installed. The traffic data available prior to the introduction of Controlled Motorways was of poor quality and could not be used to carry out a full “before and after” study of the impact of Controlled Motorways. However, some detailed traffic data was collected at a few sample sites; this has been used to examine changes in headways and speed compliance. Accident data has been available from the M25 for many years; this has been used to examine the impact of Controlled Motorways on safety.

Section 2 describes the history of Controlled Motorways, highlighting key events and significant changes to the system during the period, such as the introduction of the automatic incident detection system and EMS. This section also contains examples of the monitoring of these changes.

Section 3 presents examples of a variety of traffic trends and behaviour. Comparison of data from year to year showed increases in the daily flows throughout the Controlled section, as well as evidence of peak shifting and continued compliance. Examples of the effects of slow vehicles moving through the Controlled Motorways section and the so-called ‘rubbernecking’ problem and changes in shockwave characteristics are also presented. Trends in journey times from year to year are analysed.

Section 4 introduces the performance indicators that have formed a core part of the monitoring work during this period. Trends and results are presented since the implementation of Controlled Motorways.

Section 5 begins by describing the driver opinion survey, which provided a detailed understanding of how the Controlled Motorway was perceived by its users. An investigation into the possible effects of the variable speed limits on accidents is presented, followed by a summary of the work on noise and air pollution. The section continues with a description of the investigation into safety requirements for signal sequencing. The details of a signal relationship study concludes this section.

Section 6 describes the conclusions of this report.

Appendix A contains a full set of Performance Indicators for the Controlled section.

Appendix B describes the Motorway Traffic Viewer software and contains samples of the plots used for monitoring.

2 Project History

2.1 The Initial Study

The mandatory motorway signals were installed at the beginning of 1995, but only manually-set advisory speed limits (i.e. without red rings) were displayed until the scheme was launched in August 1995. A six-month programme of monitoring began in March 1995. A basic traffic data collection system was used to collect the traffic data needed for subsequent system performance-analysis and to develop initial control strategies. This data was not comparable to and of poorer quality than MIDAS traffic data. Some detailed traffic data was collected from a few sample sites; this provided information on headways and speed compliance at those sites.

The speed enforcement system installation was completed in May 1995, but during the period between May 1995 and August 1995 the camera “warning” signs were displayed without automatic speed enforcement.

2.2 Synopsis of Controlled Motorways Operation

A trial of mandatory speed limits on the M25 was announced in 1990 in the M25 Action Plan (DoT, 1990). The simplest method of reducing the speed limits would have been to introduce a fixed speed limit. The effects of introducing a fixed 50mph speed limit were predicted and proved to be strongly negative. As a more complex system was required, the concept of Controlled Motorways was developed during 1993 and 1994 by the Highways Agency. The basic principle of Controlled Motorways is congestion management using mandatory variable speed limits that are appropriate for the traffic conditions. This harmonises traffic speeds and reduces the severity of shockwaves (thereby reducing stop-start driving). Smoothing traffic flow in this way helps to delay the onset of flow breakdown and advances the recovery of traffic flow from congested conditions.

The Controlled Motorways system displays 60mph and 50mph congestion signal settings in response to the traffic conditions on the motorway. The congestion signal settings respond to the number of vehicles per minute passing over the MIDAS loop detectors (the traffic flow). At calculated thresholds, the speed limit displayed to drivers is reduced and increased as required.

The original plan was for Controlled Motorways to display signals whenever the flows exceeded 1000 veh/hr/lane. Prior to August 1995, there was limited traffic data available from the M25. A Traffic Data Counting System (TDCS) provided some speed and flow information, which was used by an algorithm research project (Hardman *et al*, 1995) to derive the initial parameters and thresholds for the system. This research showed that Controlled Motorways signals should not be displayed until the flows exceeded 1500 veh/hr/lane.

In August 1995, the Controlled Motorways system was introduced between Junctions 11 and 15 using a fixed time plan (setting mandatory speed limits at certain times of day, regardless of current traffic conditions) to control speeds. The fixed time plan was derived using historical traffic data to establish when flow thresholds were likely to be exceeded. It was intended that the fixed time plan would operate for a 3-month period while drivers became accustomed to the system, after which a new system driven by actual traffic flows would be introduced.

During the first two weeks of operation, the fixed time system was monitored in detail by the Highways Agency. It was discovered that the signals were not always suitable for the traffic conditions; this was confirmed by the number of complaints from drivers using this section of the M25. In response to this, the HA introduced automatic flow-based operation earlier then anticipated, in September 1995. This was important as inappropriate signal settings cause unnecessary delays and reduce driver confidence in the system.

During the early operation of the system, various enhancements were made to the control parameters. Parameters such as the flow levels at which the signals are activated and the minimum time between signal changes were systematically changed. The effects of the changes on the signal setting sequences and on traffic behaviour were studied in detail as part of the on-going monitoring programme. This tuning optimised the signal settings, so that they were appropriate to the changing traffic conditions, and so that drivers saw a consistent sequence of logical signal settings. In order to avoid the signals switching on and off too frequently, the traffic data driving the signal system was smoothed by taking a continuous moving average (the level of smoothing being varied and optimised appropriately).

In November 1995, the system was enabled for the section between Junctions 10 and 11 (where works to widen the motorway to four lanes had just been completed) using the control parameters deployed between Junctions 11 and 15. Subsequent parameters changes were deployed over the whole section.

In April 1996, an optimal set of control parameters was determined. Because traffic conditions change over the years, tuning continues to be performed to improve the operation of the system. The tuning is carried out on a site-by-site basis, to allow for differences in traffic behaviour at various locations (e.g. motorway-to-motorway junctions are given different parameters to other junctions).

Details of control parameters and other configuration data, together with a log of the modifications made since the system was switched on, can be found in MCH 1831 (TSS, 2003). Sequencing rules are described in MCH 1744 (TSS, 2002).

Analysis of the traffic signals during congested conditions showed that the signals were switching off in the presence of queues, because the flow level fell below the switch off threshold. The flow-based algorithm was unable to distinguish between free-flowing traffic conditions and low flows during heavy congestion. Drivers were complaining that the speed limits were increasing while the drivers were stuck in a queue. As a result, in February 1997 the HA modified the control algorithm to run on both flow and speed information. This prevented the signals switching off in the presence of queues.

In October 1997, the HIOCC incident detection algorithm was introduced. This detects queueing or slow-moving traffic and protects this traffic by automatically setting lower speed limits (40mph, with 60mph and 50mph settings further upstream to provide drivers with advance warning of the queues). The algorithm works in parallel with the Controlled Motorway system and offers greater scope to reduce accidents and consequential delays. The signal settings were monitored to ensure that drivers continued to see a consistent sequence of logical signal settings. Early feedback from drivers, following the introduction of HIOCC, indicated that many thought the 40mph limit caused the queue. As a result, the HA introduced a publicity campaign to explain the queue protection system.

Prior to the implementation of HIOCC, an assessment was carried out into potential safety issues arising from the introduction of a 40mph to traffic previously controlled by the national speed limit. It was recommended that in such cases, a 50mph limit should be displayed for at least 5 seconds before the 40mph limit (see Section 5.4).

In order to provide drivers with appropriate and relevant information, the setting of Enhanced Message Signs (EMS) was coordinated with the setting of signals. This feature was introduced between Junctions 10 and 13 in October 1998, and between Junctions 13 and 15 in July 1999. The EMS messages provide drivers with information about the reasons for the signal settings, and provide warnings of queues or congestion ahead. The message settings were monitored to ensure that they were consistent with the signal settings.

During 2000, work started to extend the Controlled Motorways scheme to cover Junctions 15 (M4) to 16 (M40) of the M25; this scheme became operational in March 2002. Because of the limited data available from the M25 prior to August 1995, it had not been possible to carry out an impact assessment as part of a ‘before’ and ‘after’ study for the system. The extension of the system to Junctions 15 to 16 enabled the effects of its introduction to be assessed.

2.3 HIOCC Queue Protection System

Figure 2.3.1 shows the traffic data and the corresponding signal settings on the clockwise carriageway between 12:00 and 14:00 on 21 March 1997, before the automatic incident-detection system was implemented. The passage of a slow-vehicle (joining at around 12:30 from Junction 12) acted as a moving seed-point creating a series of shockwaves. The congestion resulting from the passage of the slow vehicle is discussed in Section 3.5, but for this section it is the period just after 13:00 which is of interest. Traffic speeds upstream of the slow vehicle were around 70mph whereas the 1-minute averaged speeds within the shockwaves were around 20mph.

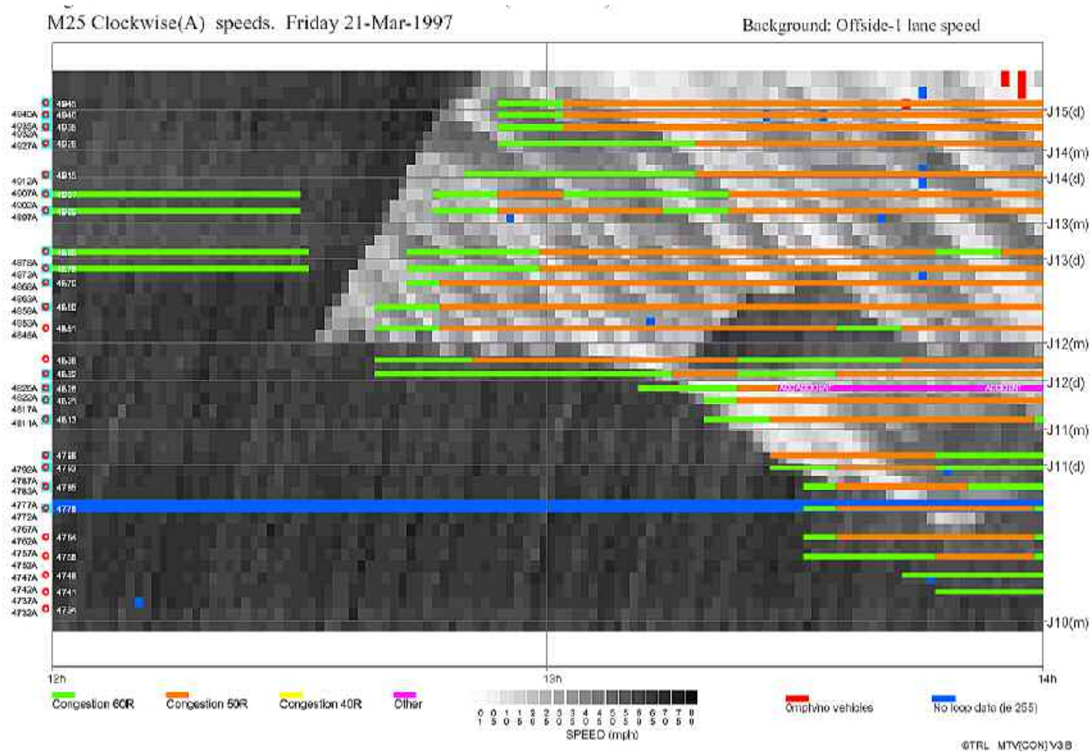


Figure 2.3.1 Flow breakdown outside the peak period (pre-HIOCC)

At 13:15, an accident occurred just upstream of Junction 12 in the offside lane. This is an example of the risk involved in having an unprotected queue, particularly outside of peak periods when drivers are not constrained by congestion.

The automatic incident-detection system was implemented on 28 October 1997. Figure 2.3.2 shows the clockwise carriageway during the morning peak period for 21 November 1997, nearly one month after implementation. Incident alerts are represented by the hatched pattern, and can be seen tracking and protecting the shockwaves as they propagate upstream. When HIOCC switches off, control is returned to the congestion alerts, and the speed limit for the current congestion alert is displayed.

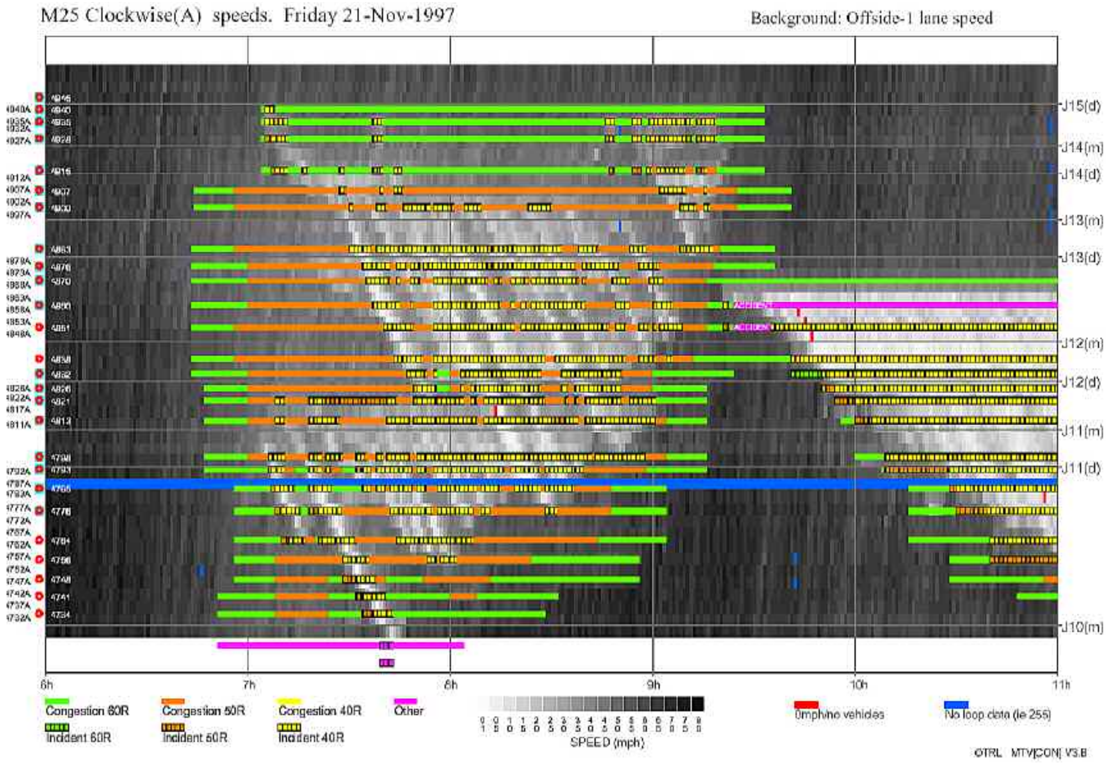


Figure 2.3.2 An illustration of HIOCC protecting queues

An accident occurred at around 09:30 on 21 November 1997, the cause of which was unrelated to the usual congestion. Here HIOCC can be seen protecting the queuing traffic, which in the vicinity on the accident appears to be near stationary for some time. The 50mph and 40mph speed limits continue to protect the back of the shockwave as far upstream as Junction 10.

Studies of the HIOCC system in general have shown that it has performed well, detecting, tracking and protecting the back of queues during both peak and off-peak periods. The signal sequences provide adequate protection for shockwaves and for traffic queuing due to an incident downstream.

Comparison of speed profiles during similar periods in consecutive years suggests that the 40mph settings have restricted traffic speeds as drivers leave a shockwave. This can be interpreted as a reduction in the amount of braking and over-accelerating, and the perception of drivers passing through the section will be that of a smoother journey. In addition to this, the applied speed limits are more appropriate to the traffic conditions thus maintaining the credibility of the system.

Studies suggest that drivers are generally complying with the mandatory HIOCC speed limits as well as the original 60mph and 50mph settings. This supports the findings observed from the performance indicators, that improved driver behaviour in response to Controlled Motorways may be responsible for the improvements in terms of more uniform headways, smoother speeds and more predictable journey times. The Controlled Motorways environment has also helped increase compliance with the national speed limit, even when no signals are displayed.

The Controlled Motorways system has performed well and the performance has continued to improve with time, due to positive changes in driver behaviour, providing optimum conditions to reduce the potential for congestion to occur. The flow-based settings switch on and off at appropriate times to control the traffic, and the HIOCC signal settings track the backs of queues, providing protection from faster-moving upstream traffic.

2.4 Use of Enhanced Message Signs

The introduction of the automatic incident-detection system generated significant interest from members of the public, especially from those who did not often use the motorway. During October 1998 the HA introduced new messages on the Enhanced Message Signs (EMS) as a further means of communicating information to drivers on the Controlled Motorway. A convention was developed which correlated the variable speed limits and the text displayed to drivers. For example, a 40mph speed-limit generated by the automatic incident-detection system is accompanied by the words “Queue Caution” on the EMS, with “Queue Ahead” and “Queue After Next Junction” messages displayed further upstream. The most commonly used messages are:

- Congestion After Next Junction
- Congestion Stay In Lane
- Congestion Caution
- Queue After Next Junction
- Queue Ahead
- Queue Caution

The EMS messages inform drivers of the reasons for the displayed speed limits. For example, the introduction of the “Queue Ahead” message warned drivers of conditions downstream and communicated that the system was not causing the queues.

Since the new messages were introduced, monitoring work has also focussed on the interplay between traffic and message displays, and confirming that the drivers are receiving information relevant to the driving conditions being experienced.

2.5 General System Operation

One of the HA objectives in installing the scheme was to prove the technology, i.e. to show that signals could be set using real-time traffic data. In addition, for the system to have an effect, it was necessary to show that drivers responded to the signals.

The monitoring has shown that the Controlled Motorways system is reliable and that it sets consistent and coherent sequences of speed limits that are appropriate to the traffic conditions, and that are generally obeyed by drivers.

The performance of the Controlled Motorways system depends on the availability of accurate MIDAS data. A faulty loop site can cause inappropriate signal settings to be displayed, and loop faults at three consecutive sites can result in HIOCC queue protection signal settings not being displayed at some signal gantries. It is therefore essential that the availability and the accuracy of the traffic data is checked at regular intervals and that any faults are repaired without delay.

PART II - GENERAL RESULTS

3 Traffic Trends and Behaviour

This section presents examples of a variety of traffic trends and behaviour observed throughout the operation of the Controlled Motorways section of the M25. Comparison of data from year to year shows increases in the daily flows, observations of peak shifting and compliance with speed limits. The effects of slow vehicles moving through the Controlled Motorways section and 'rubbernecking' issues, along with changes in shockwave characteristics are described in the following sections. Trends in journey times from year to year are also analysed.

Most of the traffic trends in this section are examined over the period when Controlled Motorways was operational. This is due to a lack of good quality data prior to the introduction of Controlled Motorways. Some data on speed compliance and headways was collected prior to the introduction of Controlled Motorways; this has been used to analyse the effects of Controlled Motorways on these aspects of traffic behaviour.

3.1 Changes in AADT Flows

The Annual Average Daily Traffic (AADT) flows for each link and for each carriageway have been calculated from the MIDAS data for each complete year of operation (i.e. 1996 to 2001). Figures 3.1.1 and 3.1.2 show the AADT flows for each month since January 1996 for two sample links (Junctions 10 to 11 on the clockwise A carriageway and Junctions 14 to 13 on the anticlockwise B carriageway). For each site, there are consistent seasonal trends, with flows dropping during the winter and reaching a peak during July. On the A carriageway, the high summer flows are sustained during August; on the B carriageway, the flows drop after July. There is a yearly growth of between 1% and 2.5%. The greatest increase has been on the section with the least traffic, namely Junctions 10-11. The dip on the figures for September 2000 for both graphs is as a result of the Fuel Crisis, the effects of which lasted for two weeks. This event is described in detail by a report to the HA on the Fuel Crisis (Quick and Turner, 2000).

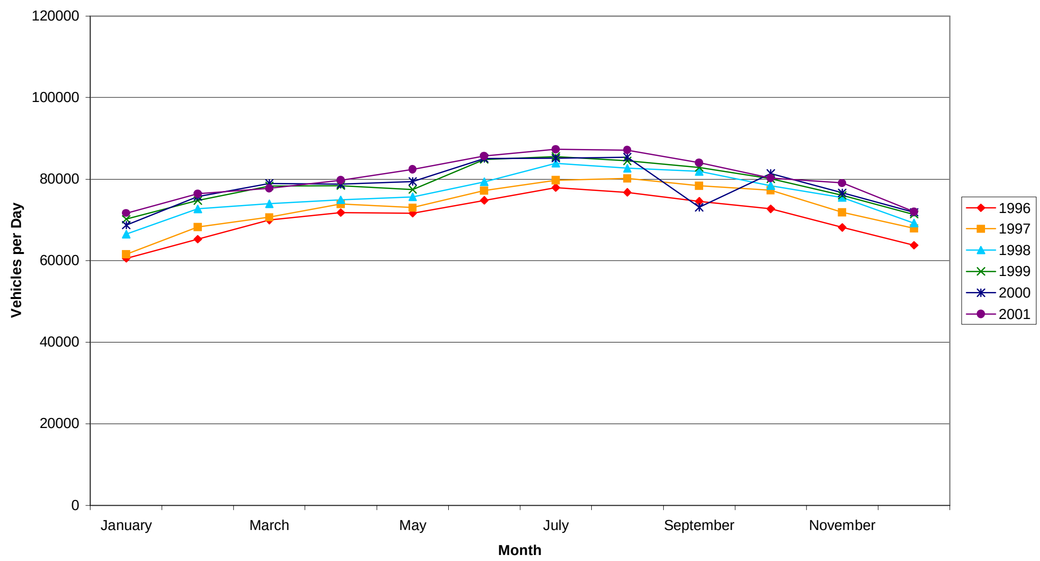


Figure 3.1.1 – AADT Flows on A Carriageway (Junction 10-11)

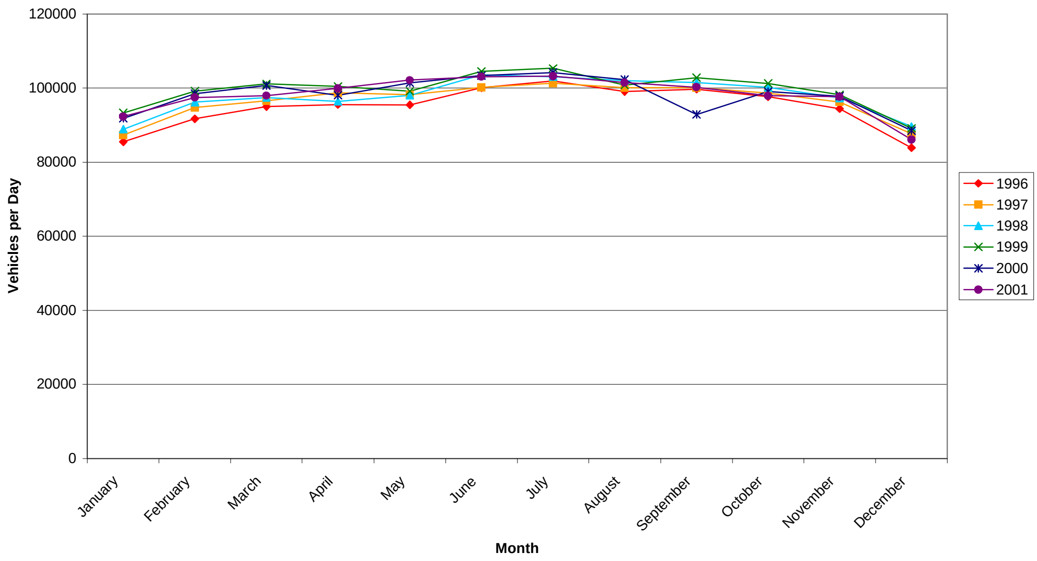


Figure 3.1.2 – AADT Flows on B Carriageway (Junction 14-13)

The AADT flows (two-way) for the M25 Controlled Motorways section are shown in Table 3.1.1. The table shows that the most heavily trafficked link is between Junctions 13 and 14. The least used link is between Junctions 10 to 11, although this is the link with the highest traffic growth over the six-year period (the analysis requires 'whole years' of data).

Table 3.1.1 AADT Flows (Two-Way)

	1996	1997	1998	1999	2000	2001
J10-11	143000	149000	156000	161000	159000	164000
J11-12	159000	165000	170000	175000	174000	177000
J12-13	165000	170000	174000	177000	175000	178000
J13-14	179000	182000	186000	188000	186000	188000
J14-15	159000	174000	177000	179000	177000	179000

In addition to the AADT flows, Annual Average Weekday Traffic (AAWT) 24-hour flows have also been analysed. AAWT flows show the same patterns as the AADT flows, but are greater in magnitude for each carriageway reflecting the fact that flows are greater during weekdays than on weekends. The AAWT 24-hour flows (two-way) are shown in Table 3.1.2.

Table 3.1.2 AAWT 24-Hour Flows (Two-Way)

	1996	1997	1998	1999	2000	2001
J10-11	150000	157000	164000	168000	167000	171000
J11-12	168000	174000	180000	185000	184000	187000
J12-13	174000	179000	184000	187000	185000	187000
J13-14	190000	193000	197000	199000	197000	198000
J14-15	170000	183000	186000	189000	187000	188000

3.2 Evidence of Peak Spreading

The performance indicators show a 2.5% increase per annum in total throughput during the 5-hour peak periods in the initial years of operation, then slowing to 1.5% by 2002 on the M25 Controlled section. Where demand is high, there is always risk of peak spreading, with drivers rescheduling their journeys to travel outside of the busiest periods, when the motorway is less congested.

To investigate this hypothesis, an initial comparison of consecutive Mondays over a 6½ year period was carried out. It suggests some evidence of peak-spreading in the initial two years, taking into account the seasonal variation.

Figure 3.2.1 shows the flow for the critical three-hour period from 05:00 to 08:00, which includes the start of the morning peak period at site 4902A (between Junctions 13 and 14). This site is identified as a seed location where flow breakdown often occurs first along the clockwise carriageway. Over the first two years, 1996 and 1997 at the top of the plot, the start of the yellow periods (indicating flows of above 6000 vehicles per hour) and red periods (indicating flows of above 8000 vehicles per hour) occurred earlier. However, since then these times have remained similar from year to year, although there are always seasonal variations.

For the years 1998 to 2002, between 05:00 and 06:00, the first occurrence of the green periods (representing flows of above 3000 vehicles per hour) has continued to occur earlier, although not at as fast a rate as in the previous two years.

Flows based on 1 minute average counts at loop site 4902A for consecutive Mondays starting on 6-Nov-95

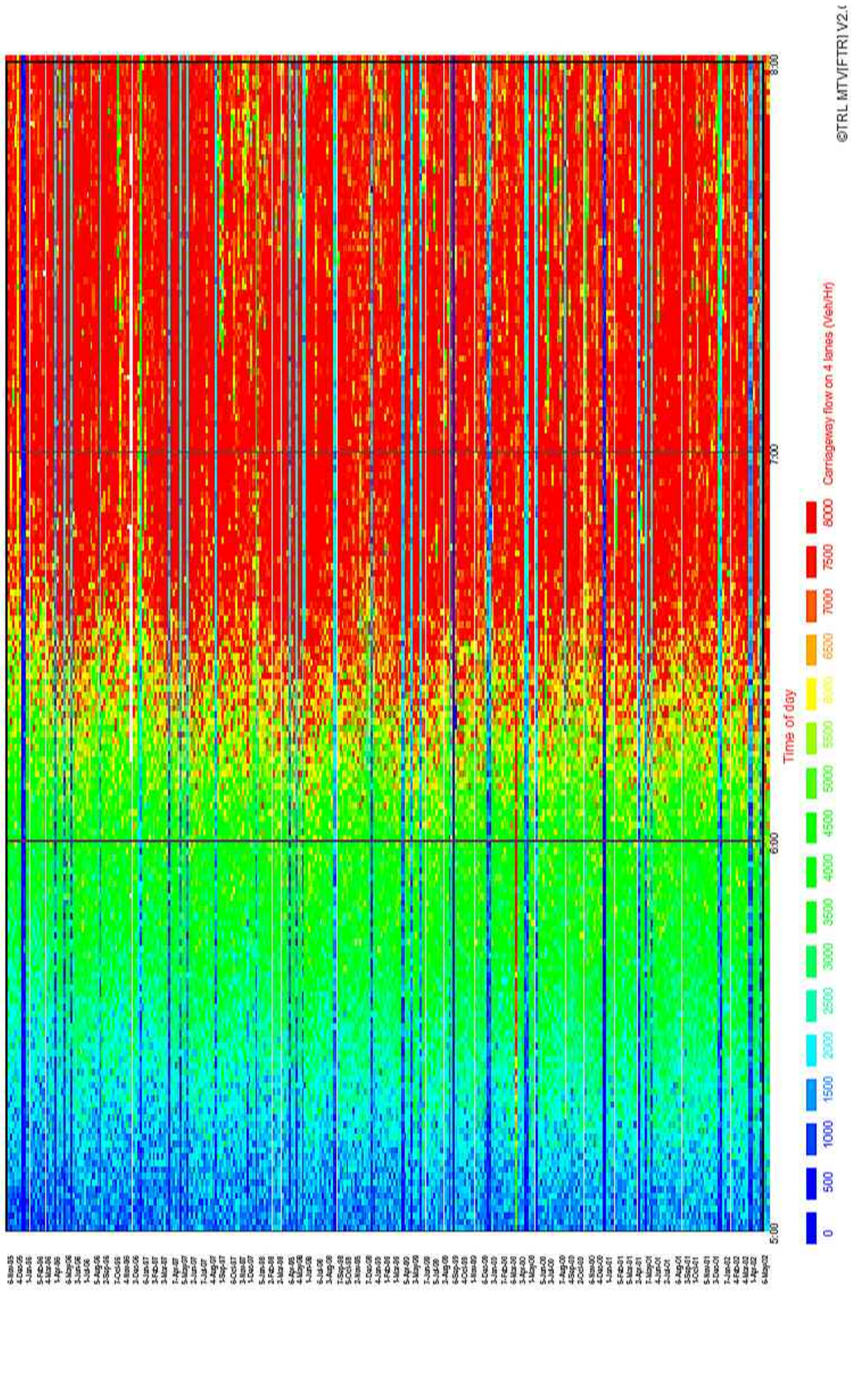


Figure 3.2.1 Peak spreading from November 1995 to May 2002 at loop site 4902A

Figure 3.2.2 shows the same range of flows, but this time at loop site 4811A near Junction 11. This location is further upstream, and demand is not as great here, but it is also known to be a site where flow breakdown can occur first on the motorway. Here, again, the first occurrences of red and yellow periods have occurred earlier, and the rate of this movement has decreased. However, at this site it is evident that the highest flows (represented by red squares) during the morning peak are now lasting for longer after 07:15. This delay in recovery may be due to the compounding effects of shock waves travelling back from the loop site further downstream at site 4902A.

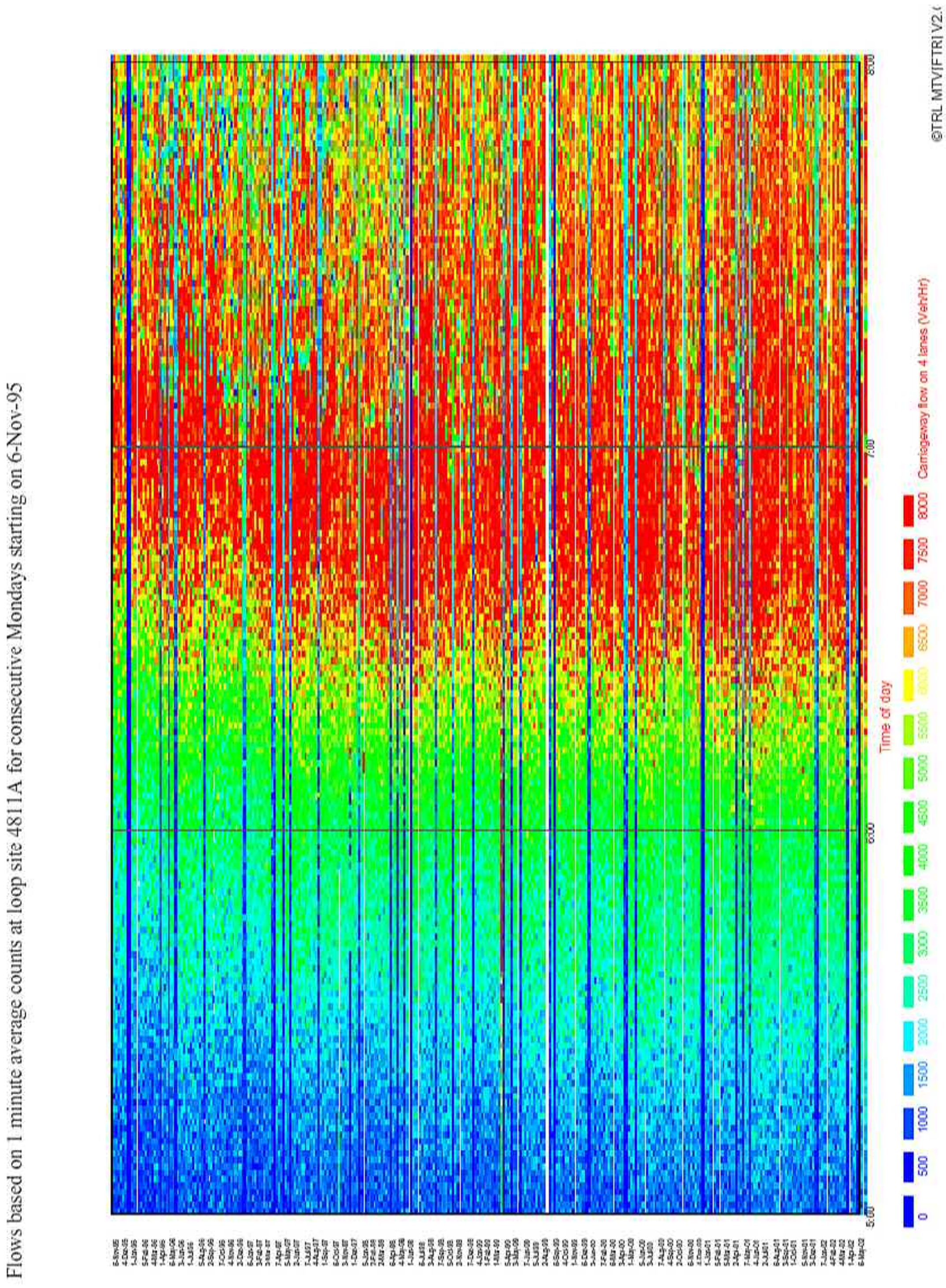


Figure 3.2.2 Peak spreading from November 1995 to May 2002 at loop site 4811A

3.3 Compliance with Speed Limits

Compliance with posted speed limits is an important test of system performance, since it is from this compliance that most of the other benefits of the system are expected to arise. The speed limits only have an impact on the traffic speeds during the shoulders of the most congested periods when the vehicles would be capable of travelling at speeds in excess of the speed limits displayed. Further details of the original study can be found in the interim report to the HA on the Controlled Motorways scheme (Rees *et al*, 1996).

The introduction of the variable speed limits in August 1995 has had a significant effect on the speeds at which drivers travel, even when the speed limits are not displayed. However, the introduction of camera warning signs in May 1995 had little effect on driver behaviour. The original study showed that typically between 39% and 44% of drivers exceeded the national speed restriction (70 mph) before the Controlled Motorways scheme was operational. The ‘After’ period showed this range was reduced to between 32% and 39%, with a greater reduction observed for very high speeds.

A study conducted in 1999, a time based evaluation during the 5-hour peak period, showed that 33% of the time the average speed was greater than the 70mph limits, 25% of the time the average speed was greater than the 60mph limits, 46% of the time the average speed was greater than the 50mph limits and 27% of the time the average speed was greater than the 40mph limits. These figures are not directly comparable with the later years observed.

Table 3.3.1 below shows the percentage of drivers exceeding the speed limit in the years 1995, 2000 and 2002 (Dixon *et al*, 2002).

Table 3.3.1 - Speed Compliance

Signal Setting	Percentage of drivers exceeding speed limit in given year			
	1995 (‘Before’)	1995 (‘After’)	2000	2002
No setting	39-44%	32-39%	19%	24%
60mph	Not applicable	Not studied	21%	28%
50mph	Not applicable	Not studied	31%	38%

These results indicate that whilst in the last two years compliance has deteriorated, compliance is still better than that observed prior to the Controlled Motorways scheme becoming operational.

Comparison of speed profiles during similar periods in consecutive years has suggested that the 40mph speed limits have restricted traffic speeds as drivers leave a shockwave. This can be interpreted as a reduction in the amount of braking and over-accelerating, and the perception of drivers passing through the section will be that of a smoother journey. In addition to this, the applied speed limits are more appropriate to the traffic speed thus maintaining the credibility of the system. This evidence points to a continued compliance with the mandatory speed limits.

3.4 Headway Analysis

One objective of Controlled Motorways is to improve the headway distribution within each of the lanes, thereby reducing the risks associated with sudden braking, as well as the stress of driving. The headway distribution is determined from individual vehicle headways, i.e. the gaps between pairs of successive vehicles. Specific objectives are to obtain a more uniform headway distribution and to eliminate very short headways, but without significantly increasing the average headway, as this would imply a reduction in the capacity of the road.

Statistical analysis has shown that the number of very short headways has decreased within all the pre-defined speed bands since August 1995. As speeds increase, the number of short headways also increases, implying that the gap some drivers leave between vehicles in based on distance, rather than time.

The headway distribution therefore has improved following the introduction of Controlled Motorways, in the sense that there are:

- fewer very short headways, and
- the headway distribution is more uniform.

The more uniform distribution of headways may reduce the necessity for braking, without reducing the capacity of the road.

The average headway within each speed band has also been reduced, implying that some of the longer headways (which do not contribute to efficient use of road space) have been eliminated. An improvement in headway has been observed at all speeds up to 50mph.

A two-year study, in response to observed improvements on the performance indicators, has shown that since the year 2000, the headways have been dropping. Between 2000 and 2002, average headways have reduced for each speed band between 20mph and 60mph, by an average of 5%. These reductions will affect performance and are in keeping with improvements found in the performance indicators. Although the proportion of vehicle headways below one second has marginally risen, this does not seem to have affected accidents, possibly because of the HIOCC queue protection.

This study also suggested that the headway distributions are more compact, with the greatest reduction in average headway following the introduction of Controlled Motorways occurring between 40mph and 50mph. This is where the Controlled Motorways system is expected to have the greatest effect.

In general, it is believed that drivers are becoming accustomed to the system, and are learning to drive more smoothly to prevent or reduce the effect of flow breakdown. The shorter headways are still safe, and may be a result of increasing driver confidence in the system.

3.5 Monitoring the Effects of Abnormal Loads

In Section 2.3 (Figure 2.3.1), the passage of a slow vehicle on 21 March 1997 through the Controlled section outside of the peak period was identified as the cause of significant congestion. The congestion pattern following the passage of the vehicle was similar to that experienced following an incident.

Figure 3.5.1 shows another example of a slow vehicle passing through the Controlled section outside of peak hours on 2 July 1997, and following a path diagonally from left to right down the figure. On this occasion, the journey is anticlockwise, and the wave of slow traffic can be seen in all lanes (the plot shows the lane adjacent to the offside lane). The slow vehicle acts as a moving seed location and the behaviour of drivers following at slow speed leads to the propagation of a number of shockwaves.

One method of evaluating the contribution of the passage of the slow vehicle to congestion relative to other causes is to use a measure called the Vehicle Hour Delay (VHD). Frith (1996) has defined VHD as the summation of the delay experienced by those drivers whose speeds are below 50 mph, because they are unable to travel this speed. For the example shown in Figure 3.5.1, the contribution of the passing slow vehicle to the overall VHD for the day on the B carriageway is approximately 30%. This slow moving vehicle caused approximately 500 vehicle hours delay.

The Controlled Motorways system cannot prevent the effects caused by abnormal loads, except to set signals when appropriate. However, better traffic management may be needed for abnormal loads.

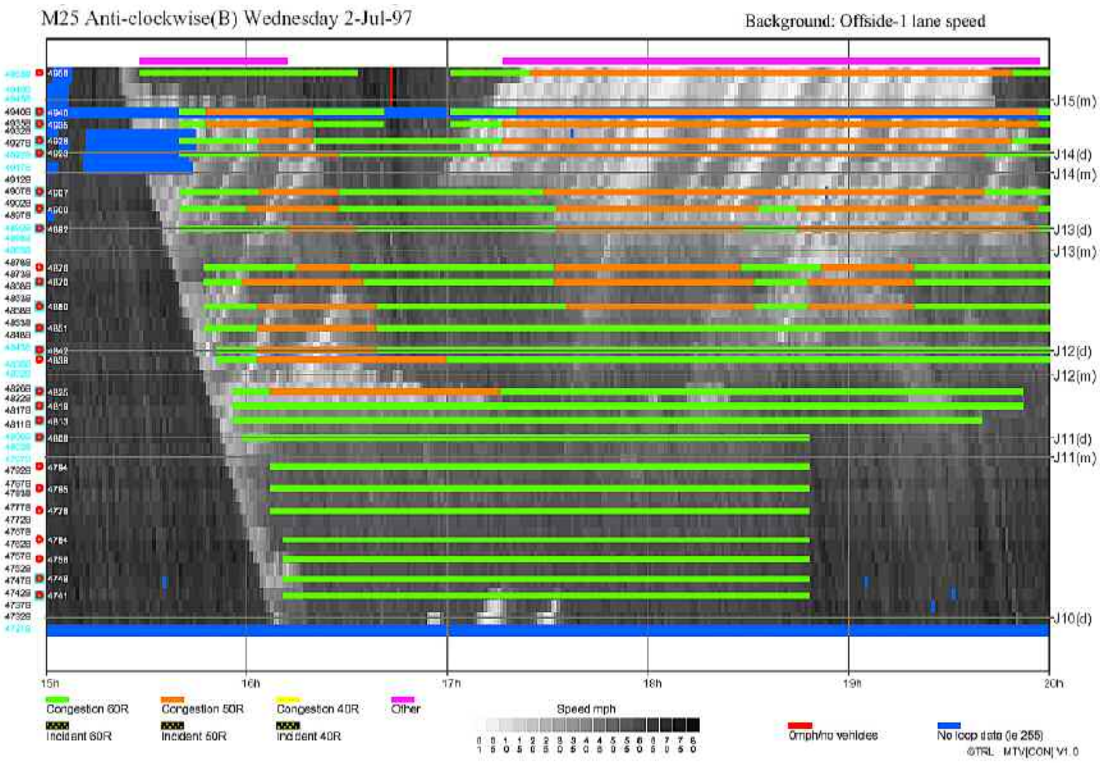


Figure 3.5.1 The effect of a slow moving vehicle on traffic before the peak period

3.6 Evidence of "Rubbernecking"

The "rubbernecking" phenomenon can be identified when a speed drop or flow breakdown occurs on one carriageway as a result of an incident or distraction on the opposite carriageway. In trying to observe events on the opposite carriageway, drivers behave in such a way as to lead to a speed disturbance, the source of which is often at the same location on the opposite carriageway.

Figure 3.6.1 shows the effects of an accident that took place on the afternoon of 23 January 1998. The accident took nearly four hours to clear and resulted in severe congestion along the clockwise carriageway. Figure 3.6.2 shows the opposite carriageway for the same time period. Careful examination of the data shows a slight disturbance on the anticlockwise carriageway for about 80 minutes after the incident, but no obvious signs of flow-breakdown due to the relatively low flows. As flows increased on the anticlockwise carriageway, the distraction of events occurring on the clockwise carriageway were sufficient to cause premature flow breakdown at around 14:20 with no other immediate cause.

The location (between 4858A and 4863A) remained a seed point for the anticlockwise carriageway until around 16:30 when it appears the accident was cleared. At this point the traffic returned to a typical peak period congestion pattern, with the main seed point for the anticlockwise carriageway occurring downstream of Junction 12. Whilst rubbernecking does not occur very frequently it can lead to double the amount of congestion for the same incident when it does occur. The Controlled Motorways system cannot prevent the effects of rubbernecking on the motorway, but the HIOCC automatic incident detection system can be seen protecting the tail of the queues on both carriageways.

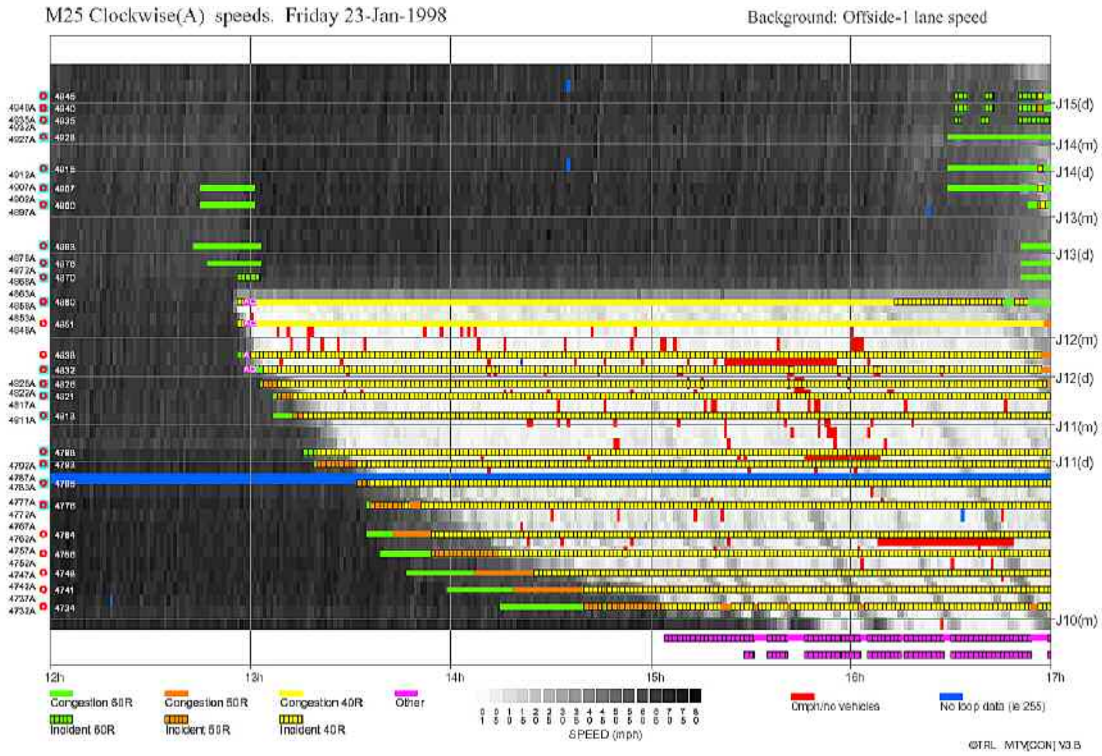


Figure 3.6.1 Effects of an accident

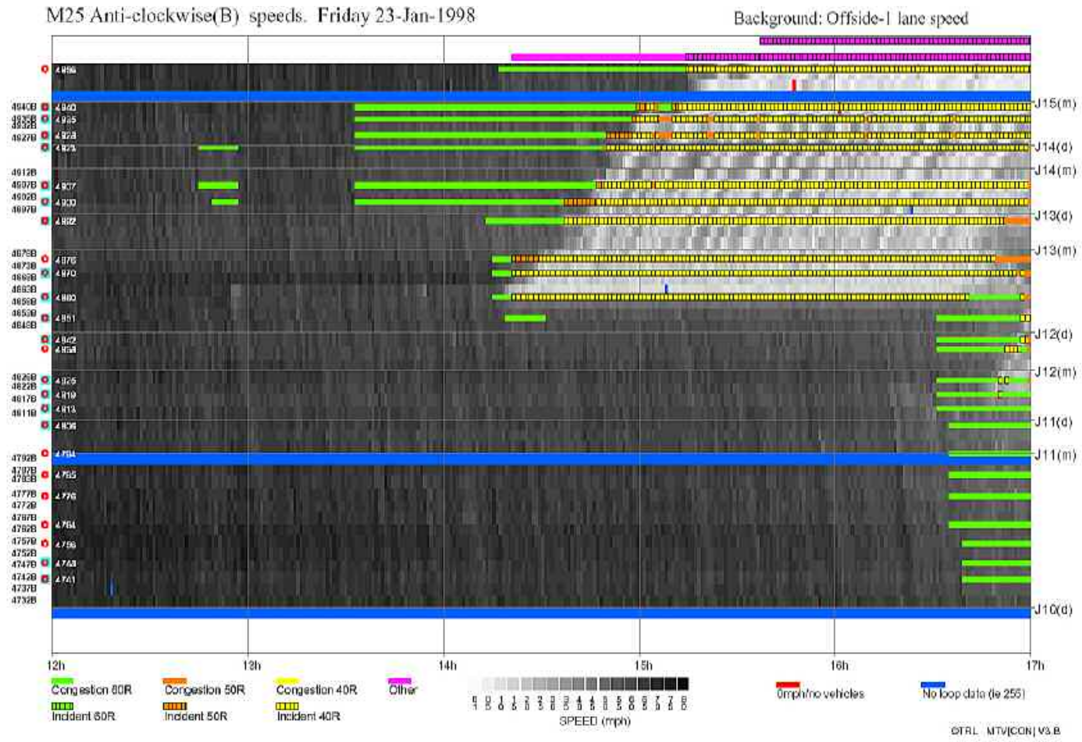


Figure 3.6.2 Effects of the 'rubbernecking' on the opposing carriageway

3.7 Changes in Shockwave Characteristics

A shockwave is a wave of flow breakdown which propagates upstream through a column of moving traffic. It originates at a seed point, a point on the motorway (defined in terms of time and position) where the first evidence of flow breakdown is detected.

During periods of flow breakdown, shockwaves propagate back upstream, affecting traffic travelling towards the seed point of flow breakdown. Any changes to the shockwave characteristics are likely to have a major effect on the performance of the Controlled Motorways system, due to changes in journey times. The shockwaves are the main contributor to delay, as vehicles travel at very slow speeds or are stationary as they pass through the shockwaves.

The plots shown in Figures 3.7.1 to 3.7.3 show a collection of information on vehicle speeds in a particular area (around site 4826A, just south of Junction 12) for a typical Tuesday morning in January in 1996, 1999 and 2002. The three windows in each Figure show a colour map of the speeds for both carriageways, a partial MTV plot showing signal settings and shockwave detail, and finally the average speeds in each lane overlaid with the displayed speed limit. This information has been analysed for successive years to enable detailed examinations of potential effects of the system as a whole, the evolving response in driver behaviour, and the effects of fine-tuning the system.

The upper part of each image shows a 'birds eye' view of the motorway for a specific loop site for both carriageways, for a 6-hour period. Traffic speeds are represented by varying colours, showing the shockwaves passing though the site. The centre part of each image shows a view of the site in the form of the standard daily plot within MTV. The site that is displayed in the upper and lower part of the image is highlighted on the left. All the times shown in this plot are 'in synch' through all three plots. The profiles shown in the lower part of each image show the average traffic speed registered in each lane at a specific location and the speed limits displayed during the period. Of particular note is the manner in which the traffic speed varies in comparison to the variation of the displayed speed limit. Since the implementation of the HIOCC algorithm (in October 1997), the signals have been able to display speed limits more appropriate to the conditions, which maintains the credibility of the system.

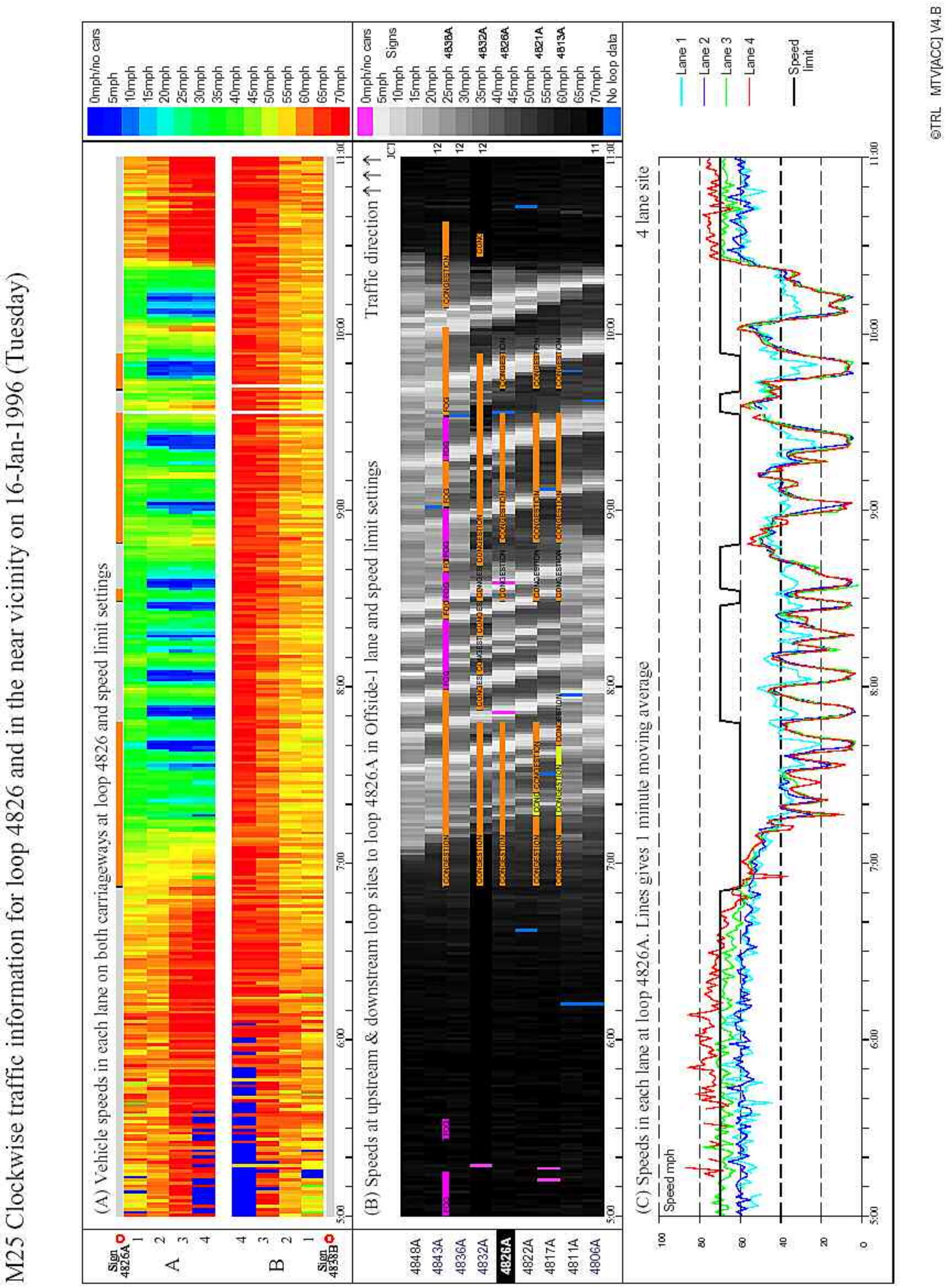


Figure 3.7.1 - Traffic information for loop 4826A and in the near vicinity on 16-Jan-1996

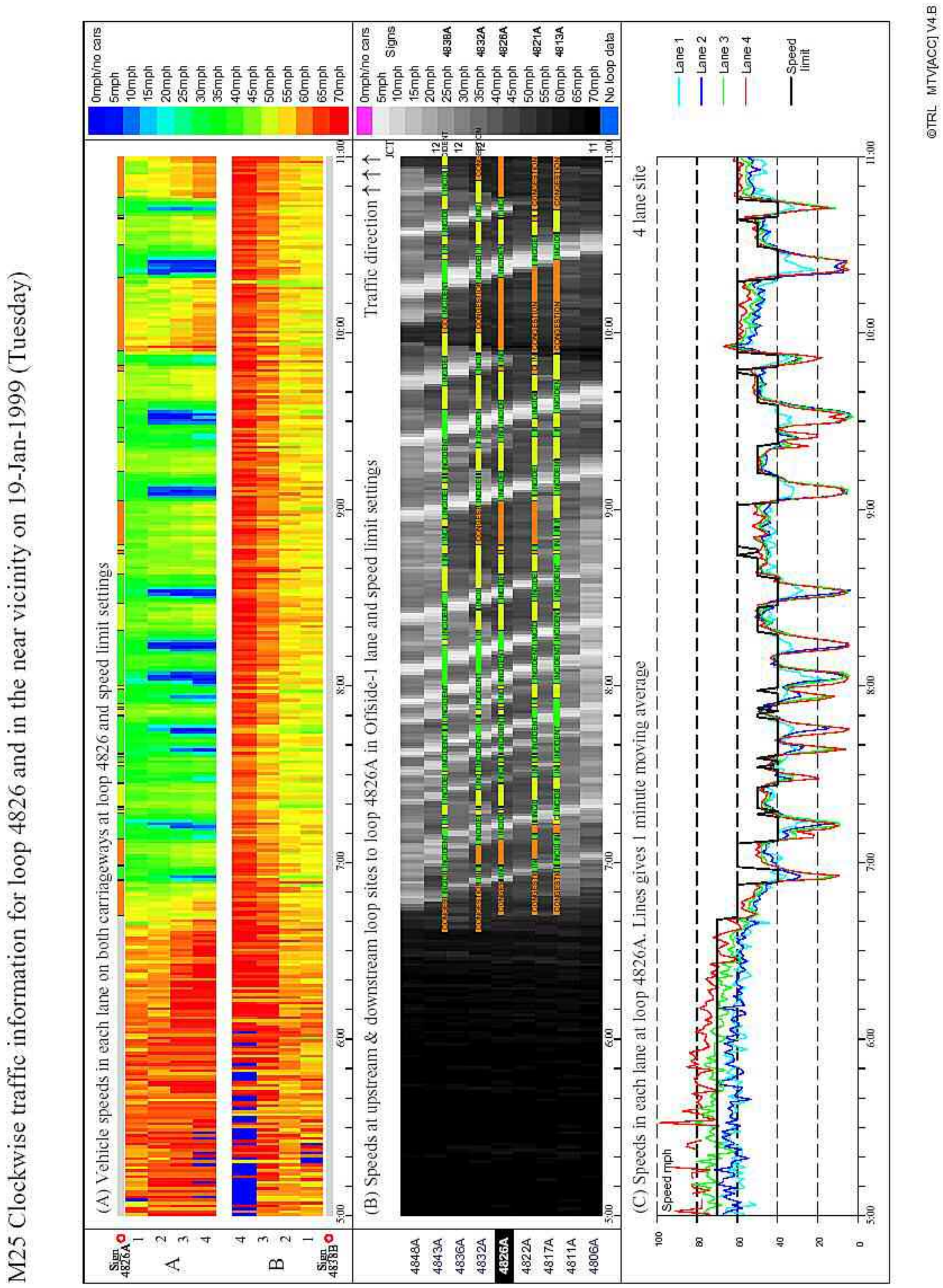


Figure 3.7.2 - Traffic information for loop 4826A and in the near vicinity on 19-Jan-1999

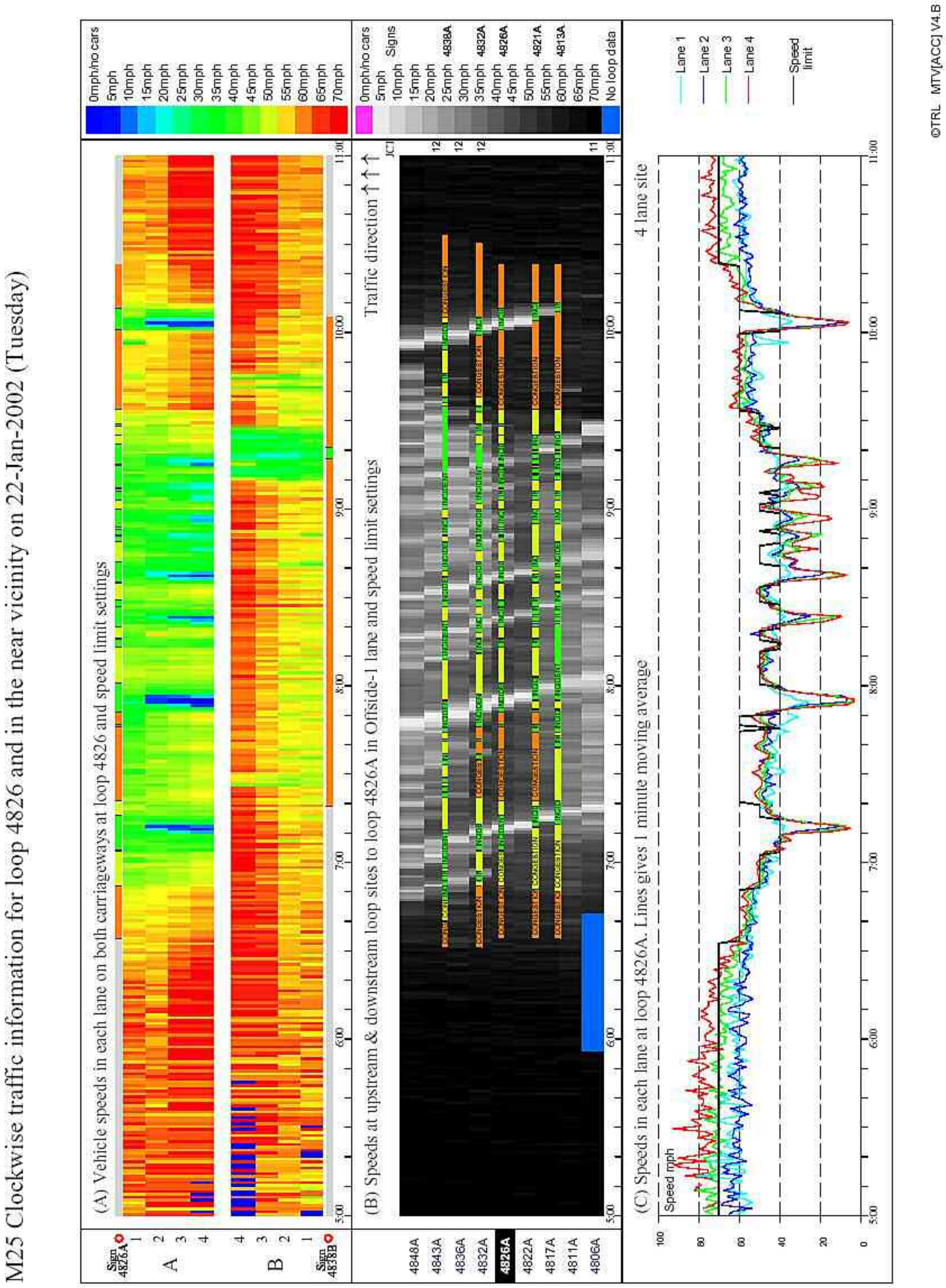


Figure 3.7.3 - Traffic information for loop 4826A and in the near vicinity on 15-Jan-2002

There is generally good compliance by drivers with the set speed limits: this is especially noticeable at approximately 06:45 on each of the plots, when the 60mph limit is set in response to high flows. The average vehicle speed in all lanes then immediately falls below 60mph. Compliance is similarly good when the 50mph limit is displayed, typically at approximately 06:55 at this site.

Examining the characteristics of the shockwaves over recent years, there is little evidence to suggest any change either in the minimum 1-minute average speed experienced within them (typically 5-10mph), or their duration (up to 10 minutes). However, the plots suggest that the frequency of occurrence of shockwaves has decreased, from approximately seven shockwaves during the 3-hour morning peak period down to five. This reduction in the number of shockwaves (together with no change in their depth or duration) would imply that fewer vehicles were affected by the shockwaves. This agrees with the improvement seen in the other performance indicators since 2000 (see Section 4.3).

3.8 Year to Year Trends

The traffic trends and behaviour described in the previous sections have changed the times of day during which Controlled Motorways has an effect. In particular, the increases in daily flows, peak spreading, compliance with speed limits, and changes to headways and shockwave characteristics have all had an effect over the years since Controlled Motorways became operational in 1995.

Figures 3.8.1 and 3.8.2 show the average journey times, by time of day, for a typical month for each year since Controlled Motorways was installed in August 1995. June was selected as there are few external variations from year to year (e.g. the weather is similar and there are no school holidays). (There are no journey times for June 1996 due to a lack of speed data.) The journey times are for typical weekdays, so Friday evenings and days with incidents have been excluded.

Figure 3.8.1 shows the journey times on the clockwise A carriageway. The basic shape of the profiles is the same from year to year. Journey times increase during the mornings at approximately the same time (about 6:10), and the longest journey times are at approximately the same time (about 8:00). The journey time profiles during the evening peak periods are also similar from year to year, especially the time at which congestion clears (about 20:00).

Figure 3.8.2 shows the journey times on the anticlockwise B carriageway. The basic shape of the profiles is the same from year to year. There is little congestion during the mornings. During the evening peak periods, congestion starts and finishes at approximately the same times (about 15:30 and 20:30 respectively).

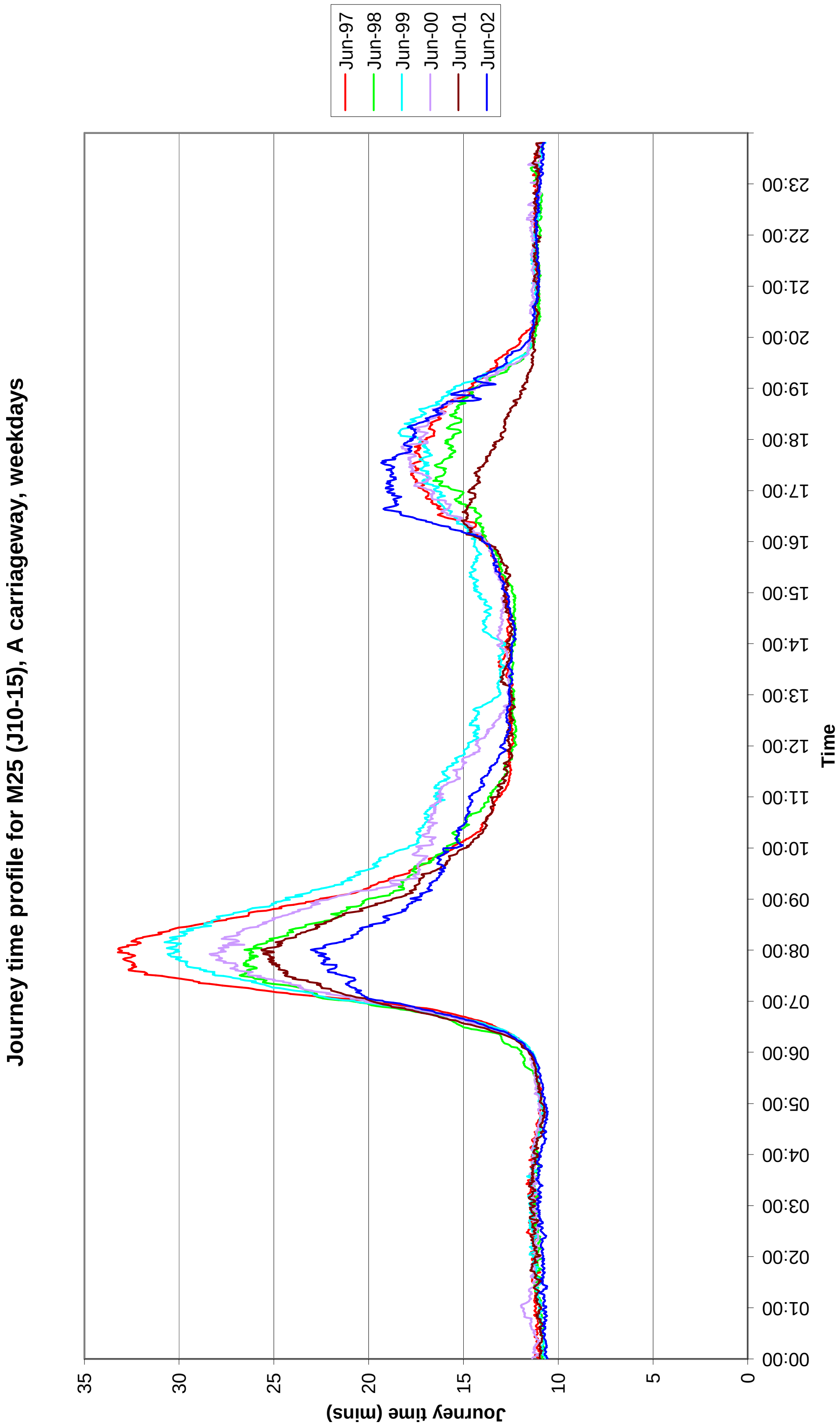


Figure 3.8.1 - Journey time profiles for M25 (J10-15) A Carriageway

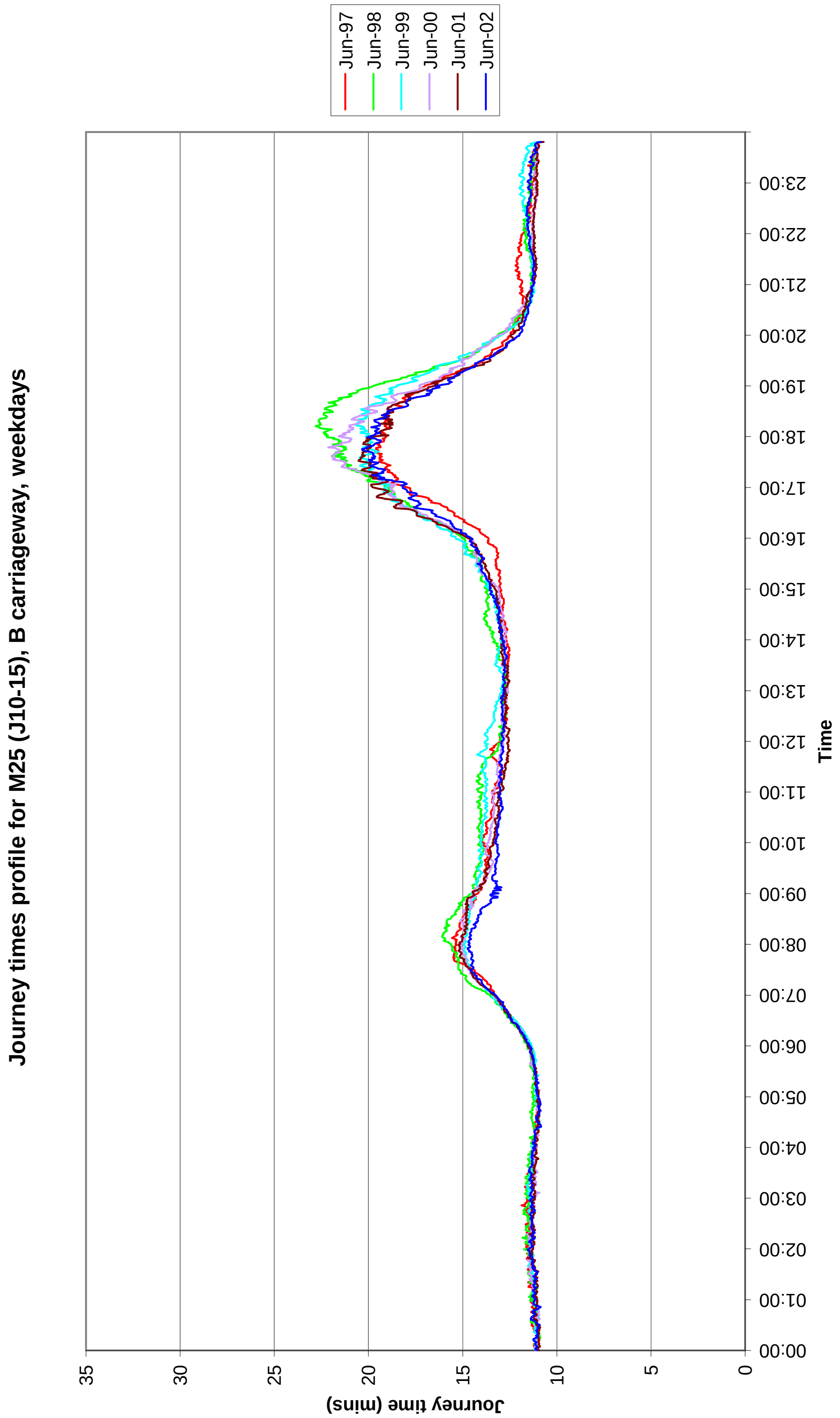


Figure 3.8.2 - Journey time profiles for M25 (J15-10) B Carriageway

Figures 3.8.3 and 3.8.4 show the journey time profiles for June 1997 and June 2002 only. These Figures enable the trends in journey times over the last five years to be easily observed. These trends (and the reasons for the trends) are:

- There has been a large reduction in journey times on the clockwise A carriageway during the mornings. This is the period when there is most congestion. It is believed that drivers have become accustomed to the Controlled Motorways system, and have learnt to drive more smoothly to prevent or reduce the effect of flow breakdown. The shorter headways are still safe, and may be a result of increasing driver confidence in the system.
- Congestion lasts for longer in the mornings, and starts earlier in the evenings. This is due to the increase in flows during the inter-peak period, caused by general peak spreading.
- Congestion in the evenings has increased slightly. This is due to the increased flows during the evenings.

There is a large difference between the year-to-year trends observed during the mornings and those observed during the evenings. Morning congestion has reduced over the last five years, whereas evening congestion has increased. The reasons for the different trends are:

- During the evenings, the levels of demand flow (i.e. the number of vehicles that desire to travel) are close to the capacity of the road. Small increases in the demand flow can cause flow breakdown to occur earlier. Once flow breakdown has occurred, it usually lasts for the remainder of the peak period. Therefore, small increases in demand flow in the evenings can cause large increases in the overall congestion levels.
- During the mornings, the demand flows on the clockwise carriageway far exceed the capacity of the road, so flow breakdown is inevitable. It is also predictable, normally to within 5 minutes. Therefore, any increases in demand flow have only a small effect on the overall congestion. A greater effect is achieved by drivers modifying their behaviour and driving more smoothly.

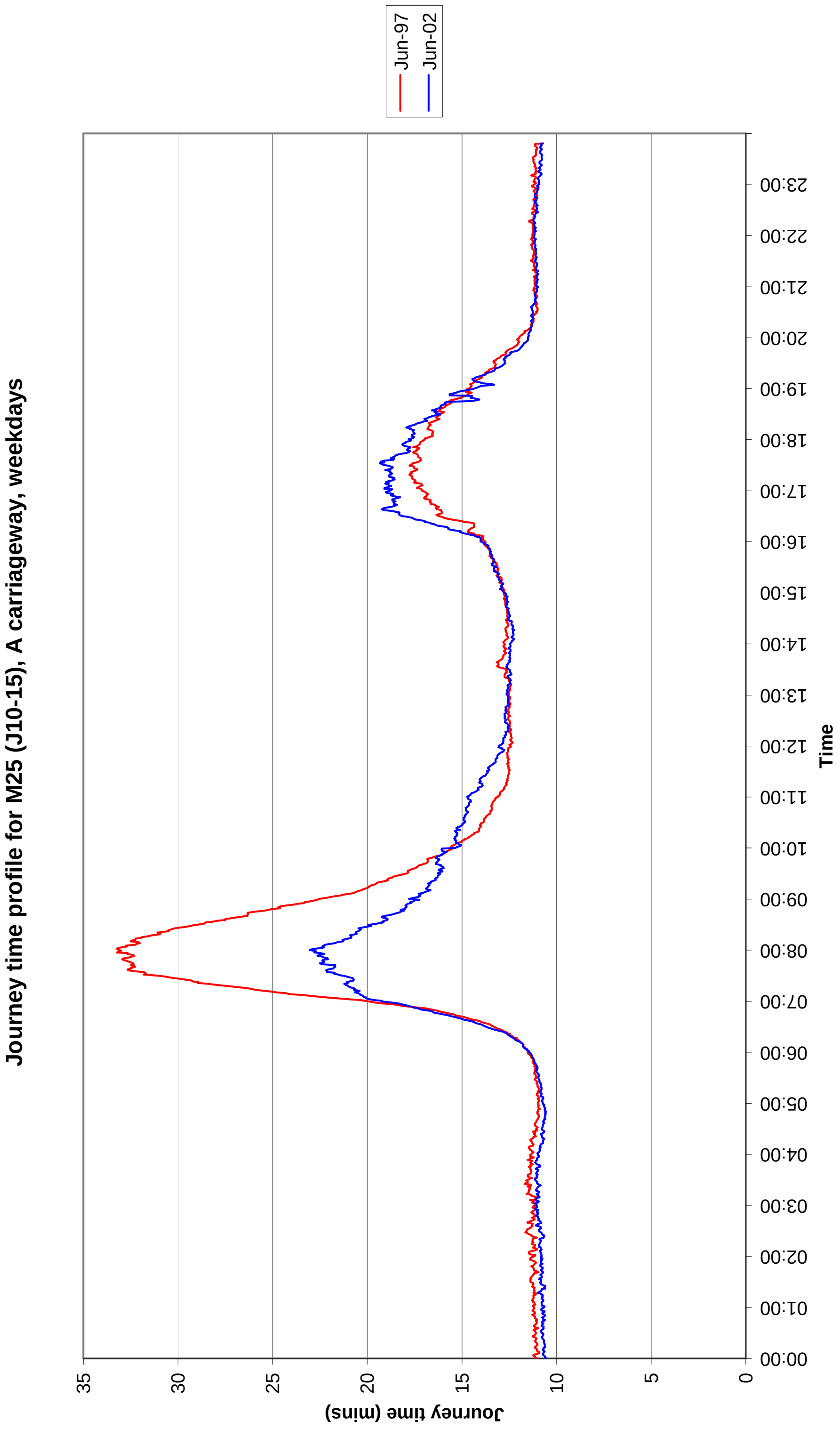


Figure 3.8.3 - Journey time profiles for M25 (J10-15) A Carriageway (1997 and 2002)

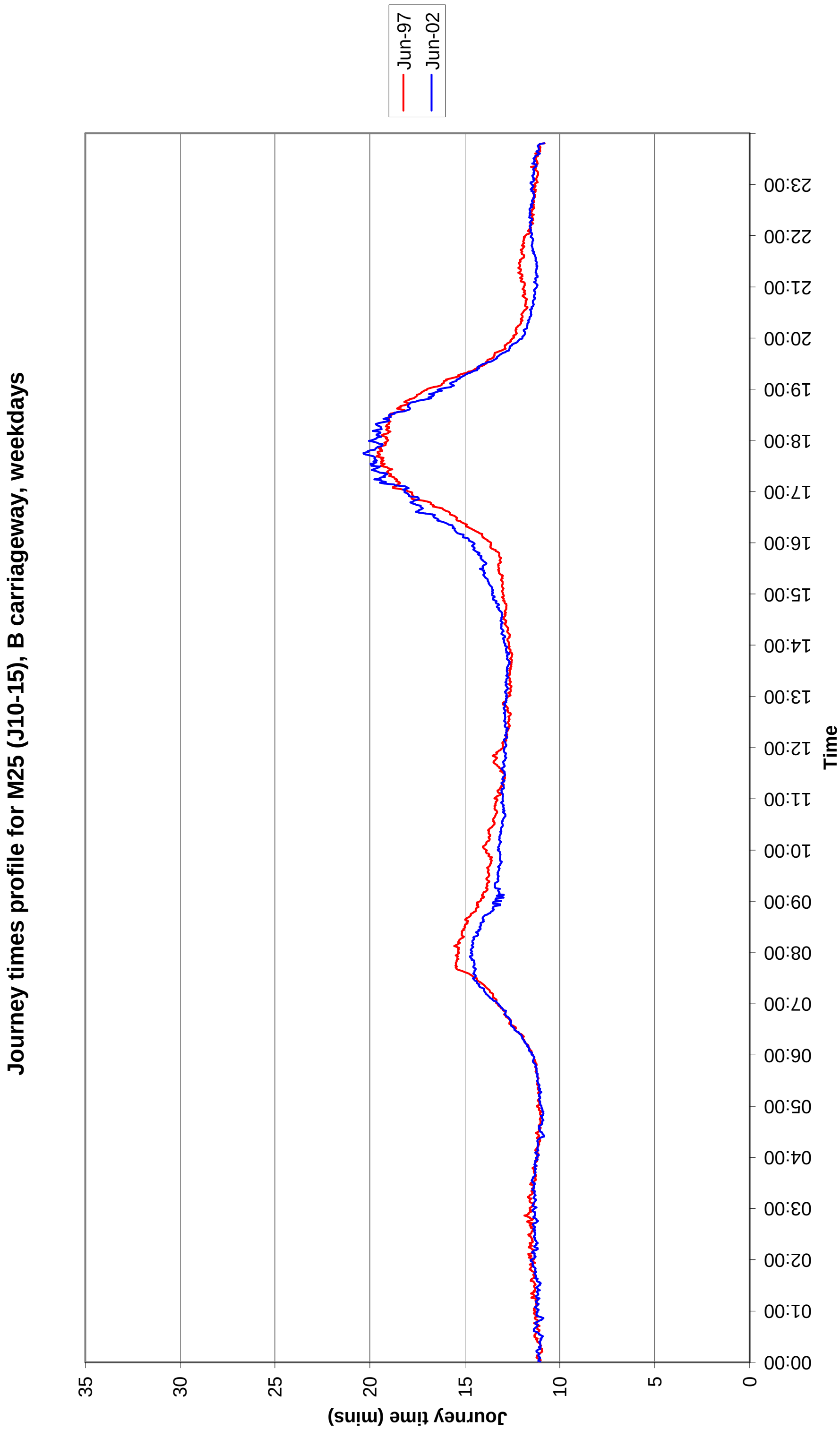


Figure 3.8.4 - Journey time profiles for M25 (J15-10) B Carriageway (1997 and 2002)

4 Performance Indicators and Trends

4.1 Introduction and Definitions

A number of Performance Indicators (PIs) have been used on a regular basis as part of the monitoring work since the system was switched on. The PIs are:

- Throughputs *(peak 15-minute, peak 1-hour, and total 5-hour flows)*
- Flow Breakdown *(duration that speeds are below 25mph for specific road length)*
- Journey Times *(average time through link, with standard deviation)*
- Lane Utilisation *(percentage of traffic using each lane)*

PIs are calculated link by link (for both Junction-to-Junction and within-Junction links) for the two busiest peak periods, namely the morning weekday peak (06:00 - 11:00) on the clockwise A carriageway, and the evening weekday peak (15:30 - 20:30) on the anticlockwise B carriageway. To make the PIs representative of typical peaks, the calculations exclude Friday evenings, weekends, bank holidays and days with major incidents or bad weather. It is important that all significant congestion is measured, so each peak period is five hours long.

The PIs are calculated for each month, or for a change in the MIDAS configuration. A complete set of PIs in a graphical format can be found in Appendix A. The following subsections describe the trends in the PIs since the system was switched on, with an emphasis on the performance during the last calendar year. (No PIs are available from before Controlled Motorways was installed, due to a lack of good quality data.)

4.2 Throughputs

4.2.1 Demand Flows

The demand flow PI for a 5-hour peak period is the total throughput during that period. The 5-hour periods were selected to encompass all regular congestion, so that there is no queueing at either end of the peak period (unless there is an incident, in which case the period is excluded from the PI calculations). Therefore, the demand flow PI represents the total traffic within a peak period.

A full summary of demand flows through the Controlled Motorways section may be found in Appendix A. Typical examples of the seasonal variations in the demand flow for the morning 5-hour peak period on the A (clockwise) carriageway are shown in Figures 4.2.1 and 4.2.2. The demand follows consistent seasonal trends, rising during the year and falling to a minimum during December and January. There is also a reduction in demand during August of each year (probably because of summer holidays). Junction 13 to 14 on the clockwise carriageway consistently has the highest levels of traffic demand on the whole of the M25.

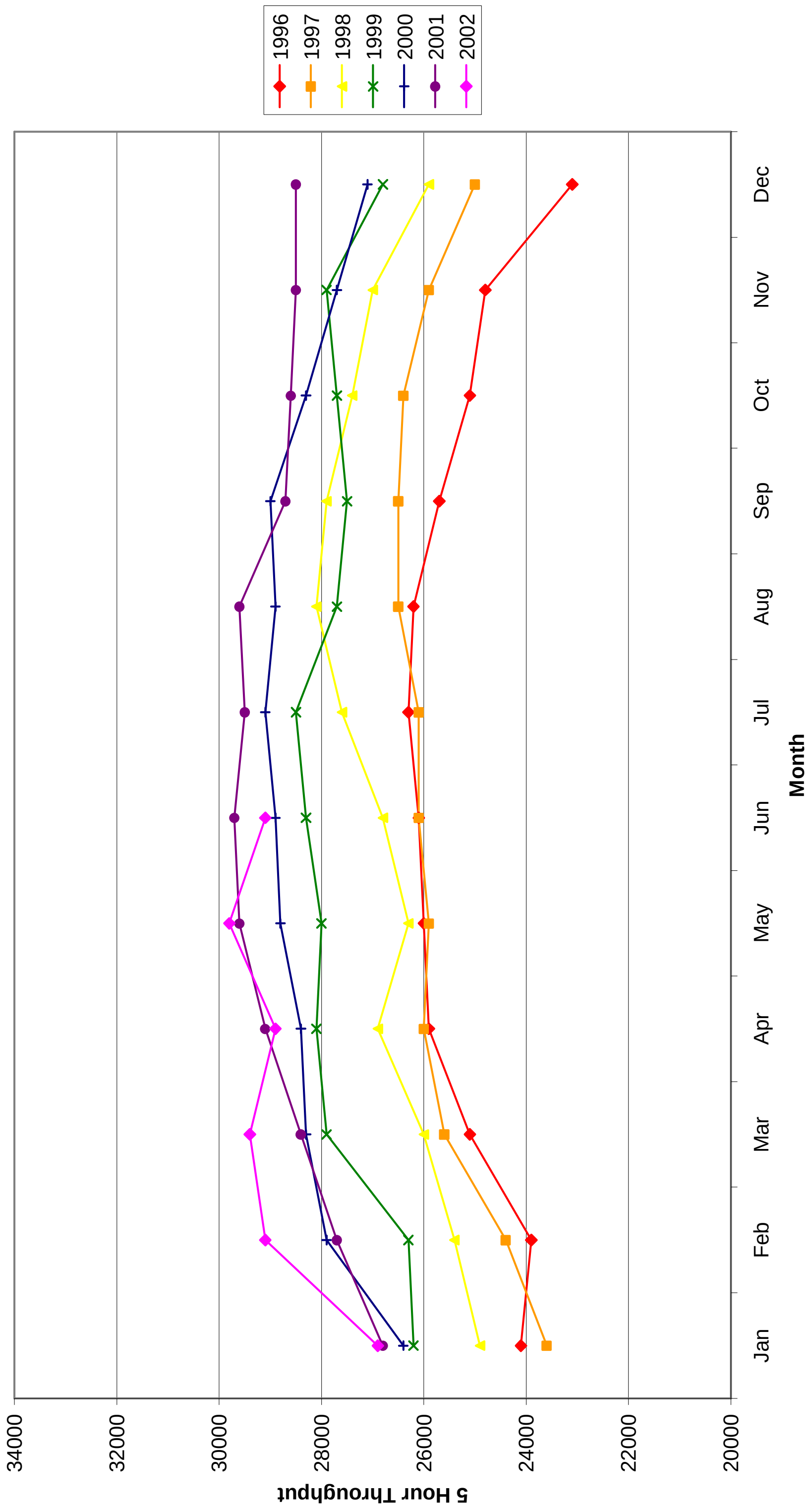


Figure 4.2.1 Five-hour throughputs for the clockwise carriageway for J10-11 link

At the southern end of the Controlled section (Junctions 10 to 12), there is little year-to-year increase in demand until September 1997, when demand rose sharply compared to previous years, due to the completion of roadworks between Junctions 8 and 10. Demand then rose at a rate of approximately 2-2.5% per year (with the highest increases for the link between Junctions 10 and 11) until 1999, since when growth has slowed to approximately 1.5% per year.

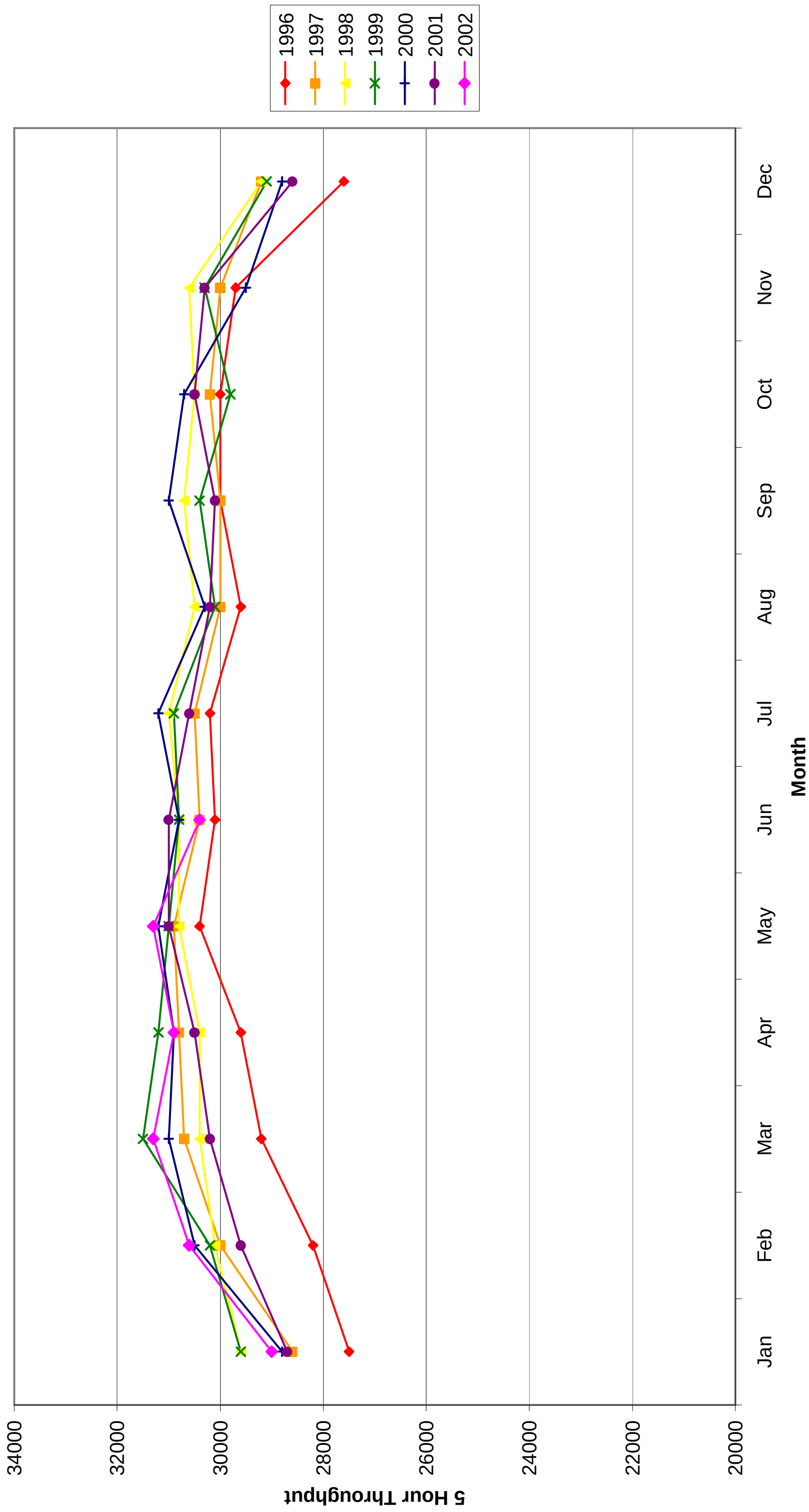


Figure 4.2.2 Five-hour throughputs for the clockwise carriageway for J14-15 link

At the northern end of the Controlled section (Junctions 12 to 16), the demand has followed a similar pattern since the summer of 1996. The link between Junctions 12 and 13 has shown a small year-on-year increase of approximately 0.5%, whereas the demand flows on the links north of Junction 13 have remained at approximately the same levels, and even started to decrease slightly.

The demand flow for selected links during the evening 5-hour peak period on the anticlockwise carriageway is shown in Figures 4.2.3 and 4.2.4. The demand follows consistent seasonal trends, with demand rising during the year and falling to a minimum during December and January.

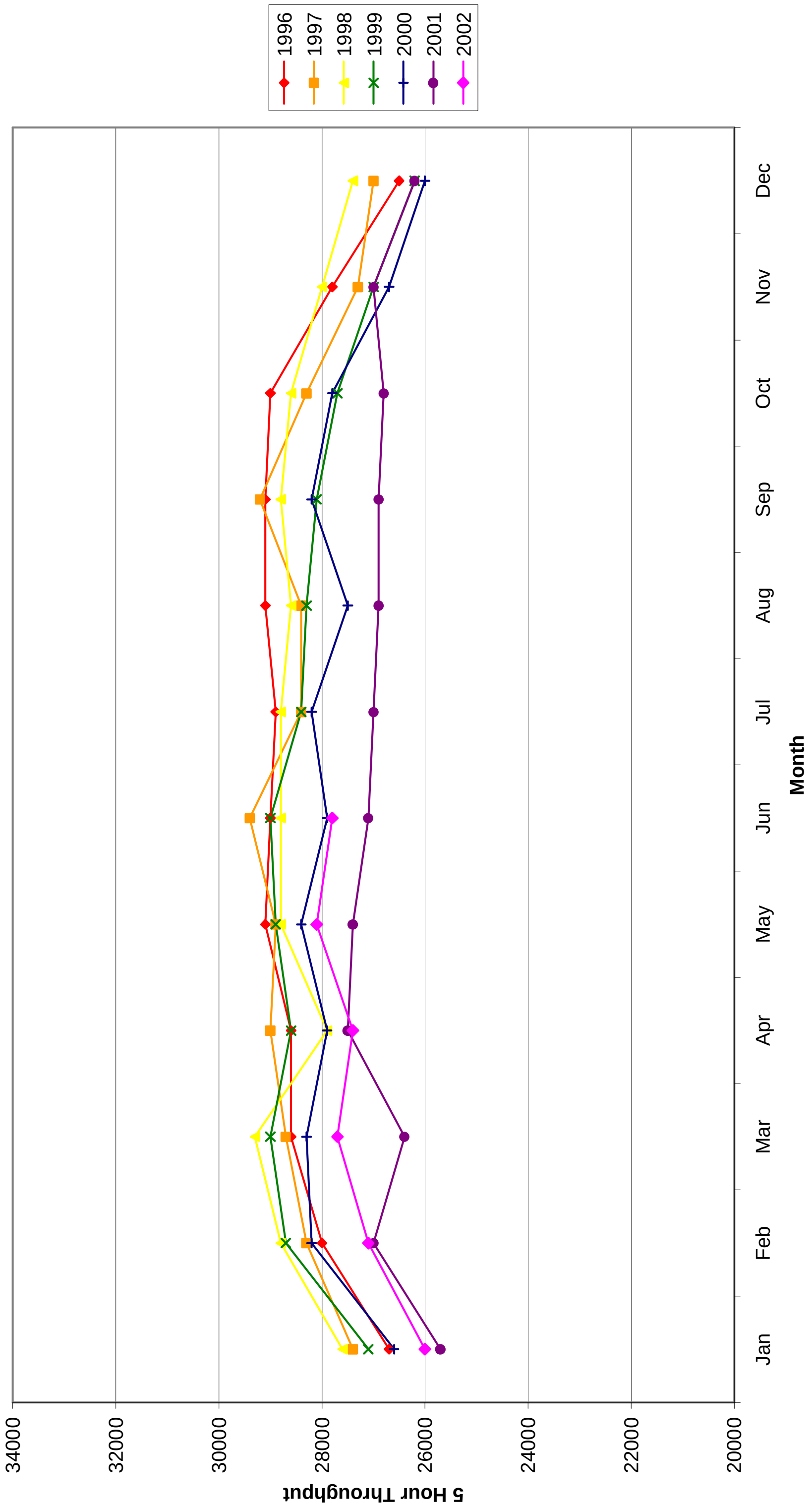


Figure 4.2.3 Five-hour throughputs for the anticlockwise carriageway for J15-14 link

At the northern end of the anticlockwise section (Junctions 16 to 12), the 5-hour throughput has been decreased year-on-year since 1996, and at a faster rate: the throughput dropped by about 1.5-2% between 1999 and 2000, compared with a reduction of approximately 0.5% between 1996 and 1997. The demand during 2001 was substantially lower than all previous years (2% lower than 2000 data), but data for 2002 appears to show an increase towards the demand values observed in 2000.

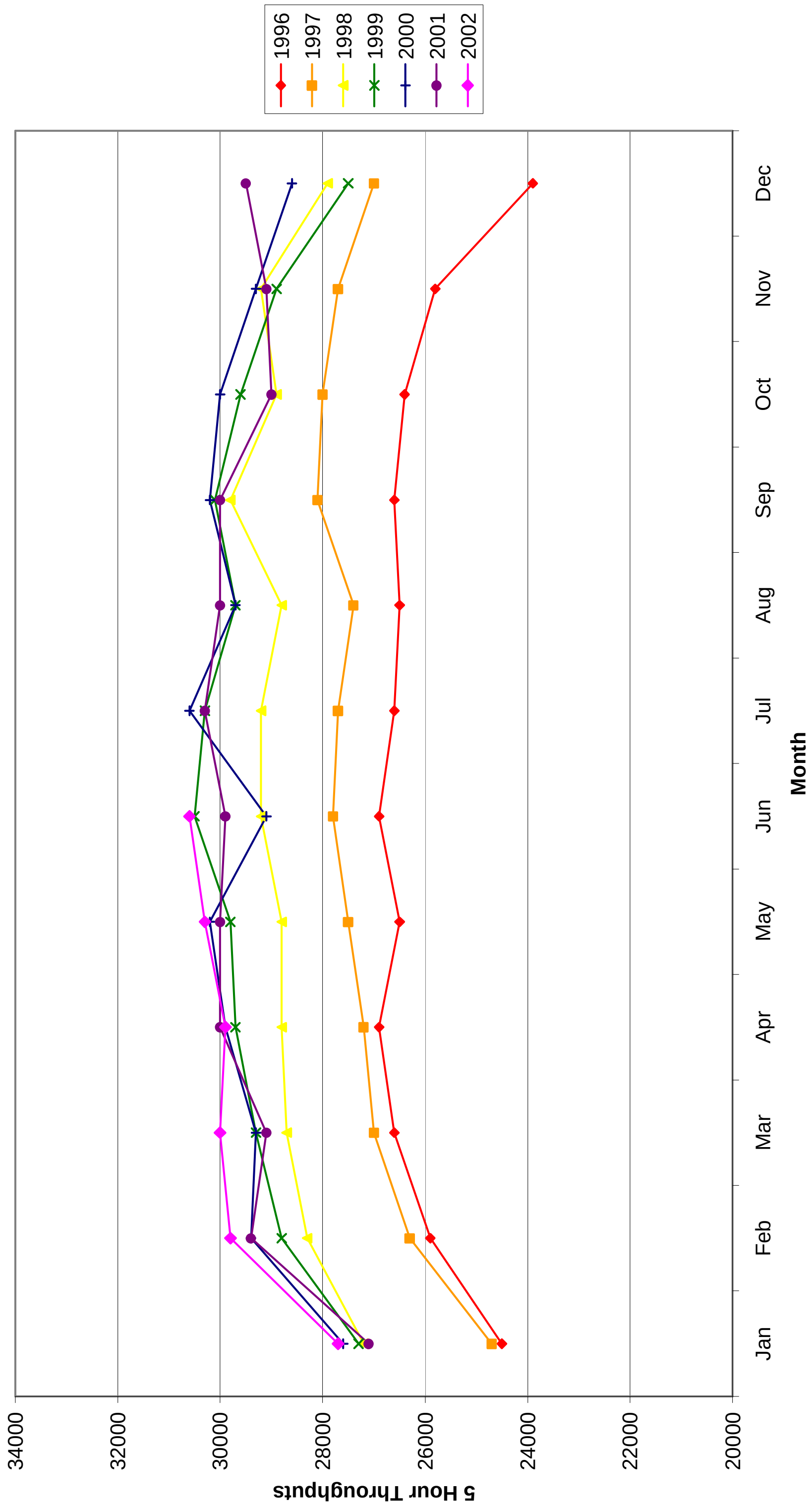


Figure 4.2.4 Five-hour throughputs for the anticlockwise carriageway for J11-10 link

At the southern end of the anticlockwise section (Junctions 12 to 10), the steady rise in demand from the removal of the roadworks in September 1997 lasted until the autumn and winter of 1998. From 1999 onwards, the demand has decreased slightly: the 5-hour throughput fell by nearly 1% between 2000 and 2001.

To summarise, for the whole period 1996 to 2002 the throughputs have typically increased by:

- Clockwise carriageway Junction 10-11 2.5% per annum
- Clockwise carriageway Junction 14-15 0.5% per annum
- Anticlockwise carriageway Junction 10-11 2.5% per annum
- Anticlockwise carriageway Junction 14-15 1.0% per annum.

4.2.2 Peak Throughputs

The peak 15-minute and peak 1-hour throughputs represent the notional capacity of the road. The peak 15-minute throughput occurs just before flow breakdown, and the peak 1-hour period encompasses the time of flow breakdown.

The capacity of the road varies from day to day by as many as 2000 vehicles per hour and there is also an underlying seasonal effect. The seasonal effects are similar on each carriageway, although more pronounced on the clockwise carriageway. The capacity is greatest during the late spring/early summer, and lowest in December.

Figures 4.2.5 and 4.2.6 show the average of the peak 1-hour throughputs on each carriageway for each month, for the links where flow breakdown most typically occurs.

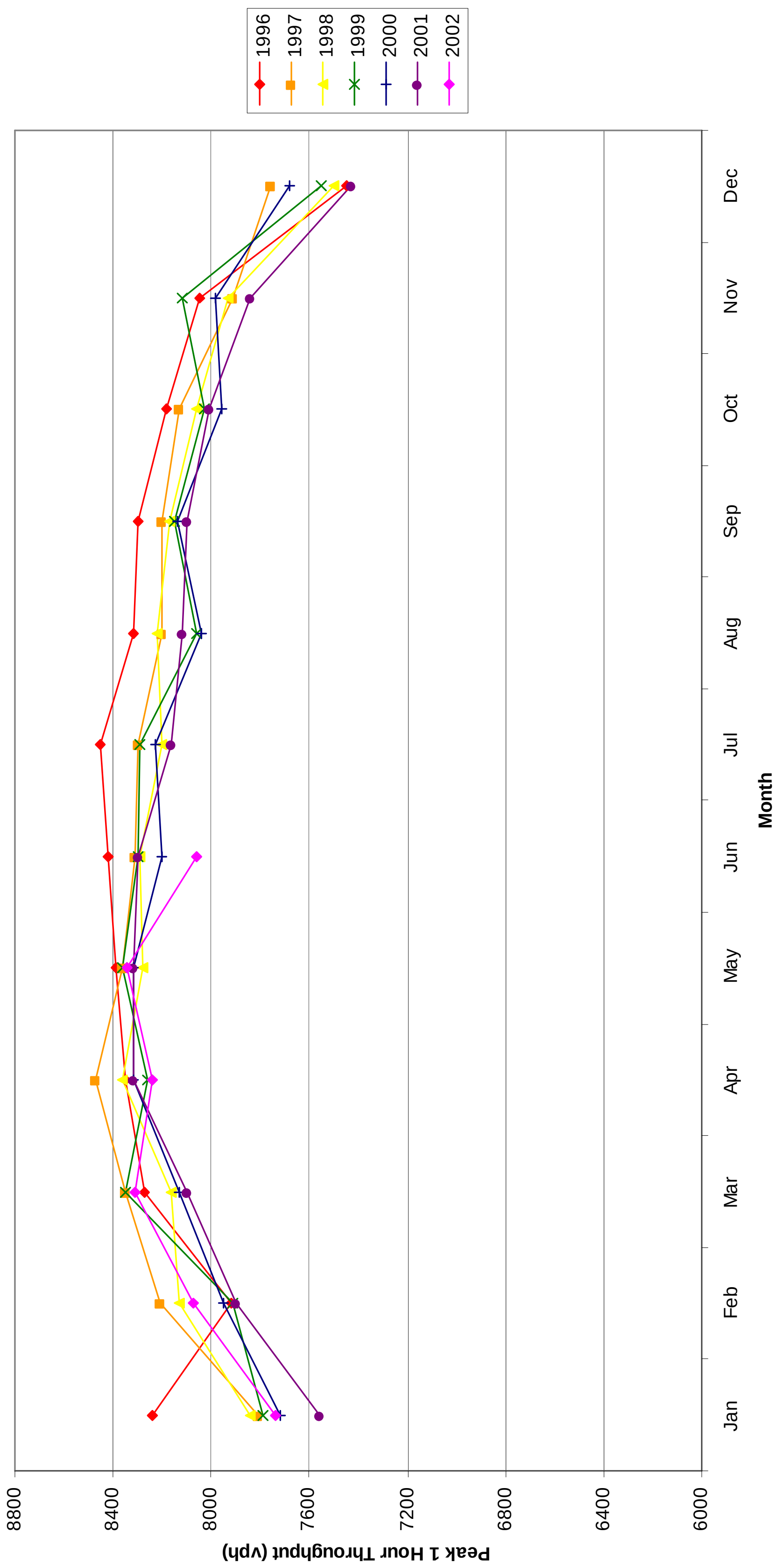


Figure 4.2.5 Peak 1-hour throughput for the clockwise carriageway for J13-14 link

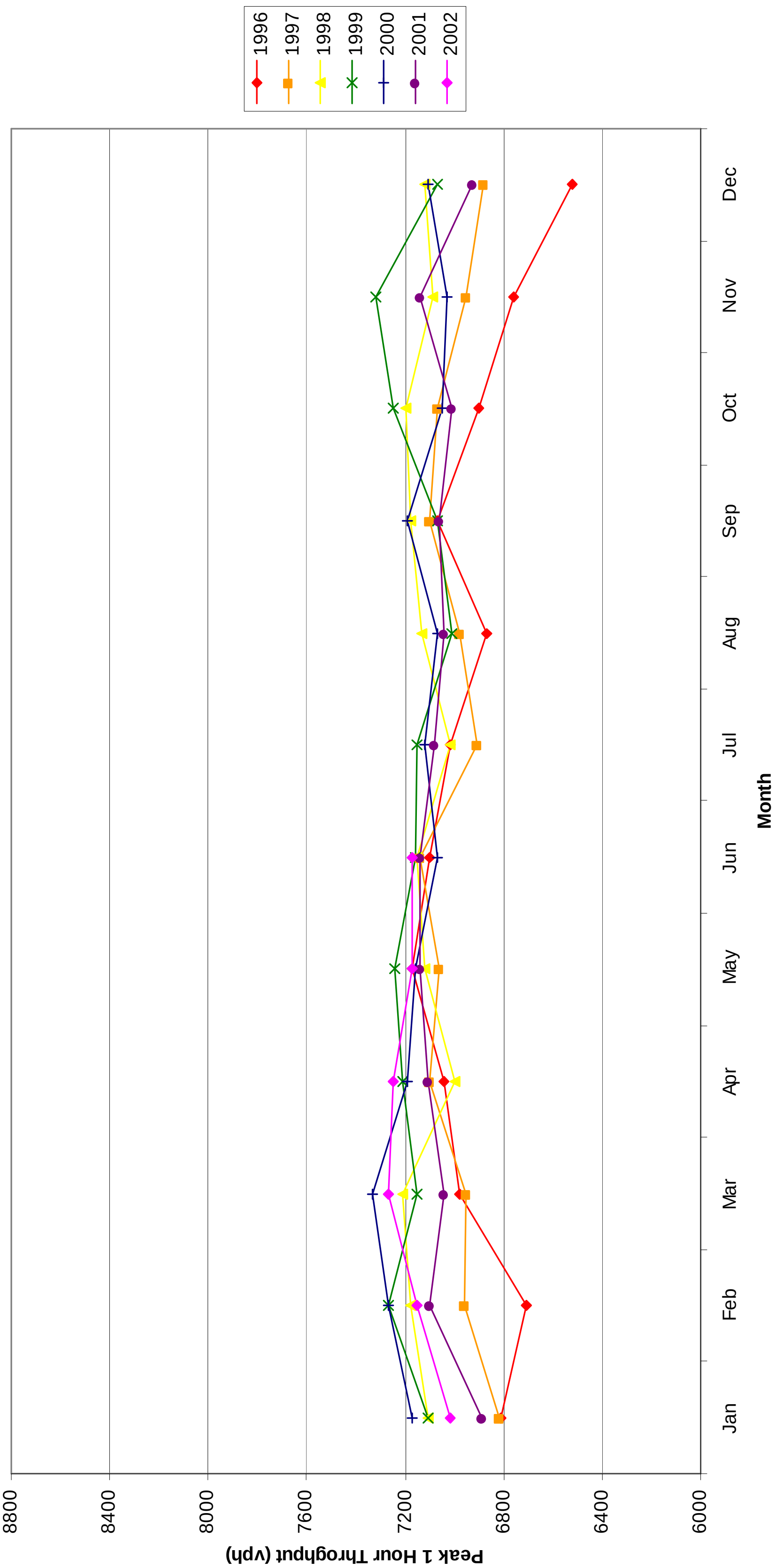


Figure 4.2.6 Peak 1-hour throughput for the anticlockwise carriageway for the J12-11 link

The peak 15-minute and peak 1-hour throughputs on the clockwise carriageway (shown in Figure 4.2.5) have followed consistent seasonal trends, although there has been a slight year-on-year reduction of approximately 0.5-1%. Peak throughputs from January 2002 to March 2002 were higher than recent years, although still below 1997 and 1998 levels, but values returned to a lower level in April 2002.

The peak 15-minute and peak 1-hour throughputs on the anticlockwise carriageway (shown in Figure 4.2.6) also followed consistent seasonal trends, with the highest throughputs during the early summer. There is little change in the values from year to year during the late spring and early summer, but more variation during autumn and winter. However, no consistent year-to-year trend has developed.

The difference between the capacities of the two carriageways is due to the cause of the congestion on each carriageway (see Section 4.3). On the clockwise carriageway, the flow breakdown on the J13-14 link occurs mid-link, and there is only a small drop in capacity (to approximately 8300 veh/hr). On the anticlockwise carriageway, the flow breakdown on the J12-11 link is due to merging traffic, and there is a much larger drop in capacity (to approximately 7100 veh/hr).

The capacity of the carriageway varies from day to day. Figure 4.2.7 shows the capacity of the clockwise carriageway for each weekday during 1998 (congestion occurs on each weekday, so each peak 1-hour throughput is a measure of the capacity on that day). Similarly, Figure 4.2.8 shows the capacity of the anticlockwise carriageway for each weekday during 1998.

Figures 4.2.7 and 4.2.8 show that the capacity can vary by over 1000 veh/hr on consecutive days. This variation is due to a number of factors such as the weather and variations in traffic patterns. For example, a higher merging percentage at Junction 12 can cause flow breakdown at lower overall flow levels on the anticlockwise carriageway.

The general seasonal trends are the same as those observed in Figures 4.2.5 and 4.2.6, with the capacity of the clockwise carriageway peaking during the summer months, whereas on the anticlockwise carriageway, there is less variation during the year.

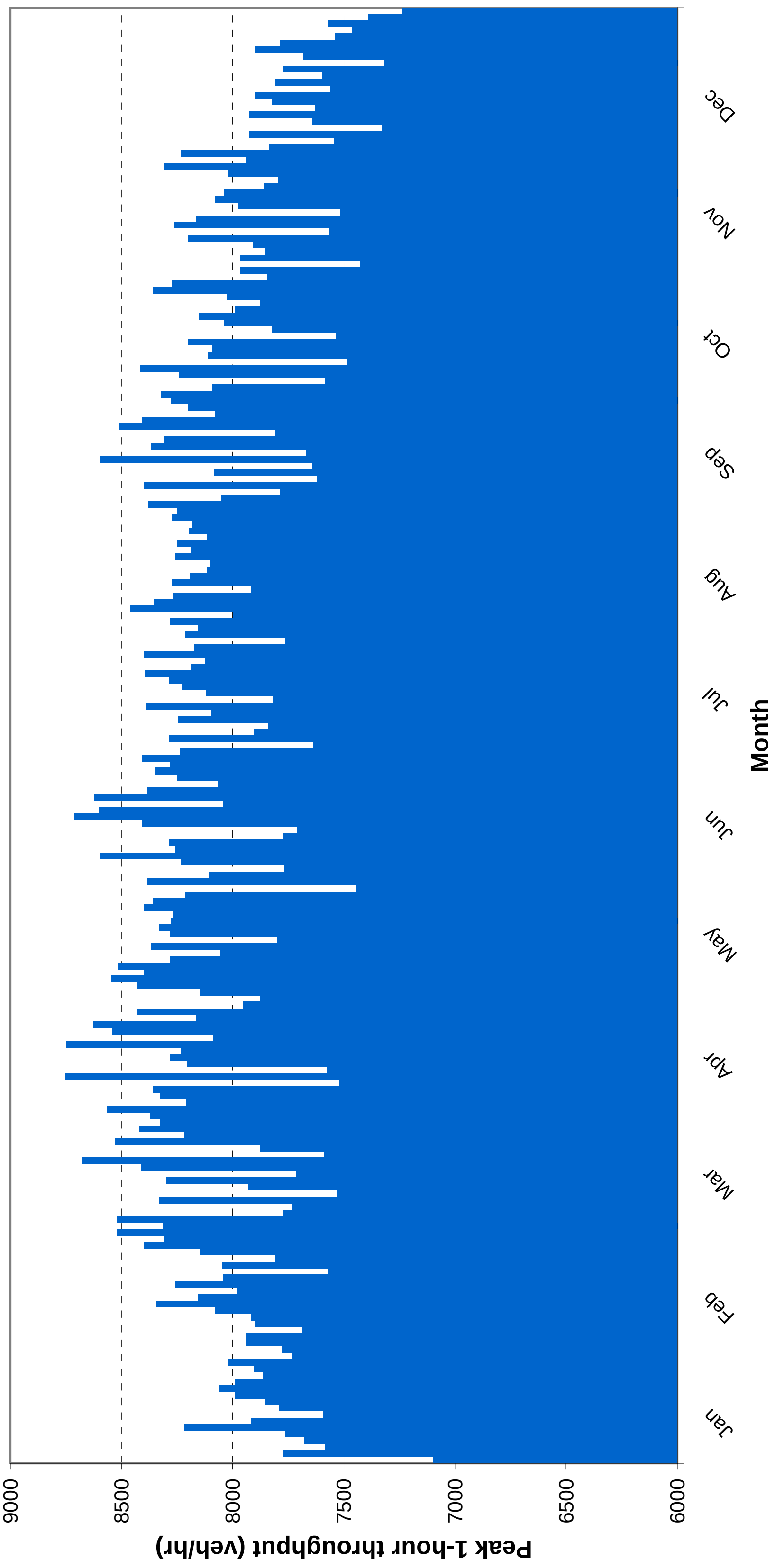


Figure 4.2.7 Peak 1-hour throughputs on J13-14 clockwise carriageway, by weekday during 1998

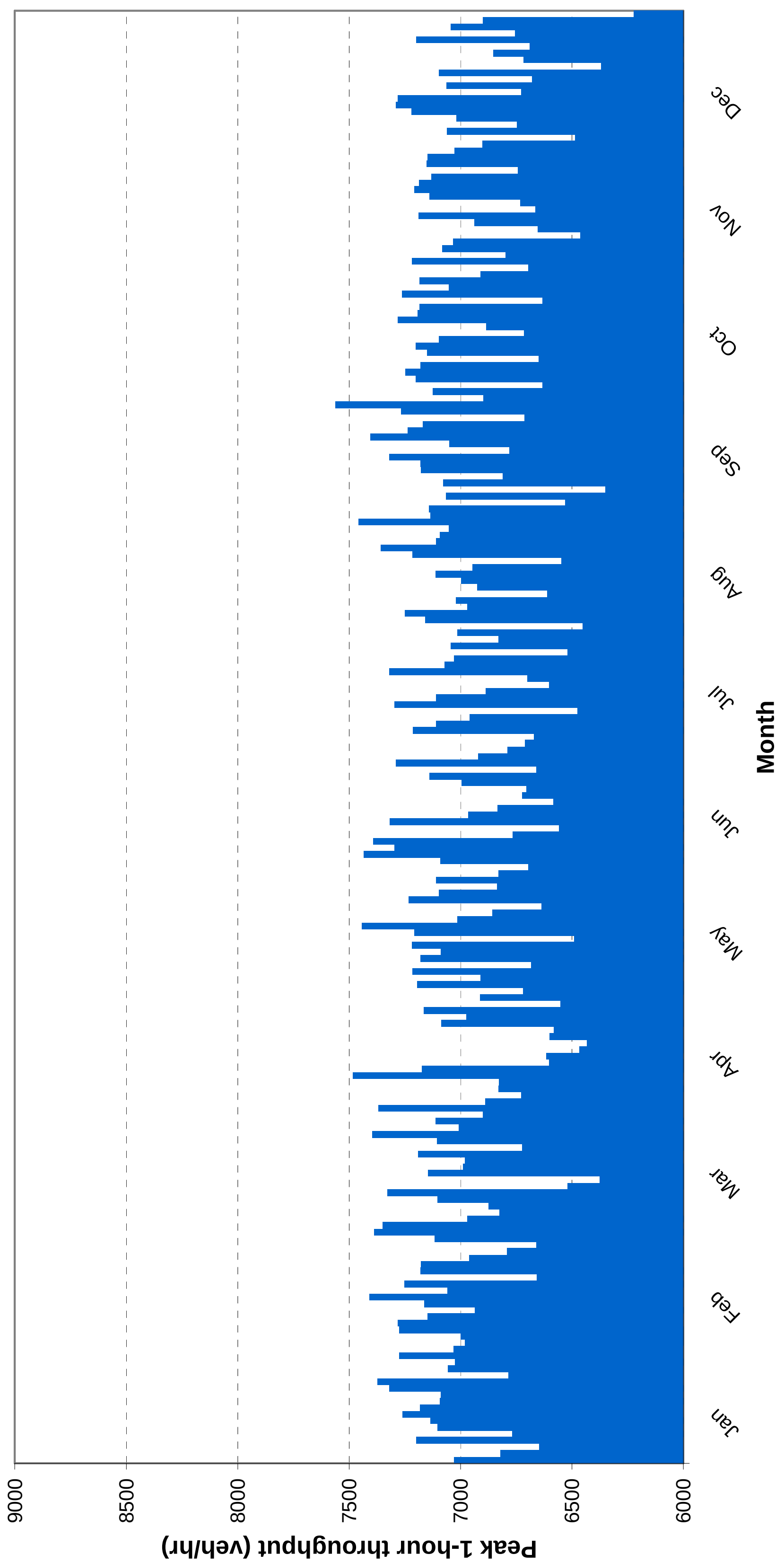


Figure 4.2.8 Peak 1-hour throughputs on J12-11 anticlockwise carriageway, by weekday during 1998

4.3 Flow Breakdown and Journey Times

Recurrent congestion on the Controlled Motorways section can be broadly categorised under three headings:

- **Merging at Junctions**: Apart from an immediate disturbance arising from drivers moving out a lane to accommodate merging vehicles or slowing to allow a merge to take place, flow breakdown can be initiated by an unsustainable increase in capacity due to temporary acceptance (by drivers) of a smaller headway. This tends to occur between 800m and 1000m downstream of the merge point.
- **Diverging at Junctions**: The most likely cause for disturbance here is the activity of drivers making a late lane change (the so-called “swooping” manoeuvre). Other activities involve slowing to make a normal lane change, cautious driving, and drivers coming back out of the diverge lane to overtake a vehicle before making their exit. There can also be queueing on the exit slip road.
- **Mid-Link**: These causes are harder to identify than merge or diverge effects. However, a detailed observation of traffic behaviour between junctions indicates that flow breakdown from causes unrelated to the influence of motorway junctions is not uncommon. This ‘phenomenon’ has been classified as mid-section flow breakdown and includes the most subtle of perturbations to unstable flows, critical headway being encroached, excessive lane changing, influence of geometry and other local effects.

Within close proximity of the seed point of a shockwave, the flow breakdown may only be in the form of a small reduction in speed. As the shockwave propagates upstream from the seed point, the associated flow breakdown may result in a sharp fall in speed and a reduction in the effective road capacity.

The journey time performance indicators are used to detect the extent to which speeds fall during shockwaves; the flow breakdown performance indicators represent how often speeds fall during shockwaves. The change of frequency in the shockwaves on the M25 (see Section 3.7) agrees with the findings of the journey time and flow breakdown performance indicators.

The flow breakdown PI is calculated as a total over a 5-hour peak period (morning for the clockwise carriageway, evening for the anticlockwise carriageway). The journey time PI is calculated as an average for the 5-hour peak period.

4.3.1 Clockwise Carriageway

The flow breakdown and journey times during the 5-hour morning peak period on the clockwise carriageway (shown in Figures 4.3.1 and 4.3.2) follow consistent seasonal trends, with the best performance (i.e. the lowest journey times) being during the summer.

Along the clockwise carriageway, the merge at Junction 11 and mid-link Junction 13-14 remain the two most common sites for flow breakdown. At the beginning of the morning peak period the first shockwaves generally occur at one of these sites. The times of flow breakdown and the levels of congestion during the morning peak period are generally predictable.

Journey times rose by approximately 5% between 1996 and 1997, but then stabilised. From 2000 onwards, however, there has been a consistent reduction in the total journey time by about 2-3% per year; the lowest values recorded for each month on Figure 4.3.2 are frequently from 2000 or 2001 data.

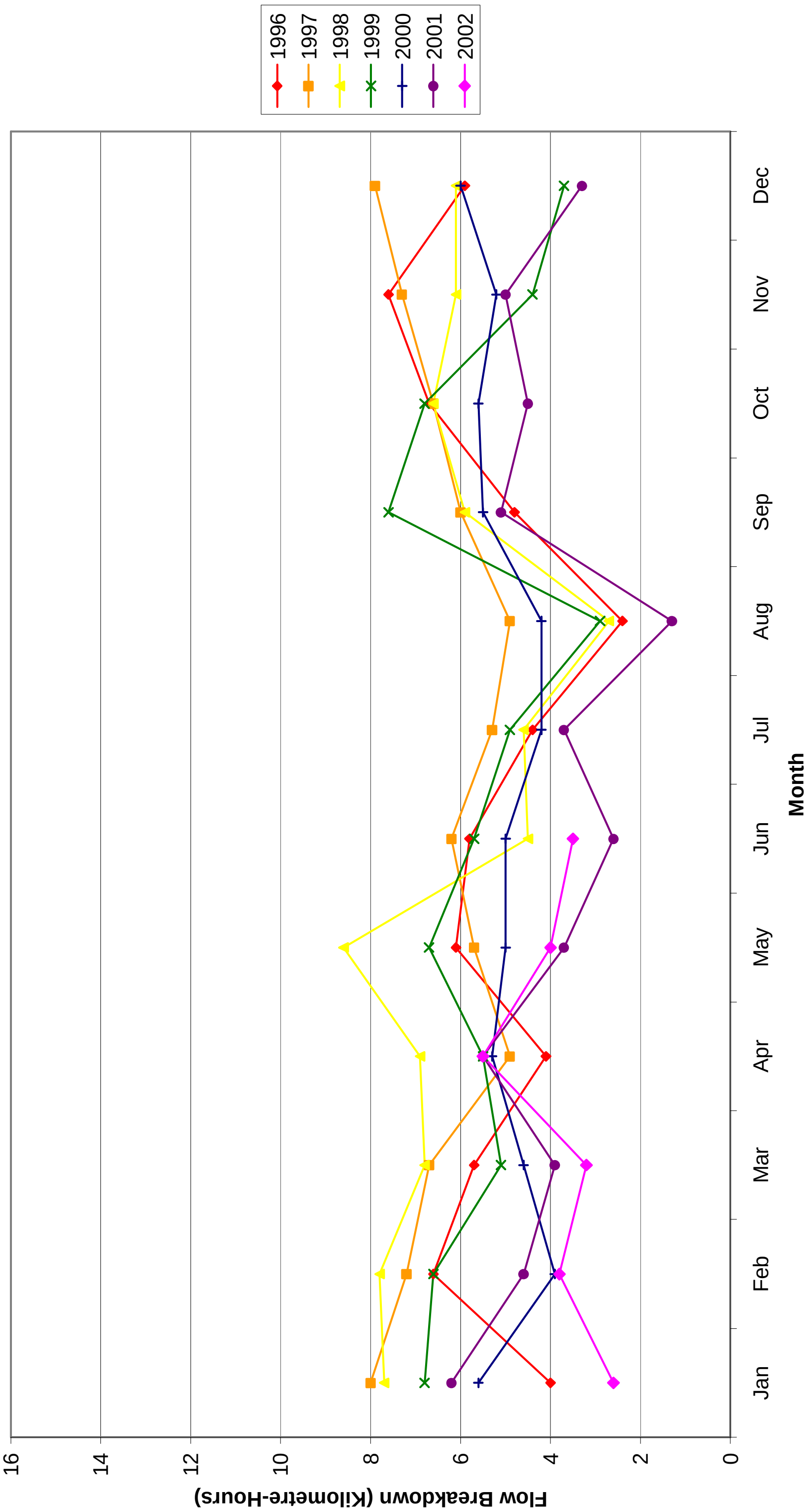


Figure 4.3.1 Flow breakdown for the A carriageway for J11-15 section (morning peak period)

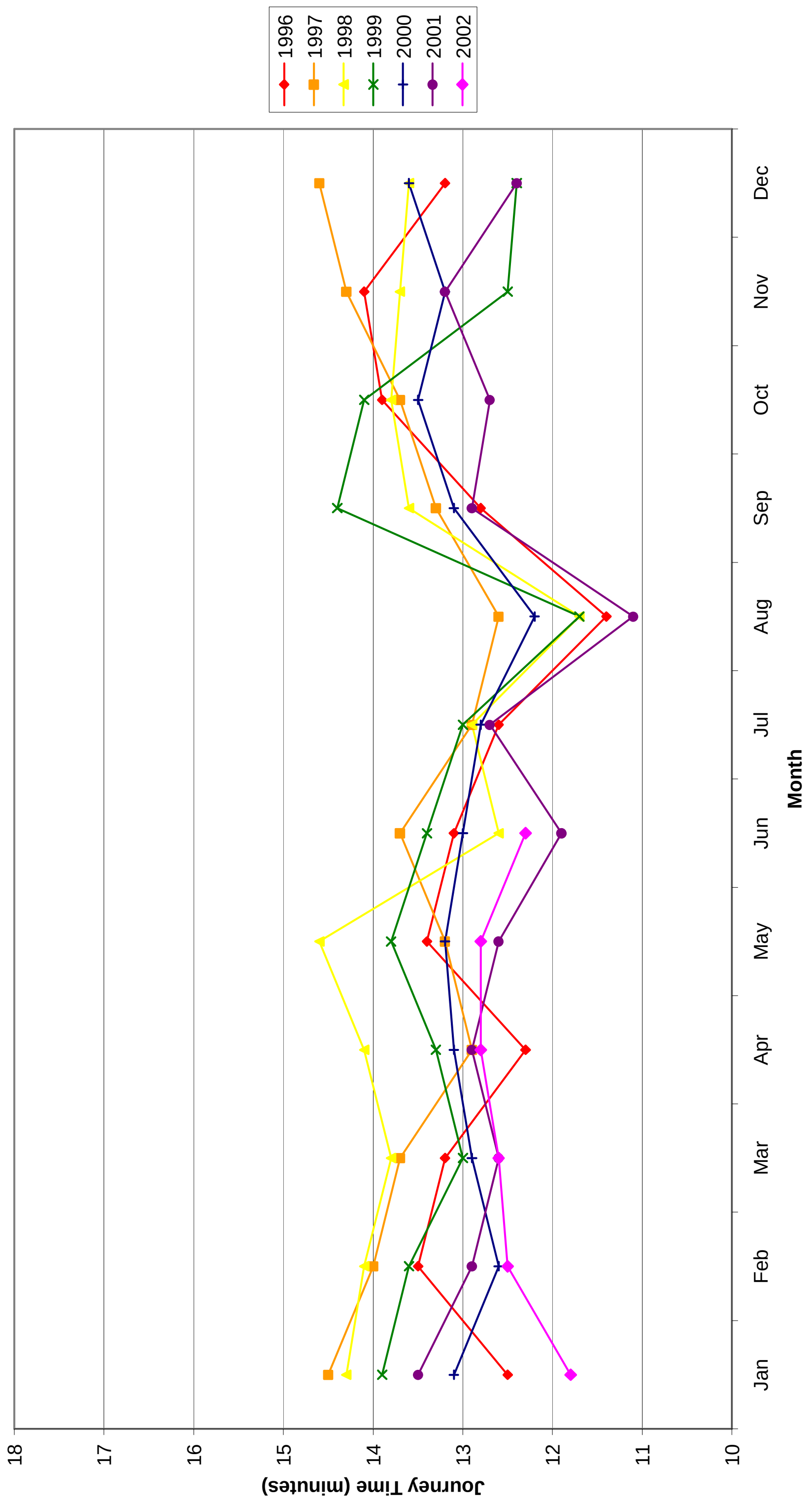


Figure 4.3.2 Journey times for the A carriageway for J11-15 section (morning peak period)

4.3.2 Anticlockwise Carriageway

The seasonal trends for flow breakdown and journey times during the 5-hour evening peak period on the anticlockwise carriageway (shown in Figures 4.3.3 and 4.3.4) are less evident, which is mainly due to the less consistent nature of the evening peak. The demand does not rise as rapidly as in the morning peak, and so the time of flow breakdown is much less predictable, which affects the journey time and quantity of flow breakdown a great deal. Performance is generally at its best during December and January (when demand flows are lower), although in 1996 and 1997 journey times and flow breakdown were also low during the summer.

From 1998 onwards however, there has been much more congestion. This is because the congestion generated by the seed point between Junctions 12 and 11, which was once only occasional, now occurs much more frequently and is no longer seasonal. When flow breakdown occurs at that point, traffic queues back through the whole of the upstream section, causing significant delays. The performance in each year from 1999 to 2002 has been broadly similar, with a general deterioration during the spring and summer (although some of these months have relatively little congestion), then remaining static until December of each year.

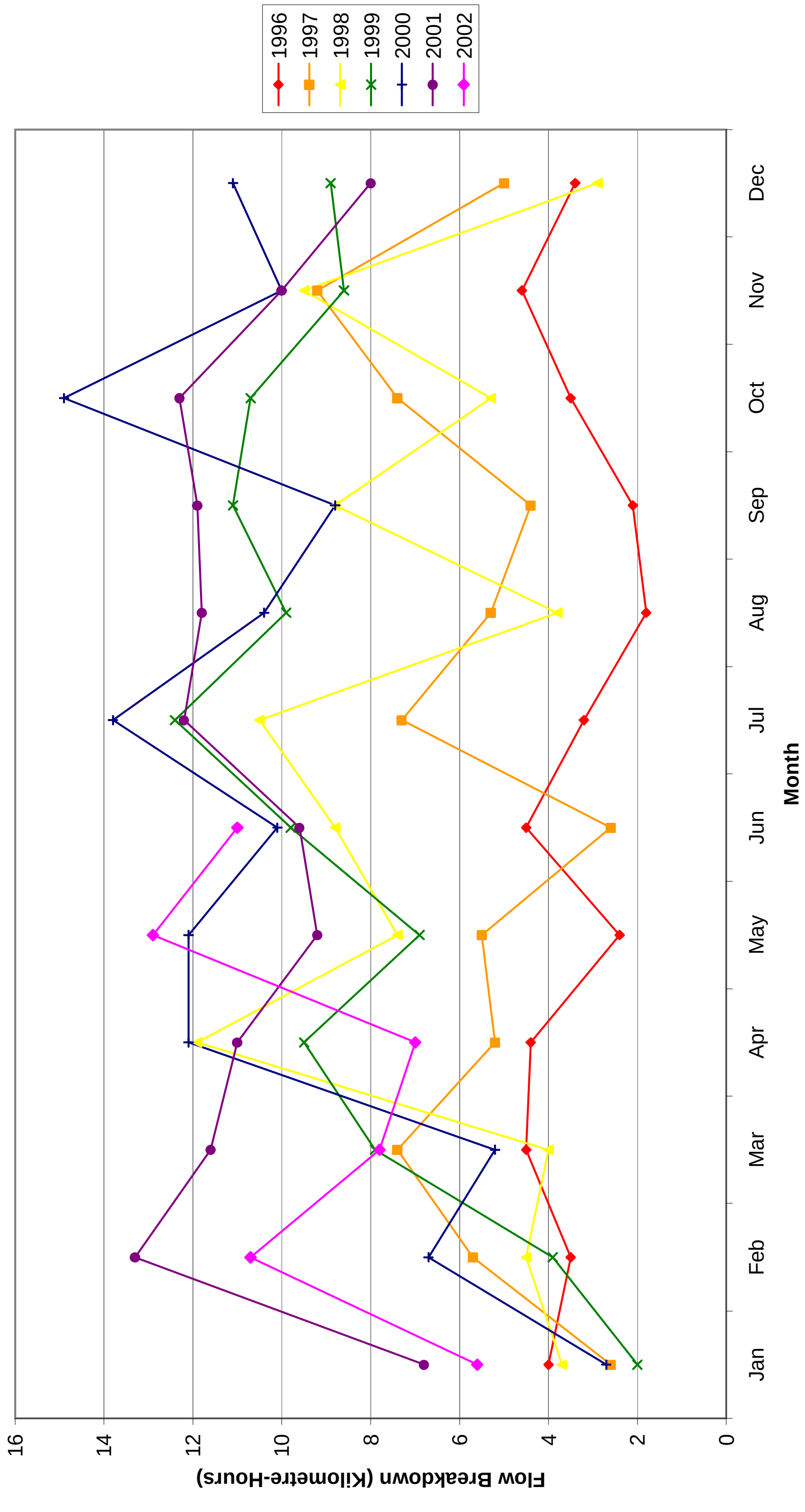


Figure 4.3.3 Flow breakdown for the B carriageway for J15-11 section (evening peak period)

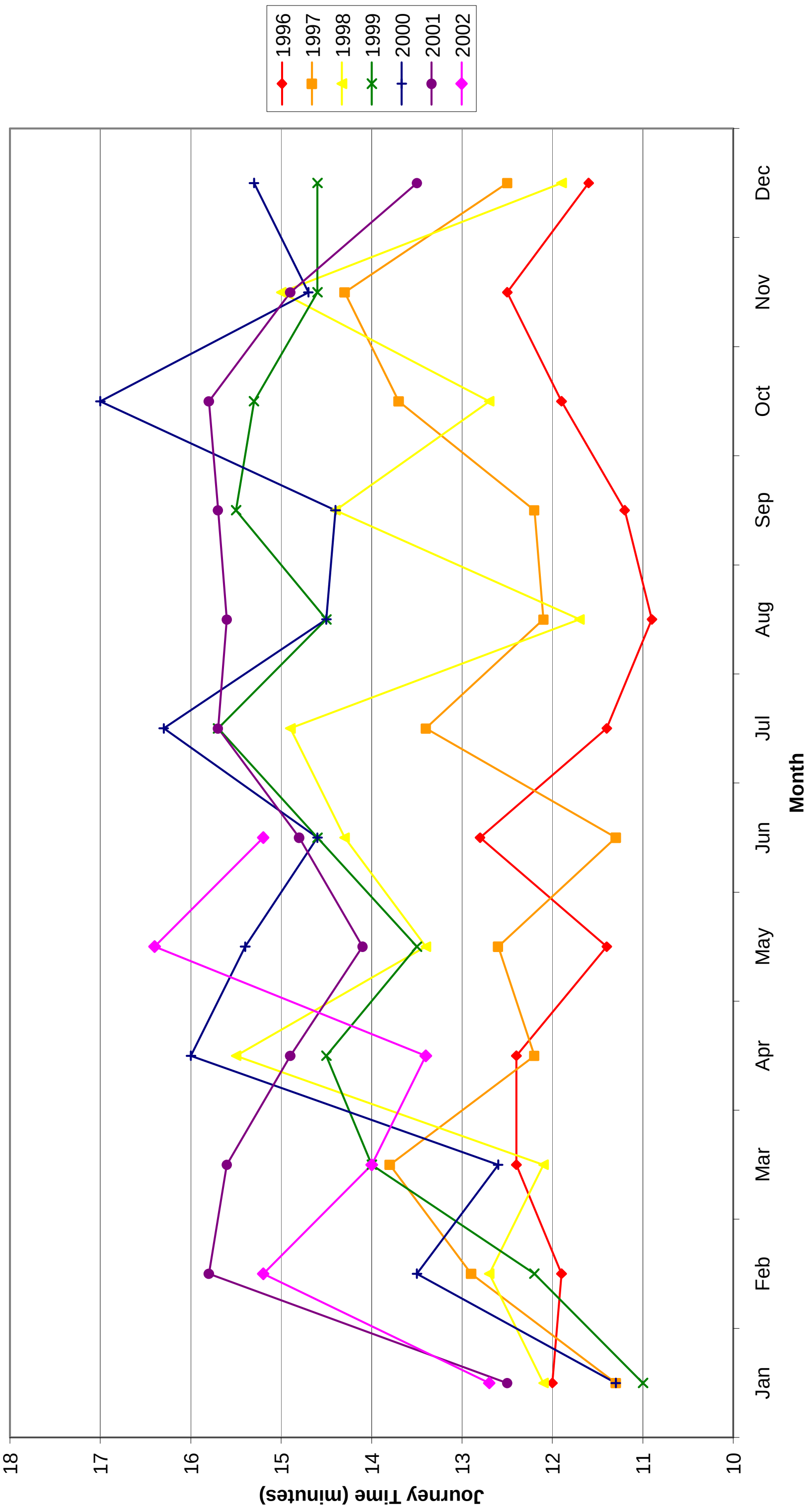


Figure 4.3.4 Journey times for the B carriageway for J15-11 section (evening peak period)

4.4 Lane Utilisation

The more balanced lane utilisation observed when the system became operational at the end of August 1995 has been maintained, with slightly less traffic using lane 4 and slightly more using lane 1. There was been little change in lane utilisation between August 1995 and December 1998 as shown by the lane utilisation between Junctions 13 and 14 for each carriageway in Figures 4.4.1 and 4.4.2.

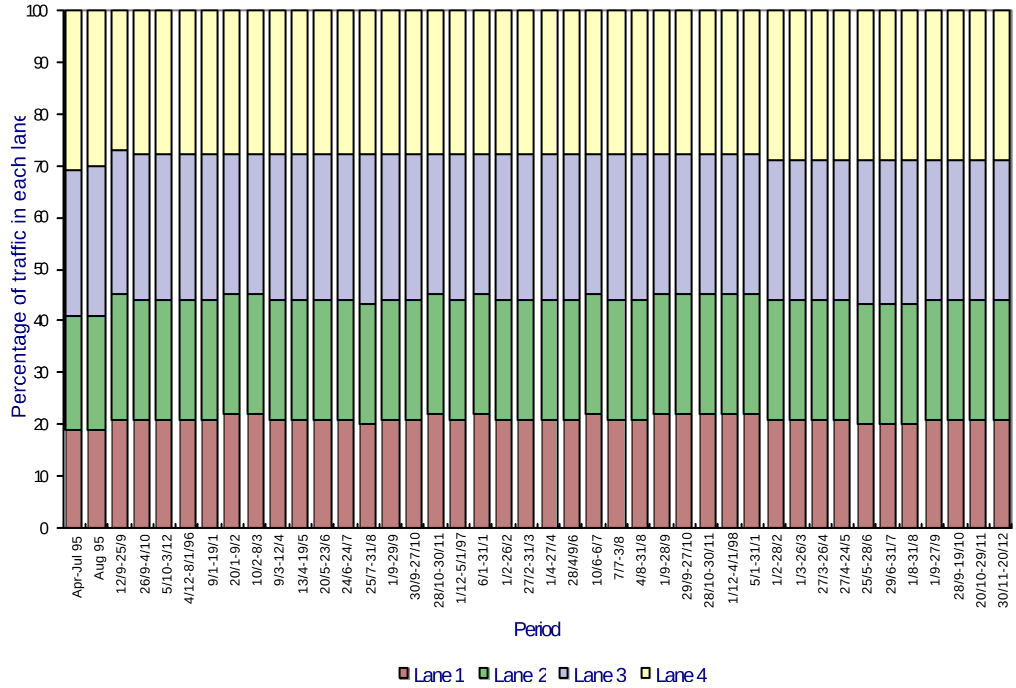


Figure 4.4.1 Lane Utilisation (J13-14 Clockwise)

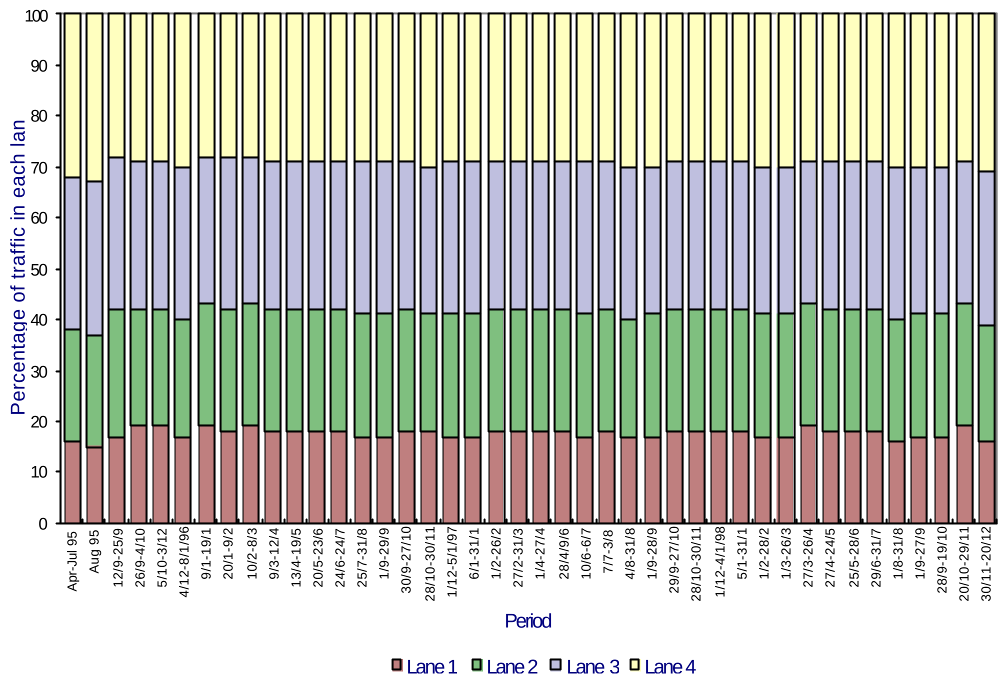


Figure 4.4.2 Lane Utilisation (J14-13 Anticlockwise)

Lane utilisation is highly site specific since drivers tend to position themselves for approaching junctions. Lane utilisation is also dependent on the amount of congestion. In free flowing conditions, more traffic uses lane 4 and lane 1 is used less. In highly congested conditions, lane usage is more evenly distributed.

4.5 Summary of Performance Indicators

During the monitoring period there have been three significant changes to the control system, namely the upgrading of the flow algorithm to a speed/flow algorithm (February 1997), the implementation of the automatic incident-detection system (October 1997), and the introduction of the EMS text displays (October 1998). The monitoring has indicated that none of these events had any significant effect on the PIs.

Clockwise carriageway

The demand has continued to rise, although at a slower rate (1.5% per year) since 1999, and is continuing to follow the same seasonal patterns. The peak 15-minute and peak 1-hour throughputs have reduced slightly (by 0.5-1% per year) and are still showing consistent seasonal trends. The performance (as measured by journey times and flow breakdown) has improved, after an initial deterioration until 1997 and stabilisation in the years that followed.

It is very encouraging that performance has improved despite the increased demand and despite a reduction in peak throughput. This appears to indicate that traffic flow is smoother, and could be explained by an improvement in driver behaviour: drivers ‘conditioned’ to the system could be driving more smoothly to prevent or reduce the effect of flow breakdown. However, in the absence of comparable data from similar locations on other motorways, this cannot be proven as being attributable to the Controlled Motorways system.

Anticlockwise carriageway

The demand is following the same seasonal trends, but has been decreasing slightly across the section since 1998. The peak 15-minute and peak 1-hour throughputs are also following seasonal patterns, and there has been little change from year to year.

The performance (as measured by journey times and flow breakdown) has been relatively stable from year to year since 1999, although there are large differences from one month to the next. Any long-term trends are harder to identify than on the clockwise carriageway due to the differing nature of the morning and evening peaks. The Performance Indicators on the clockwise carriageway are for the morning peak, when the time of the onset of flow breakdown is generally predictable. On the anticlockwise carriageway, the Performance Indicators are for the evening peak, when the time of the onset of flow breakdown can vary by several hours from day to day.

A seed point for flow breakdown between Junctions 12 and 11 has affected the performance of the anticlockwise carriageway since 1998. When flow breakdown occurs at that point, traffic queues back through the whole of the upstream section, causing significant delays.

5 Specific Studies

5.1 Driver Opinion Survey

In 1996, a driver opinion survey was undertaken to determine the impact of the Controlled Motorways system on drivers who were using it. Files containing 5,600 registration numbers of vehicles using the M25 were sent to the Driver and Vehicle Licensing Agency (DVLA), whose contractor then extracted the names and addresses of the registered keepers of the vehicles from their database. Full details of this survey can be found in the report to the HA on the first year of operation of the Controlled Motorways scheme (Taylor *et al*, 1997).

Ministerial approval was granted for the survey through the Survey Control Unit in February 1996. Assuming a 40% response rate, it was estimated that 4,000 questionnaires would need to be mailed to achieve the required 1,500 responses.

The questionnaires asked respondents whether they would be prepared to take part in a repeat survey, and if so, whether they would provide a contact telephone number for this purpose. Valid responses were received from 1,676 drivers, with 880 respondents providing contact details for a repeat survey. Those who declared that they had never driven along this section of the M25, or returned the questionnaire blank, were discarded.

Ninety-five percent of drivers reported that they had noticed the speed camera signs on their most recent trip along the section. Of those, three-quarters reported that the signs affected the speed at which they drove.

Of those people who reported that they drove at about the speed limit (65%), over half said that they did so to obey the speed limit signs. Almost half said they did so because they had no choice as the traffic was moving at this speed. Forty per cent said that the speed camera signs encouraged them to drive within the limits.

The respondents were asked to tick from a list those purposes that they perceived as being the intended purposes of the system. Table 5.1.1 shows the percentages of respondents who ticked each purpose.

Table 5.1.1 - Perceived Purposes of the System

Purpose	%
to reduce stop/start traffic	81
to improve safety/reduce accidents	71
to reduce congestion	56
to increase the capacity of the motorway	30
to reduce journey times	29
to reduce speeds	28
to reduce lane changing	23
to reduce air pollution	7
to reduce the noise level	3

Overall, 57% of respondents said that they thought that the variable speed limit system had resulted in an improvement. Only 10% said they thought it had resulted in a worsening. Those who had a high “ideal cruising speed”' favoured the system less than those who preferred to drive more slowly. Of those who preferred to drive at 70 mph or below, 65% thought the system had resulted in an improvement. This compares with 57% of those who liked to drive between 71 and 80 mph, and 49% of those who preferred to drive at over 80 mph.

Respondents were given a list of statements regarding the variable speed limit system and asked to indicate their level of agreement with each statement. Table 5.1.2 shows the percentages of respondents who agreed and disagreed with each statement. It is clear from Table 5.1.2 that drivers responded positively to most of the statements. However, almost half of the drivers responded that they neither agreed nor disagreed with the statement that the Controlled section is more pleasant to drive.

Table 5.1.2 - Driver Opinion of the System

Statement		% agree	% disagree
a	I think that the speed limits are usually appropriate to the conditions and level of traffic.	59	25
b	I am less pressured by other drivers to drive fast.	49	24
c	I find this section more pleasant to drive on.	21	32
d	I find it easier to maintain a constant speed, rather than continually stopping and starting.	68	17
e	I don't need to change lanes so frequently.	52	15
f	My journey time is reduced by the new system.	19	31
g	I think the system encourages drivers to 'undertake' (i.e. overtake on the left).	60	17
h	I find the speed limits frustrating.	25	47
i	I feel more relaxed and free of stress when I drive along this section.	23	34
j	I find this section very similar to other stretches of motorway.	18	53
k	I find the signs confusing.	5	80
l	I find it easier to change lanes.	15	30

**shading indicates the 'favourable' response to the statement.*

When asked whether they would like to see the system introduced on other motorways, 47% replied that they would on "particularly busy motorway sections". A further 16% said they would like the system introduced on *all* motorways and 5% said they would like it extended to the whole of the M25. 24% said that they would not like to see the system introduced on other motorway sections.

Overall the Controlled Motorways scheme has been well received by users of the Controlled section; with well over half reporting that it had resulted in an overall improvement and only one in ten reporting a worsening. Furthermore, over two-thirds of respondents reported that they would like to see the system extended in some way to other stretches of motorway.

The signs and system are well understood, compliance with speed limits is good, and the enforcement by the use of speed cameras effective.

While the results relating to general stress are ambiguous, drivers appear to be more positive about specific benefits of the system, and are especially positive about the system as a whole. This, together with anecdotal evidence, suggests that drivers have experienced an increase in "comfort" on the Controlled Section.

5.2 Accident Survey

An assessment of the possible effect of the signal pilot on accidents was required as part of the monitoring work. The assessment was carried out using two different techniques. A summary of the results is presented here, but full details are given in the reports to the HA on the assessments (Summersgill *et al*, 1998 and Baruya *et al*, 2000).

The overall aim of the study was to seek to determine any effect that the signal pilot (conducted between August 1995 and November 1997) might have had on injury accidents.

The study objectives may be summarised as follows:

- To analyse the Stats-19 injury accident records for the 5 year period before the system switch-on, and 2 years afterwards, using the DETR annual average daily total traffic flow statistics
- To include comparison data for the remainder of M25 in the analysis, and comment on the quality of accident statistics previously supplied by the Surrey and Metropolitan police forces.
- To consider the effect of roadworks, motorway widening (from 3 lanes to 4 lanes), and lighting, identifying the specific effect that the signal pilot may have had on the severity of the injury accidents.

For the first technique (Summersgill *et al*, 1998), a database was set up to hold the large quantity of required data (28 links, each with entries for all variables for each of the 30 quarters of the year include in the study period). A form of regression analysis known as Generalised Linear Modelling (GLM) was used in order to estimate the effect of all the variables tested (including the factor that represents the signal pilot). It also provides information about the standard errors of the estimates, the confidence intervals, and other useful statistical output.

The number of injury accidents on the pilot section was compared with those on a comparator section, making no allowance for any effect arising from differences in lighting, in roadworks, or in the number of lanes. This comparison showed a net reduction in injury accidents on the pilot section of around 12% during the period of signal operation, with best estimates of a 14% reduction and an 11% reduction obtained using two different models.

Variables representing lighting, roadworks, and the number of lanes were included in the analysis. Allowing for lighting alone had little effect on the best estimates, which were reductions of 14% and 12% respectively for the two models. Allowing for roadworks alone produced estimated reductions of 7% and 2%, and allowing for lanes alone produced an estimated reduction of 7% and an estimated increase of 2% respectively. When all three of these variables were included, the estimated net change in injury accidents on the pilot section was a reduction of 6% and an increase of 10% respectively for the two models. The results are summarised in Table 5.2.1 below.

Table 5.2.1 Summary of Results for Statistical Analysis

Allowance for the following		Net change in numbers of injury accidents on the pilot section: Best Estimate	95% Confidence Interval
None	(1)	–14 %	–33 to +9 %
	(2)	–11 %	–31 to +15 %
Lighting	(1)	–14 %	–32 to +10 %
	(2)	–12 %	–32 to +14 %
Roadworks	(1)	–7 %	–27 to +18 %
	(2)	–2 %	–24 to +26 %
Lanes	(1)	–7 %	–28 to +19 %
	(2)	+2 %	–22 to +32 %
All	(1)	–6 %	–26 to +21 %
	(2)	+10 %	–16 to +42 %

(1) = Model 1 (2) = Model 2

The confidence interval for each of the variables considered in the study is large, even when data for the entire day is considered. The confidence interval for the predicted ratio of the number of injury accidents on the pilot section during the pilot period, compared to the number before the pilot period is ± 25%. It is therefore possible to be confident only that the true ratio lies between about minus 25% and plus 25% of its estimated value, taking into account any changes on the comparator section.

In conclusion, the relatively small amount of data has meant a large uncertainty band surrounding the results using this technique. It is estimated that in order to reduce the uncertainty level to ±15%, a pilot-period of around five years on the existing length of motorway (or around two years on twice the length) would have been required. Since October 1997, conditions on the motorway have changed due to the introduction of the automatic incident-detection system, and any possible extension to the pilot period will need careful consideration.

Further work on the safety study was undertaken (Baruya *et al*, 2000) employing a slightly different technique.

A literature review was initially carried out to establish the best approach to the problem of observational ‘before-after’ studies of this nature. Some recent studies carried out both in the UK and abroad suggest that ‘naïve’ methods based on only one kind of evidence, such as the accident history, and untenable assumptions like the flow being constant, are flawed. Such methods may lead to misleading results and can underestimate or overestimate the pilot effect. Those methods can also produce results that are subject to RTM (regression-to-mean) bias, which can give rise to exaggeration of ‘adverse’ effects or underestimation of ‘favourable’ effects. Recent research suggests that the best approach to the problem is to use all kinds of evidence and to employ the so-called Empirical Bayes (EB) method. The EB method provides an unbiased estimate for the expected number of accidents, against which the ‘after’ accidents need to be judged. The EB method uses two kinds of evidence - accident history and predictions based on the ‘trait’ (e.g. flow, geometry, or traffic environment) of the entities - in the most efficient manner to produce the unbiased estimate.

For the trait-based predictions an accident predictive model is required. Such a prediction model needs to be based on an ‘appropriate’, and preferably independent, data set. An appropriate comparison set serves this purpose. In this study the whole of M25, excepting the links in the pilot section, has been used as the ‘comparison set’. Three models have been derived for three time periods – ‘24-hour’, ‘Peak’ and ‘Off-peak’. The ‘Peak’ period was defined as the weekday morning and evening peak periods combined with the Saturday and Sunday peak periods. The remaining time of the day was defined as ‘Off-peak’. (A parallel set of models was also derived from a slightly smaller database consisting of periods when no roadwork was involved. These ‘non-roadwork’ based models were slightly inferior in quality, even though they produced similar results.)

The derived models enabled us to estimate the effects of the various factors, (such as flow, link length, lighting, or roadworks), that can have significant effects on accidents during different periods of the day. The results suggest that accidents are roughly proportional to flow and link length. The presence of roadworks is associated with a 45% increase in accidents (31% during ‘Peak’, and 55% during ‘Off-peak’ periods). On a 4-lane section (D4M) accidents are 30% lower than on a 3-lane section. The corresponding reductions in ‘Peak’ and ‘Off-peak’ periods are 41% and 22%. The accidents are 21% higher on the lit sections than the unlit sections. The corresponding figures for the ‘Peak’ and ‘Off-peak’ periods are 33% and 14%. This is not to suggest any causality between lighting and accidents, but to say that the lit sections are probably more hazardous, hence they needed to be lit.

The EB method was employed to obtain unbiased estimate of the ‘target’ accidents. A comparison of the EB estimates with the model predictions indicates that the predictions underestimate the accidents by –6% to –12%.

It is estimated that there would have been 170 accidents (actual 176) on the pilot section during the pilot period, had there been no pilot, which suggests that there was a nominal increase in accidents by a factor of 1.03 (± 0.093). The 95% confidence interval is 0.85 to 1.21 - meaning that the effect is between 15% reduction and 21% increase. The ‘Peak’ accidents are expected to be 65.4 (actual 89), meaning that the observed number is 36% higher than expected. The ‘Off-peak’ accidents were expected to be 98.6, against the observed number of 87. This reduction of 12% is not statistically significant.

The results for the two Police forces patrolling the area were also critically examined. The section between J10 and J13 is patrolled by the Surrey police and that between J13 and J15 is patrolled by the Metropolitan police. A comparison of the actual number with the expected number of accidents shows that in the Surrey police district there was an increase of +20% (± 12.2%), whereas in the Metropolitan area there was a reduction of -40% (± 9.2%). During the ‘Peak’ and ‘Off-peak’ periods accidents were respectively +54% and +6% higher than expected in Surrey, whereas in the Metropolitan area the corresponding figures were –5% and –62%. The reason for the difference between the two results is not fully understood. It is possible that there is a different reporting policy in the two police districts.

The pilot effect was also examined over time, for each link and for each police district. The results suggest that that there was an overall increase of +0.69 (± 1.44) accidents per quarter in the pilot section during the pilot period. There was an increase of +3.08 (±1.36) accidents per quarter in Surrey area and a significant reduction of -2.39 (± 1.03) accidents per quarter in the Metropolitan area.

Given the results it remains inconclusive whether the pilot has a ‘neutral’ effect or a ‘favourable’ effect on accidents. According to the accident data the Surrey accidents were higher than expected during the pilot period and the Metropolitan accidents were significantly lower than expected. The positive and negative results for the two police districts tend to cancel out each other, making the overall result neutral.

The investigation has brought to light some important theoretical and practical issues. The methodological issues have been addressed. Practical issues, such as the effect of possible changes in reporting policy, if any, need to be addressed. Similar pilots on other motorways may help resolve some of the issues raised in this study.

Further work is being conducted on safety aspects of the M25 Controlled Motorways section as part of the Business Case for Controlled Motorways, based on the extension of the scheme between

Junctions 15 and 16. Initial results indicate that there was a combined benefit of 30% in reduction of injury accidents following the introduction of the HIOCC (queue protection) system and the Controlled Motorways system (congestion signal settings). Work is in progress to separate the estimated benefits of the two systems.

5.2.1 Summary

Several safety studies have been carried out during the life of the project. The studies have concentrated on injury accidents; as there are relatively few of these, data from several years is required before any conclusions can be drawn. Each study used all of the accident data that was available at that time, and allowed for external changes to the section, e.g. changes in flow levels. The studies provide different estimates of the effects on safety, as different amounts of data were available for each study. The more recent studies provide the more accurate estimates, as more data was available. The final study separates the estimated benefits of the queue protection system and the Controlled Motorways system.

The initial study on the effect that the Controlled Motorways scheme might have had on injury accidents compared accident statistics from five years before and two years after the introduction of the scheme. Regression analysis showed a net reduction in injury accidents on the Controlled section of around 12% during the period of signal operation.

Further research on the safety aspects was carried out using a second technique. The study period was for five years before and five years after the introduction of the scheme. Different accident rates were obtained for the two Police forces patrolling the area. (The section between J10 and J13 is patrolled by the Surrey Police and that between J13 and J15 is patrolled by the Metropolitan Police.) On average, there was a reduction in injury accidents of 10%.

Further work is being conducted on safety aspects of the M25 Controlled Motorways section as part of the Business Case for Controlled Motorways, based on the extension of the scheme between Junctions 15 and 16. Initial results indicate that there was a combined benefit of 30% in reduction of injury accidents following the introduction of the HIOCC (queue protection) system and the Controlled Motorways system (congestion signal settings). Work is in progress to separate the estimated benefits of the two systems.

5.3 Noise and Air Pollution

5.3.1 Noise Study

A number of roadside traffic-noise surveys were carried out on the Controlled Motorways section of the M25 both before and after implementation of the variable speed limits, to ascertain the changes in traffic noise. Further details regarding this study can be found in the report to the HA on the first year of operation of the Controlled Motorways scheme (Taylor *et al*, 1997).

The specific objectives of the study were to:

- Evaluate and compare noise levels, (normalised to traffic flows and the percentage of heavy vehicles), between the ‘Before’ and ‘After’ periods,
- Determine whether there has been any significant change and whether such a change is consistent with a change in traffic speeds.
- Examine whether the signals have had any specific effect on noise levels.

The noise index ($L_{A10,t}$) is the noise level in dB(A) which is exceeded for 10% of the measurement period t (Bond, 1996). The influence on traffic noise of changes in traffic conditions depends primarily on traffic flows, mean traffic speed and vehicle composition (Delany *et al*, 1976). The relationship established between traffic noise and mean speed is dependent upon vehicle composition, and therefore the traffic noise levels were normalised to isolate the relationship. Measurements were checked against theoretical estimates based on the DoT recommended method for predicting traffic noise (Department of Transport and Welsh Office, 1988).

Table 5.3.1 presents a comparison of changes in traffic noise levels at three locations during signal-on and signal-off periods. The three time periods specified are morning peak (0700-1000), daytime (1000-1600), and evening peak (1600-1900). The results show that traffic noise levels during the periods when the variable speed limits were displayed were generally lower than when the limits were off, although these differences were small on average, i.e. 0.3dB(A). This is probably because the differences in mean traffic-speed were also generally modest, at around 5.9kph less during the period when the variable speed limits were displayed.

Table 5.3.1 - Differences in the averaged normalised traffic noise levels between when variable speed limits were on and off (weekdays only)

Time period	Site 1 J14-J13 (4906B)		Site 2 J13-J14 (4897A)		Site 3 J13-J12 (4853B)	
	Difference in		Difference in		Difference in	
	Traffic noise Level L_{A10} dB(A)	Speed (kph)	Traffic noise level L_{A10} dB(A)	Speed (kph)	Traffic noise level L_{A10} dB(A)	Speed (kph)
07:00 to 10:00	-0.6 (+0.2)	2	-0.1 (-0.2)	-2	-0.9 (-0.8)	-10
10:00 to 16:00	-2.3 (-1.6)	-22	-0.6 (-0.6)	-8	+0.1 (0.0)	0
16:00 to 19:00	-0.2 (-1.1)	-12	+0.9 (-0.2)	-3	+1.4 (+0.2)	2

NOTES. dB(A) and speed differences are defined as (value when signals On - value when signals Off).
Upper dB(A) figures are measured differences.
Lower dB(A) figures (in brackets) are predictions of the CRTN model.

Large differences in the speed were measured at Site 1 between the signal-on and signal-off states during the middle of the day period (when variation in flow levels can be as high as 40%). For the whole of this period the speeds were reduced by around 22kph and the corresponding measurements for noise levels showed a *reduction* of 2.3dB(A) due to signal operation.

It can be concluded that the impact of signal operation in terms of noise disturbance to communities located alongside the motorway is not noticeable (a reduction of 3dB(A) is considered necessary for the change to be generally noticeable). It can also be concluded that the benefits arising from the operation of the variable speed limits are to be found at the shoulders of the peak and outside the peak periods.

5.3.2 Pollution Study

The insight provided by comprehensive monitoring has assisted in the interpretation of results from pollution studies undertaken for the HA under various contracts. Speed profiles derived from probe vehicles driving along the Controlled Motorways section during peak and off-peak periods were used to model emissions with respect to engine load.

Examination of the results in context led to the observation that the difference in speed profiles with and without speed-control is only significant:

- during the period of around 15 to 20 minutes at the beginning of each peak period before flow breaks down (this is commonly known as the shoulder of the peak).
- during periods of low flow the high level of enforcement (that is, speed control of the 70mph limit) has reduced the number of vehicle travelling significantly above the National Speed Limit.

There is also some evidence (see Section 3.3) to suggest that in congestion, the maximum speeds between shockwaves are slightly reduced and minimum speeds are slightly increased with speed control. This would suggest that the periods between successive shockwaves also benefit from speed control, but further research is required to consolidate this conclusion.

As with the results for the noise study, it is clear that the environmental benefits derived from speed control are to be found during the shoulders of the peak periods, and outside the peak periods. As for the noise study, the reduction in emission levels is not large enough to be considered significant.

5.4 Safety Requirements for HIOCC Queue Protection

The introduction of a 40mph speed limit to warn of dangerous downstream conditions carries a measure of risk when displayed to traffic not previously controlled by a speed limit below 70mph. This is due to the possibility of excessive braking under certain conditions, and an investigation was carried out to ascertain whether, and under what conditions, a safety issue might exist.

A simple model was designed, involving two consecutive vehicles approaching a gantry. It was assumed that the lead vehicle would see the new speed limit at the last possible moment and attempt to comply with that speed limit. The characteristics of the lead and following vehicles were varied, as was the distance between them. Test scenarios included a heavy goods vehicle following a car in wet conditions. Further details of this study (including assumptions) can be found in the annual report to the HA on continued monitoring of the M25 (Abou-Rahme *et al*, 1998).

The initial distance of the lead vehicle to the gantry was fixed to 50m, based on a 10-degree field of view and a gantry height of around 7 metres. The following vehicle would not commence braking until the brake lights on the lead vehicle come on. The mean value for reaction time was taken from the latest edition of the Highway Code. Testing with a low reaction time for the following vehicle covered the event of the lead vehicle's brake light failing to operate. Typical braking capabilities for the various vehicle types were used, and the range for the headway between the lead and following vehicles was as observed on the M25 (Taylor *et al*, 1997).

Most of the results from this investigation suggested that under favourable conditions and with good drivers involved, the sudden setting of a 40mph speed limit would not give cause for concern. However, there were a number of cases involving wet weather and a laden HGV following a car, where the sudden setting of a 40mph speed limit had the potential to create a situation which could lead to an accident. The models were re-run to consider the application of a 50mph first. For the worst possible scenario the minimum separation of the vehicles (after they had achieved their target speed) was equal to 0.45 seconds.

The initial implementation of the system therefore included the requirement to display 50mph for a minimum of 5 seconds, after which a 40mph setting could be displayed. This ensured that there was no longer a safety issue with regard to the display of a 40mph setting to traffic not previously controlled by a speed limit below 70mph.

5.5 Signals - Relationship Study

The general monitoring conducted by TRL has highlighted an apparent change in the pattern of signals set. It was observed that while the amount of congestion settings (50mph and 60mph signals) set during the day had increased over the years, there had been little effect on the duration of HIOCC settings (40mph signals) since the HIOCC system was switched on.

To produce a quantitative measure of the amount of signal activity per day, the length of time for which each MIDAS signal aspect was shown on each gantry on both carriageways between Junctions 10 and 15 of the M25 was summed for each day. This resulted in three values for each day: the duration of signal settings for each of 40mph, 50mph and 60mph.

Only signal settings appearing over lane 3 on the main carriageway were used for the calculation, to ensure that the results were not biased because of the differing number of lanes at different sites. Days with incidents and bad weather were excluded, as a study of ‘typical’ days makes trends easier to identify. Data between Junctions 15 and 16 were not included, as HIOCC has only become operational since March 2002 on this section. Figure 5.5.1 shows the results of the analysis.

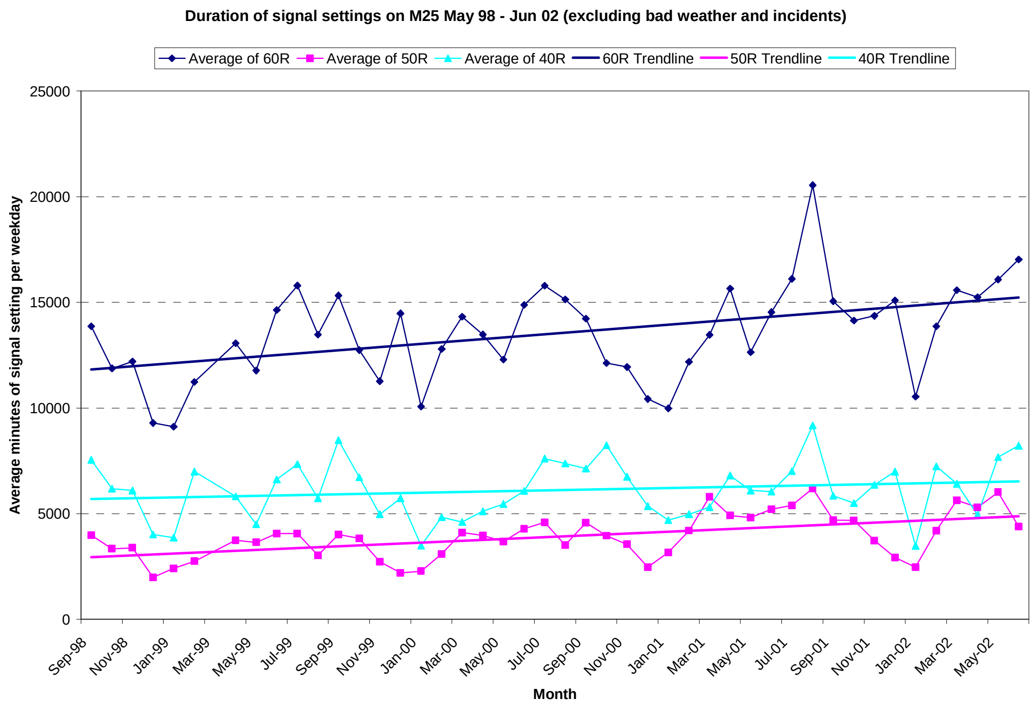


Figure 5.5.1 – Duration of signal settings on M25 J10-15

There appears to be a seasonal pattern in the daily duration of MIDAS signal settings, which has a greater effect than year-on-year trends. The amount of signal settings increases (along with the total throughputs) during the summer months, and is at its lowest during January of each year. To date, signals were set for the longest period of time during September 2001.

A yearly increase in the duration of all three signal aspects can be observed; this is most evident in the 60mph settings. The increase in 50mph and 60mph signal settings is due to increasing throughputs during the inter-peak period. The rate of increase in 40mph settings has not been so great, which means that flow breakdown has been increasing at a slower pace than throughput. However, no firm conclusions can be drawn from this, as increased throughputs during off-peak periods may be sufficient to trigger 60mph settings, but not sufficient to lead to flow breakdown.

To examine this effect in greater detail, signal settings over predefined 1-hour periods were analysed. The morning peak period was chosen for analysis, because one would expect any changes to be evident, as most of the signal activity occurs within the peaks, and the morning peak period is more consistent from day to day than the evening peak. However, during the time period for which demand is at its maximum and flow breakdown is inevitable, there are unlikely to be any changes since the demand is in excess of capacity. Therefore, the ‘shoulders’ of the peak were examined. These are the 1-hour periods between 06:30 and 07:30, 09:00 and 10:00.

Figures 5.5.2 and 5.5.3 both show that while the amount of 50mph and 60mph settings has increased, the duration of 40mph settings has reduced. As monitoring has shown that 40mph settings map flow breakdown patterns very well, this indicates that flow breakdown is decreasing during the morning peak period, despite an increase in throughput during the shoulders of the peak. This is consistent with the improvements observed for the performance indicators.

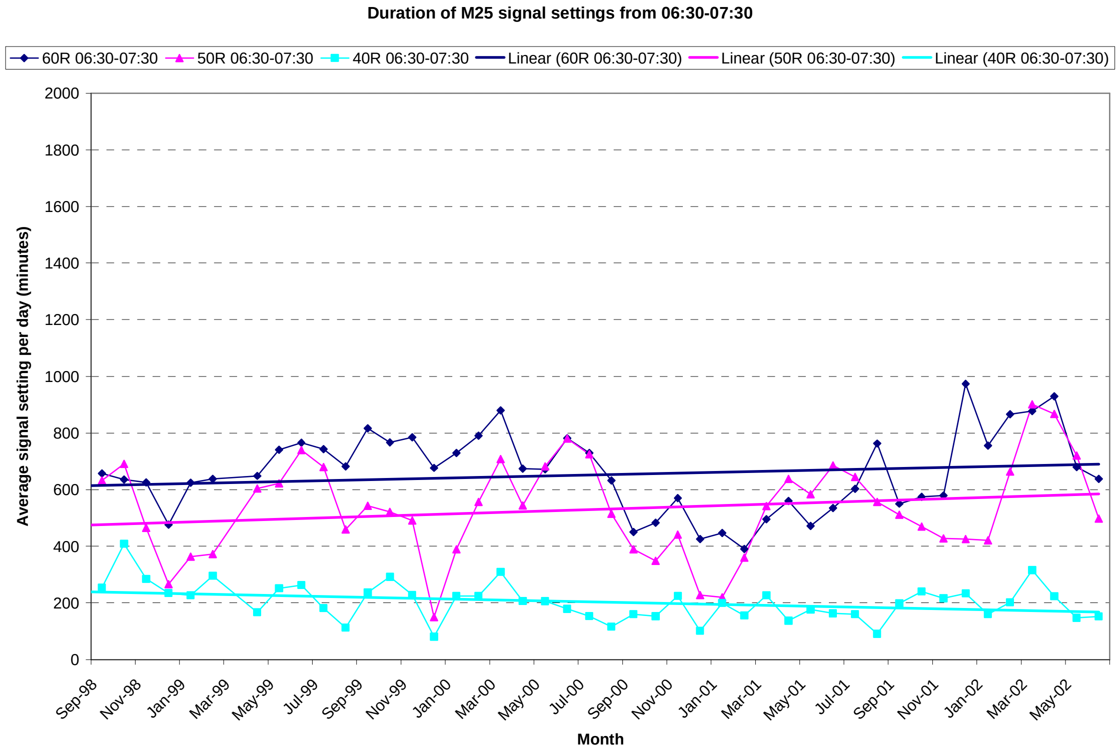


Figure 5.5.2 – Duration of signal settings between 06:30 and 07:30

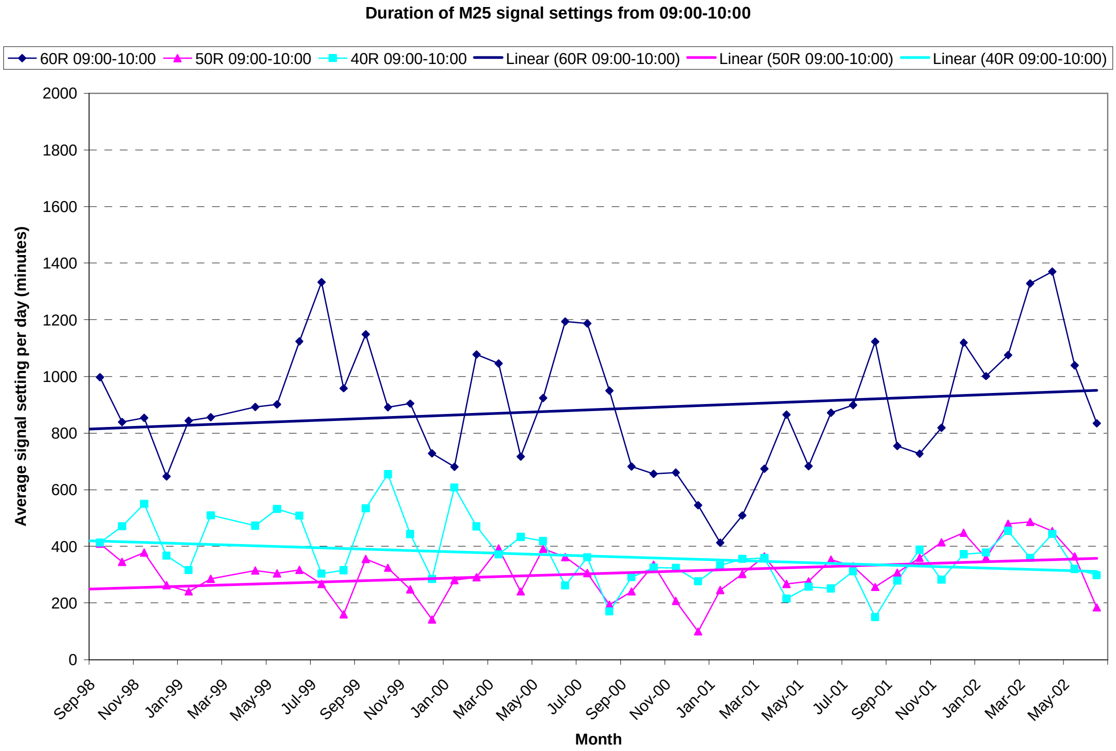


Figure 5.5.3 – Duration of signal settings between 09:00 and 10:00

In conclusion, this study has shown that the duration of 60mph and 50mph (congestion) settings are increasing from year to year at approximately the same rate, whilst the duration of 40mph (queue protection) settings is increasing less rapidly.

This effect is most pronounced in the shoulders of the periods of heaviest congestion, when fewer 40mph signals are being set despite an increase in throughput. Although the flows are increasing, there is less queueing. This suggests that one effect of control on the section, over an extended time period, is to reduce the risk of flow breakdown occurring.

PART III - CONCLUSIONS

6 Conclusions

6.1 System Operation

One of the HA objectives in installing the Controlled Motorways scheme was to prove the technology, i.e. to show that signals could be set using real-time traffic data. In addition, for the system to have an effect, it was necessary to show that drivers responded to the signals.

The monitoring has shown that the Controlled Motorways system is reliable and that it sets consistent and coherent sequences of speed limits that are appropriate to the traffic conditions, and that are generally obeyed by drivers.

The performance of the Controlled Motorways system depends on the availability of accurate MIDAS data. A faulty loop site can cause inappropriate signal settings to be displayed, and loop faults at three consecutive sites can result in HIOCC queue protection signal settings not being displayed at some signal gantries. It is therefore essential that the availability and the accuracy of the traffic data is checked at regular intervals and that any faults are repaired without delay.

6.2 Summary Of Monitoring Results

Core performance indicators have been calculated since the implementation of the Controlled Motorways system in 1995, and trends have been analysed. The core performance indicators (journey times, throughputs and lane utilisation) show how the traffic conditions have varied over the period. In addition, studies have been carried out into the underlying traffic behaviour. These provide the reasons behind the changes in traffic conditions. Also, driver opinions have been analysed and studies have been carried out into the effects of the system on accidents and the environment.

The performance indicators and most of the changes to traffic conditions have been analysed for the period since Controlled Motorways was implemented. This is due to a lack of good quality data prior to the introduction of Controlled Motorways, which meant it was not possible to carry out an impact assessment as part of a “before and after” study for the system. Some data on speed compliance and headways was collected prior to the introduction of Controlled Motorways; this has been used to analyse the effects of Controlled Motorways on these aspects of traffic behaviour.

Traffic Conditions on the M25

The development of the Motorway Traffic Viewer (MTV) has enabled all aspects of traffic conditions to be assessed. As well as the performance of the system, the performance of the motorway can be assessed. The effects of traffic management, traffic trends, demand hotspots, driver behaviour and MIDAS availability have been studied. MTV has enabled the identification of locations where congestion first occurs (called “seed points”), and the study of shockwaves of slow moving traffic propagating back from these seed points.

On the M25, there are several seed points on each carriageway. The seed points that cause the most congestion are:

- on the clockwise carriageway at Junction 14. Traffic that joins the motorway at Junction 14 conflicts with traffic preparing to leave at Junction 15.
- on the anticlockwise carriageway between Junctions 12 and 11. Traffic that joins the motorway at Junction 12 has to change lanes prior to the lane drop at Junction 11.

During peak periods, shockwaves propagate back from both of these seed points on a regular basis.

During the system tuning following the introduction of Controlled Motorways, the thresholds for the signal settings were raised in the vicinity of the seed points. It was found that locations of the seed points and the resulting shockwaves remained unchanged. This showed that the system itself was not causing the congestion.

The passage of a slow vehicle outside of the peak period (often accompanied by a police escort) can act as a moving seed point. The behaviour of drivers following at slow speed leads to the propagation of a number of shockwaves in the wake of the slow vehicle. The delays arising from the passage of a slow vehicle can be of the same magnitude as the delays arising during a peak period.

Whilst rubbernecking (drivers slowing to look at an event on the opposite carriageway) does not occur very frequently, when it does occur it can lead to almost double the amount of congestion for the same incident. Analysis has shown that the flow levels need to be sufficiently high before a disturbance due to a distraction on the opposite carriageway will actually lead to flow breakdown.

Effects on Traffic

Following the introduction of Controlled Motorways, it was established that speed limit compliance was good, lane utilisation and headway distribution had been improved and the driver response had been favourable. The lane utilisation became more balanced, thereby making better use of the available road space. There was a reduction in the occurrence of very short headways, which has led to smoother traffic flows.

Throughout the monitoring period a variety of traffic trends and behaviour have been identified. A comparison of data from year to year showed evidence of peak shifting, with the rise in traffic flow associated with the start of the morning peak period moving forward by a few minutes for the first two years of operation. Since 1998, the time at which the traffic flow increases has remained consistent.

The year-to-year trends in journey times show that journey times have been reducing on the clockwise carriageway during the mornings. This is the period when there is most congestion. It is believed that drivers have become accustomed to the Controlled Motorways system, and have learnt to drive more smoothly to prevent or reduce the effect of flow breakdown (see the section on Traffic Behaviour). The year-to-year trends in journey times also show that congestion during the evenings has risen slightly, due to the increased flows. During the evenings, the performance of the road is more susceptible to changes in flow levels than it is during the mornings, when the flow profile is more compressed.

Observations of the changes in shockwave characteristics have shown that whilst the general profile of the shockwaves has remained the same throughout the duration of the monitoring period, the number of shockwaves during the 3-hour morning peak period has reduced. In 1995, there were typically seven shockwaves during the morning peak; by 2002, the number of shockwaves during the morning peak had dropped to five. As there are fewer shockwaves, there will be fewer delays, as shown by the journey times.

Traffic Behaviour

Traffic conditions have been analysed to identify underlying trends and to determine the effect of the system on traffic behaviour. Performance indicators have been produced to measure demand flows, peak throughputs, journey times and flow breakdown on the Controlled section. There have been standard seasonal trends throughout the seven years of monitoring. This has enabled the underlying year-to-year trend to be identified.

During the 5-hour morning peak period, the total throughput has increased by 1.5% per year, and the peak 1-hour throughputs have reduced by 1% per year. Despite this, journey times and the amount of flow breakdown remained unchanged during 2001 and reduced during 2002. The signal activity provides confirmation of the observed trends. The traffic levels (as measured by the flow-based signal activity) have increased, and the amount of queueing (as measured by the HIOCC signal activity) has reduced.

Additional studies into traffic behaviour during 2000 and 2002 have provided some possible reasons for an improvement in performance, despite the increased total throughput and the reduction in peak throughput. These reasons include:

- Drivers are leaving shorter headways during 2002 than they were during 2000, at all speeds up to 50mph. The reduction in average headway implies a more efficient use of road space, and suggests that more vehicles will travel through the section in a given period than was previously the case. Although the proportion of vehicle headways below one second has marginally risen, this does not seem to have affected accidents, possibly because there are fewer very short headways (less than 0.8 seconds) and possibly because of the HIOCC queue protection. The shorter headways observed during 2002 are longer than they were before the system was introduced in 1995.
- There has been a reduction in the frequency of shockwaves. Typically, there were seven shockwaves during a morning peak period; now there are five. The characteristics of a typical shockwave are unchanged, i.e. the same number of vehicles are delayed for the same length of time. Since there are fewer shockwaves, fewer vehicles overall are affected by the shockwaves.
- There has been a reduction in compliance with the speed limits, possibly due to a reduction in levels of speed enforcement. If vehicles travel faster than they did before, then journey times reduce.

The factors described above can all have contributed to the change in performance. In general, it is believed that drivers are becoming accustomed to the system, and are learning to drive more smoothly which has had the effect of preventing or reducing the effect of flow breakdown. The drivers are likely to be using the information provided by the system to modify their behaviour. For example, if a 60mph or 50mph setting is displayed, then the drivers can be confident that there is no queueing traffic before the next gantry. The shorter headways may be a result of increasing driver confidence with the system. However, in the absence of comparable data from similar locations on other motorways, this cannot be proven.

The benefits from the smoother driving regime are being realised towards the end of the peak periods, when the demand flows are close to or lower than the capacity. It appears that there is no benefit during the period immediately before flow breakdown (when the peak throughput occurs). At this time, the demand flow is much greater than the capacity of the section (especially during the morning peak period). This suggests that it is not always necessary to increase the peak throughput or capacity of a section of road in order to improve its performance.

During the evening peak period, there has been little change in traffic behaviour over the last two years. The total evening throughputs have stabilised, and are now decreasing slightly. There are no noticeable long-term trends in performance. There are large differences in journey times and flow breakdown from day to day and month to month, primarily due to the variable effect of the seed point between Junctions 12 and 11.

Driver Opinion Survey

During the first year of operation, a driver opinion survey was carried out to determine the impact of the Controlled Motorways scheme on drivers who use it. Valid responses were received from over 1,600 drivers, with over 800 respondents providing contact details for a repeat survey. Ninety-five per cent of drivers reported that they had noticed the speed camera signs on their most recent trip along the section. Of these, three-quarters reported that the signs affected the speed at which they drove. (An analysis of speed profiles showed that the signs had little effect, with speeds only reducing when the speed cameras started to flash.) More than half the respondents said the system had resulted in an overall improvement, and over two-thirds said they would like to see the system extended in some way to other stretches of motorway. The Controlled Motorways scheme has therefore been well received by its primary users.

Safety Studies

Several safety studies have been carried out during the life of the project. The studies have concentrated on injury accidents; as there are relatively few of these, data from several years is required before any conclusions can be drawn. Each study used all of the accident data that was available at that time, and allowed for external changes to the section, e.g. changes in flow levels. The studies provide different estimates of the effects on safety, as different amounts of data were available for each study. The more recent studies provide the more accurate estimates, as more data was available. The latest study will separate the estimated benefits of the queue protection system and the Controlled Motorways system.

The initial study on the effect that the Controlled Motorways scheme might have had on injury accidents compared accident statistics from five years before and two years after the introduction of the scheme. Regression analysis showed a net reduction in injury accidents on the Controlled section of around 12% during the period of signal operation.

Further research on the safety aspects was carried out using a second technique. The study period was for five years before and five years after the introduction of the scheme. Different accident rates were obtained for the two Police forces patrolling the area. (The section between J10 and J13 is patrolled by the Surrey Police and that between J13 and J15 is patrolled by the Metropolitan Police.) On average, there was a reduction in injury accidents of 10%.

Further work is being conducted on safety aspects of the M25 Controlled Motorways section as part of the Business Case for Controlled Motorways, based on the extension of the scheme between Junctions 15 and 16. Initial results indicate that there was a combined benefit of 30% in reduction of injury accidents following the introduction of the HIOCC (queue protection) system and the Controlled Motorways system (congestion signal settings). Work is in progress to separate the estimated benefits of the two systems.

Environmental Studies

Benefits from the reduction in noise levels and air pollution are attributable to the effects of the enforcement of the speed limits, a key characteristic of the Controlled Motorways section. Both noise levels and air pollution levels have decreased as a result of the introduction of Controlled Motorways.

Research indicates that further benefits are likely to occur at the shoulders of the peak period or during periods when the signs are set and flow breakdown has not yet occurred.

HIOCC Queue Protection

The HIOCC system has performed well, detecting, tracking and protecting the back of queues during both peak and off-peak periods. The signal sequences provide adequate protection for shockwaves and for traffic queuing due to an incident downstream.

Comparison of speed profiles during similar periods in consecutive years suggests that the 40mph settings have restricted traffic speeds as drivers leave a shockwave. This can be interpreted as a reduction in the amount of braking and over-accelerating, and the perception of drivers passing through the section will be that of a smoother journey. In addition to this, the applied speed limits are more appropriate to the traffic conditions thus maintaining the credibility of the system.

Studies suggest that drivers are generally complying with the mandatory HIOCC speed limits as well as the original 60mph and 50mph settings. This supports the findings observed from the performance indicators, that improved driver behaviour in response to Controlled Motorways may be responsible for the improvements in terms of more uniform headways, smoother speeds and more predictable journey times. The Controlled Motorways environment has also helped increase compliance with the national speed limit, even when no signals are displayed.

The Controlled Motorways system has performed well and the performance has continued to improve with time, due to positive changes in driver behaviour, providing optimum conditions to reduce the potential for congestion to occur. The flow-based settings switch on and off at appropriate times to control the traffic, and the HIOCC signal settings track the backs of queues, providing protection from faster-moving upstream traffic. The text messages on Enhanced Message Signs (EMS) inform drivers of the reasons for the displayed speed limits. The introduction of the ‘Queue Ahead’ message warned drivers of conditions downstream and communicated that the system was not causing the queues.

Signal Study

A study has been carried out into the relationship between the different speed limit settings. It shows that the duration of 60mph and 50mph (congestion) settings are increasing from year to year at about the same rate, whilst the duration of 40mph (queue protection) settings is increasing less rapidly.

This effect is most pronounced in the shoulders of the periods of heaviest congestion, when fewer 40mph signals are being set despite an increase in throughput. Although the flows are increasing, there is less queueing. This suggests that one effect of control on the section, over an extended time period, is to reduce the risk of flow breakdown occurring.

Traffic Demand

The underlying traffic demand (i.e. the total throughput during a peak period) should be taken into account when considering any changes to the performance of the motorway. If the demand increases, then the congestion levels would also be expected to increase. If there has been an increase in demand during peak periods, but little or no increase in congestion, this can represent an improvement in performance.

The total throughput during the 5-hour morning and evening peak periods has continued to rise on both carriageways, with each year showing the same seasonal patterns. The total throughput during off-peak periods has also continued to rise.

Since September 1997, when the widening work between Junctions 8 and 10 of the M25 was completed, the demand at the southern end of the section (Junctions 10 to 12) has increased more rapidly than at the northern end, for both carriageways.

The total throughput on all sections is increasing, especially in the evening peak period, with the overall increase in demand being about 2.5% in 1995 and then slowing to about 1.5% per year by 2002.

6.3 Summary and Future Work

The Controlled Motorways system has provided a beneficial environment for drivers using the M25 between Junctions 10 and 16. The system sets consistent and coherent sequences of speed limits that are appropriate to the traffic conditions, and that are generally obeyed by drivers.

Although limited information is available about the direct effects of introducing the system, the Controlled Motorways section has absorbed an increase in throughput over 5-hour peak periods from year to year, without a detectable increase in congestion levels. Although journey times increased during the first few years of operation, there have been improvements in journey times and changes in headway distribution and shockwave behaviour in the last few years (since 2000). These improvements suggest that there may be long-term benefits from installing a Controlled Motorways system, with drivers using the information provided by the system to drive more smoothly to reduce the effects of flow breakdown. However, in the absence of comparable data from similar locations on other motorways, this cannot be proven as being attributable to the Controlled Motorways system.

Since the implementation of the HIOCC automatic incident detection system during October 1997, the system has detected, tracked and protected the back of queues during both peak and off-peak periods. The Enhanced Message Signs (EMS) serve to provide additional information to drivers regarding the reason for a particular signal display.

The performance of the incident-detection algorithm needs continued monitoring in order to ensure that the full benefits are being achieved. Regular monitoring will also allow the continued identification of locations along the Controlled section from which shockwaves appear to propagate. It will also ensure that the system remains operational and reliable, so that the full benefits of Controlled Motorways are achieved. In addition to this, the ability of the control system to adapt and respond to a variety of traffic patterns and trends can be highlighted through monitoring. This in turn will help identify specific areas where further research is required, particularly for traffic behaviour.

The scheme was extended to cover Junctions 15 to 16 of the M25 in March 2002 and the specific monitoring of this section will be used as a Business Case for further roll-out of MIDAS Controlled Motorways schemes across the English network. The results of this study will be published during 2004.

During 2004 and 2005, the section of the M25 between Junctions 12 and 15 will be widened, prior to the opening of Heathrow Terminal 5. The Controlled Motorways system will continue to operate during the period of the roadworks. The parameters will be modified to allow for changes to traffic conditions, and the section will continue to be monitored.

7 References

Abou-Rahme N, Rees T, Dixon C and Paulo D (1998). *Monitoring of the M25 Controlled Motorway (March 97 - March 98) Including the Implementation of HIOCC*, Unpublished Report PR/TT/083/98 (with permission), Transport Research Laboratory, Crowthorne, UK.

Baruya A, Fletcher J and Abou-Rahme N (2000). *M25 Controlled Motorways - A follow-up study on accidents.* Unpublished Report PR/SE/038/00 (with permission), Transport Research Laboratory, Crowthorne, UK

Bond M (1996). Plagued by Noise. *New Scientist*, 16 November 1996, 14-15

Delany M E, Harland D G, Hood R A and Scholes W E (1976).The Prediction of Noise Level L_{10} Due To Road Traffic, *Journal of Sound and Vibration*, **48**(**3**), 305-325

Department of Transport and Welsh Office (1988). *Calculation of Road Traffic Noise (CRTN)*, HMSO, London.

Department of Transport (1990). *M25 Action Plan – 1990 (Transport Planning Associates)*, HMSO, London.

Dixon C, T Rees, T Sutch, G Lunt and J Quick (2002). *Monitoring of the M25 Controlled Motorway 2000-2002.* Unpublished Report PR/T/077/02 (with permission), TRL Limited, Crowthorne, UK.

Eastman R and Harbord B (1997). *Controlled Motorways – The M25 Pilot Scheme*, ITS World Conference, Berlin 1997. Copies available from The Highways Agency, Temple Quay House, Bristol, UK.

Frith B (1996). *A Review of Congestion Indicators for Monitoring Network Performance*, Unpublished Report PR/TT/168/96 (with permission), Transport Research Laboratory, Crowthorne, UK.

Harbord B (1997). Success over 'stop-start' – results of the M25 Controlled Motorway pilot, *Traffic Technology International*, Oct/Nov 97, 57-60.

Harbord B (1998). M25 Controlled Motorway – Results of the First Two Years, Proc 9th Int. Conference on Road Transport Information and Control, Institution of Electrical Engineers, 21-23 April 1998, London, 149-154.

Hardman E J, Robin B E, Smith R and Williams B G (1995). *Controlled Motorways - Development of initial algorithm*, Unpublished Report PR/TT/010/95 (with permission), Transport Research Laboratory, Crowthorne, UK.

Quick J I and P Turner (2000). *The Fuel Crisis: The Effect on Sections of the Motorway Network*. Unpublished Report PR/T/173/2000 (with permission), TRL Limited, Crowthorne, UK.

Rees T, Abou-Rahme N, Taylor N and Still P (1996). *M25 Controlled Motorways Monitoring Stage 1 Report*, Unpublished Project Report PR/TT/053/96 (with permission), Transport Research Laboratory, Crowthorne, UK.

Rees T and Taylor N, (1997). *M25 Controlled Motorways Monitoring, Supplement to Final Report,* Unpublished Report PR/TT/094/97 (with permission), Transport Research Laboratory, Crowthorne, UK.

Summersgill I, Fletcher J and Broomfield S (1998). *M25 Accident Analysis - Final Report,* Unpublished Report PR/TT/062/98 (with permission), Transport Research Laboratory, Crowthorne, UK.

Taylor N, Rees T, Bryan Brown K, Abbott P, Abou-Rahme N, and Still P (1997). *M25 Controlled Motorways Monitoring - Final Report* Unpublished Report PR/TT/177/96 (with permission), Transport Research Laboratory, Crowthorne, UK.

TSS (2002). NMCS2 MIDAS Signal and Sign Setting Strategy, *Document MCH **1744** Issue E* (September 2002), Highways Agency.

TSS (2003). NMCS2 Changes to System Data Godstone/Heston, *Document MCH **1831** Issue C* (July 2003), Highways Agency.

All unpublished reports are on limited release and are obtainable only through prior permission of the Highways Agency and TRL Limited.

8 Acknowledgements

The authors would like to acknowledge the colleagues at the following organisations for their involvement and contributions to the monitoring work.

- The Highways Agency
- TRL Limited
- Information Processing Limited (IPL)

Peter Gray (DfT) has offered valuable advice and discussions regarding the peculiar problems associated with assessing traffic behaviour. Robert Stewart has provided advice and direction as the HA project sponsor. Peter Morris (HA) has provided much information and feedback regarding the operation of the system. Peter Still (TRL) is responsible for the original concept and development of Motorway Traffic Viewer. The TRL Monitoring Team (in particular, James Quick, Tom Sutch and George Lunt) has contributed much of the research material to this report. Rob Power and Neroli Blake (IPL) have offered technical support particularly with regard to data acquisition.

APPENDICES

APPENDIX A

PERFORMANCE INDICATORS

This Appendix contains tables of Performance Indicators (PIs) for the last two years of monitoring (July 2000 to June 2002), plus plots showing seasonal and year-to-year trends from 1995 to 2002.

Each PI is calculated for the A and B carriageway separately, and averaged by month. Each PI is calculated over a 5-hour peak period; the peak periods are 06:00-11:00 and 15:30-20:30. The PIs for the A carriageway are calculated for the morning peak, and the PIs for the B carriageway are calculated for the evening peak.

The PIs are:

- 5-Hour Throughput. This is a measure of the demand flow on a section. It is calculated for each junction-to-junction link and also within each junction.
- Peak 15-Minute Throughput. This is a measure of the capacity of a section. It is calculated for each junction-to-junction link and also within each junction. The monthly average is obtained by averaging the peak values for each day.
- Peak 1-Hour Throughput. This is a measure of the sustainable throughput of a section. It is calculated for each junction-to-junction link and also within each junction. The monthly average is obtained by averaging the peak values for each day.
- Journey Time. This is an estimate of the average journey time through a section over a 5-hour peak period. The variability (ie standard deviation) within each day is also calculated. The journey time and its variability are calculated for each junction-to-junction link, and for the whole length between Junctions 11 and 15.
- Flow Breakdown. This is a measure of how often the average traffic speed dropped below 25mph. The length of time for which the drop occurred is multiplied by the distance that was affected, to give a value in kilometre hours (kmh). The amount of flow breakdown is calculated for each junction-to-junction link, and for the whole length between Junctions 11 and 15.

Within each table, the PIs are coloured according to whether they increased from the previous month (red), decreased from the previous month (green) or remained unchanged (blue).

Figures A1 to A12 contain the plots showing seasonal and year-to-year trends from 1995 to 2002. The plots are:

- 5-Hour Throughput. There are plots for the throughputs at the southern end of each carriageway (Figures A1 and A2) and at the northern end of each carriageway (Figures A3 and A4).
- Peak 15-Minute & Peak 1-Hour Throughputs. There are plots for the throughputs at the most significant seed point on each carriageway. On the A carriageway, this is between Junctions 13 and 14 (Figures A5 and A7); on the B carriageway, this is between Junctions 12 and 11 (Figures A6 and A8).
- Journey Time. There are plots for the journey times between Junctions 11 and 15 on the A carriageway (Figure A9) and on the B carriageway (Figure A10).
- Flow Breakdown. There are plots for the amount of flow breakdown between Junctions 11 and 15 on the A carriageway (Figure A11) and on the B carriageway (Figure A12).

AVERAGE WEEKDAY THROUGHPUT

(AM PEAK ON 'A' CARRIAGEWAY & PM PEAK ON 'B' CARRIAGEWAY)

The following throughput figures are totalled across all lanes and are split according to the dates of changes in the MIDAS configuration data; where the MIDAS configuration is stable, the figures have been split into months. Friday evenings, bank holidays and days with bad weather or accidents have been excluded.

This document shows the throughputs since the start of July 2000. If the maximum value of a Throughput PI for a link has occurred since the start of 1998, it has been highlighted by asterisks.

Total throughput (5 hours) on 'A' carriageway

	J10-11	J11	J11-12	J12	J12-13	J13	J13-14	J14	J14-15	J15	J15-16	Comments
4/1/1999-31/1	*26200*	*22600*	*29700*	*20200*	*31700*	*26800*	*33800*	*26500*	*29600*	-	-	*No change*
1/2-28/2	*26300*	*22500*	*29900*	*20400*	*32000*	*27300*	*34200*	*27000*	*30200*	-	-	*No change*
1/3-1/4	*27900*	*24000*	*31500*	*21700*	*33700*	*28800*	*35800***	*28200***	*31500***	-	-	*No change*
2/4-30/4	*28100*	*24100*	*31400*	*21700*	*33100*	*28500*	*35500*	*27900*	*31200*	-	-	*No change*
1/5-31/5	*28000*	*24000*	*31400*	*21400*	*33400*	*28400*	*35500*	*27800*	*31000*	-	-	*No change*
1/6-2/7	*28300*	*24300*	*31400*	*21500*	*33300*	*28500*	*35200*	*27500*	*30800*	-	-	*No change*
3/7-28/7	*28500*	*24700*	*31700*	*21700*	*33400*	*28600*	*35300*	*27800*	*30900*	-	-	*No change*
29/7-30/8	*27700*	*24100*	*30700*	*20900*	*31900*	*27600*	*34000*	*26800*	*30100*	-	-	*EMS messages enable*
31/8-1/10	*27500*	*23300*	*30400*	*20700*	*32200*	*27700*	*34900*	*27000*	*30400*	-	-	*No change*
2/10-31/10	*27700*	*23500*	*31100*	*20900*	*32600*	*27600*	*34500*	*26700*	*29800*	-	-	*No change*
1/11-28/11	*27900*	*23900*	*31700*	*21200*	*32700*	*27900*	*34700*	*27200*	*30300*	-	-	*No change*
29/11-31/12	*26800*	*23300*	*30400*	*20400*	*31400*	*26800*	*33200*	*26000*	*29100*	-	-	*No change*
1/1/2000-30/1	*26400*	*22700*	*29900*	*20100*	*31300*	*26500*	*32800*	*25800*	*28800*	-	-	*No change*
31/1-27/2	*27900*	*23900*	*31400*	*21200*	*32900*	*27800*	*34100*	*27300*	*30500*	-	-	*No change*
28/2-31/3	*28300*	*24200*	*31700*	*21500*	*33300*	*28400*	*35000*	*27800*	*31000*	-	-	*No change*
1/4-30/4	*28400*	*24300*	*31300*	*21600*	*33100*	*28500*	*35400*	*27600*	*30900*	-	-	*No change*
1/5-2/6	*28800*	*24500*	*31900*	*21700*	*33700*	*28800*	*35300*	*27900*	*31200*	-	-	*No change*
3/6-30/6	*28900*	*24700*	*32100*	*21800*	*33200*	*28300*	*34900*	*27600*	*30800*	-	-	*No change*
1/7/2000-30/7	29100	24900	32100	22000	33400	28600	35300	27900	31200	18900	28200	J15-16 included
31/7-31/8	28900	24900	31500	21400	32800	28200	34200	27100	30300	18400	27500	No change
1/9-30/9	29000	24600	31800	21700	33500	28600	35200	27700	31000	18800	27800	No change
1/10-31/10	28300	24000	31300	21400	33300	28300	35000	27500	30700	18600	27200	No change
1/11-30/11	27700	23500	31000	21000	32300	27200	34000	26300	29500	17800	26100	No change
1/12-31/12	27100	23000	30700	20600	31900	26800	33100	25500	28800	17600	25800	No change

	J10-11	J11	J11-12	J12	J12-13	J13	J13-14	J14	J14-15	J15	J15-16	Comments
1/1/2001-31/1	26800	22600	30000	20500	31500	26500	33000	25600	28700	17100	25400	No change
1/2-28/2	27700	23500	30800	21000	32600	27400	33800	26400	29600	17800	26200	Roadworks J16-17
1/3-31/3	28400	24100	31700	21500	33300	28100	34700	27000	30200	18100	26500	No change
1/4-30/4	29100	24800	32000	21700	33600	28300	34800	27300	30500	18400	27600	No change
1/5-31/5	**29600**	**25100**	**32600**	**22100**	**34200**	**29200**	**35600**	**27800**	**31000**	**18700**	**27600**	**No change**
1/6-30/6	**29700**	**25400**	**32700**	**22100**	**34100**	**29100**	**35400**	**27800**	**31000**	**18600**	**27500**	**No change**
1/7-31/7	29500	25200	32300	21900	33800	28800	32000	27500	30600	18600	27600	No change
1/8-31/8	29600	25600	32100	21500	33000	28500	34300	27300	30200	18300	27200	No change
1/9-30/9	28700	24600	31600	21300	33000	28200	34500	27100	30100	18500	27200	No change
1/10-31/10	28600	24400	31400	21300	33000	28200	34600	27400	30500	18800	27600	No change
1/11-30/11	28500	24200	30700	20700	32300	27300	33800	26900	30300	18500	27200	No change
1/12-31/12	28500	24100	30000	20000	32400	26400	33000	25400	28600	17700	26200	No change
1/1/2002-31/1	26900	23200	29900	20300	31800	27100	33300	26100	29000	17900	26300	No change
1/2-28/2	29100	25000	32200	21800	33700	28500	35000	27400	30600	19000	27700	No change
1/3-31/3	29400	25100	32500	22200**	34200**	29300**	35700	28000	31300	19600**	28500**	No change
1/4-30/4	28900	24600	31700	21600	33600	28600	35100	27600	30900	19500	28400	No change
1/5-31/5	29800**	25500**	32820**	22100	34200**	29200	35600	28000	31300	19500	28100	No change
1/6-30/6	29100	25000	32000	21600	33100	28400	34600	27300	30400	19100	28200	No change

Peak 15-minute throughput on 'A' carriageway (veh/hr)

	J10-11	J11	J11-12	J12	J12-13	J13	J13-14	J14	J14-15	J15	J15-16	Comments
4/1/1999-31/1	*7470*	*6440*	*7840*	*5450*	*7860*	*6710*	*8200*	*6330*	*6990*	-	-	*No change*
1/2-28/2	*7540*	*6400*	*7860*	*5460*	*7830*	*6760*	*8190*	*6430*	*7140*	-	-	*No change*
1/3-1/4	*7900*	*6670*	*8110*	*5750*	*8220*	*7140*	*8700*	*6720*	*7420*	-	-	*No change*
2/4-30/4	*7970*	*6650*	*8140*	*5780*	*8220*	*7190*	*8710*	*6650*	*7380*	-	-	*No change*
1/5-31/5	*8030*	*6800*	*8320***	*5910***	*8380***	*7290***	*8730***	*6730*	*7420*	-	-	*No change*
1/6-2/7	*7920*	*6740*	*8160*	*5770*	*8330*	*7190*	*8630*	*6580*	*7300*	-	-	*No change*
3/7-28/7	*7990*	*6740*	*8130*	*5750*	*8310*	*7160*	*8640*	*6740*	*7440*	-	-	*No change*
29/7-30/8	*7560*	*6540*	*7820*	*5480*	*7990*	*6950*	*8530*	*6570*	*7290*	-	-	*No change*
31/8-1/10	*7770*	*6560*	*8010*	*5580*	*8040*	*6990*	*8540*	*6500*	*7220*	-	-	*No change*
2/10-31/10	*7560*	*6490*	*7920*	*5480*	*7870*	*6840*	*8370*	*6250*	*6960*	-	-	*No change*
1/11-28/11	*7600*	*6470*	*7930*	*5480*	*7900*	*6810*	*8390*	*6430*	*7130*	-	-	*No change*
29/11-31/12	*7050*	*6140*	*7490*	*5160*	*7440*	*6440*	*7900*	*6150*	*6840*	-	-	*No change*
1/1/2000-30/1	*7320*	*6360*	*7750*	*5320*	*7660*	*6570*	*7990*	*6160*	*6840*	-	-	*No change*
31/1-27/2	*7700*	*6510*	*7950*	*5500*	*7940*	*6800*	*8250*	*6520*	*7290*	-	-	*No change*
28/2-31/3	*7950*	*6790*	*8140*	*5670*	*8220*	*7030*	*8480*	*6640*	*7350*	-	-	*No change*
1/4-30/4	*7850*	*6630*	*8090*	*5620*	*8110*	*7060*	*8640*	*6590*	*7390*	-	-	*No change*
1/5-2/6	*7870*	*6830*	*8180*	*5730*	*8270*	*7190*	*8640*	*6660*	*7370*	-	-	*No change*
3/6-30/6	*7980*	*6850***	*8190*	*5700*	*8170*	*7160*	*8630*	*6670*	*7350*	-	-	*No change*
1/7/2000-30/7	7880	6710	8090	5650	8210	7130	8590	6710	7360	4760	7020	J15-16 included
31/7-31/8	7720	6640	8020	5550	8130	7020	8480	6590	7310	4650	6810	No change
1/9-30/9	7870	6690	8040	5630	8140	7000	8480	6560	7300	4750	6950	No change
1/10-31/10	7650	6550	7910	5530	7950	6850	8330	6470	7170	4660	6870	No change
1/11-30/11	7570	6420	7840	5490	7890	6800	8330	6420	7110	4620	6670	No change
1/12-31/12	7350	6280	7590	5290	7610	6570	8030	6180	6860	4490	6610	No change

	J10-11	J11	J11-12	J12	J12-13	J13	J13-14	J14	J14-15	J15	J15-16	Comments
1/1/2001-31/1	7330	6350	7670	5400	7610	6520	7880	6110	6770	4310	6330	No change
1/2-28/2	7610	6400	7820	5450	7870	6740	8210	6310	7040	4530	6590	Roadworks J16-17
1/3-31/3	7770	6500	7910	5550	8060	6900	8380	6420	7150	4560	6710	No change
1/4-30/4	7990	6740	8150	5710	8300	7120	8610	6560	7300	4660	6880	No change
1/5-31/5	**7920**	**6700**	**8100**	**5650**	**8340**	**7230**	**8670**	**6680**	**7360**	**4660**	**6800**	**No change**
1/6-30/6	**7920**	**6800**	**8250**	**5690**	**8360**	**7240**	**8630**	**6620**	**7350**	**4700**	**6810**	**No change**
1/7-31/7	7920	6740	8000	5550	8170	7110	8480	6580	7290	4710	6860	No change
1/8-31/8	7540	6480	7790	5320	8130	6930	8430	6570	7220	4570	6670	No change
1/9-30/9	7720	6520	7900	5460	8040	6890	8420	6490	7180	4650	6780	No change
1/10-31/10	7700	6560	7840	5440	7930	6840	8300	6470	7200	4700	6880	No change
1/11-30/11	7610	6520	7750	5340	7830	6770	8160	6380	7120	4730	6780	No change
1/12-31/12	7610	6490	7300	5040	7540	6270	7660	5930	6580	4330	6420	No change
1/1/2002-31/1	7290	6220	7630	5170	7660	6510	8020	6160	6850	4450	6600	No change
1/2-28/2	7750	6570	7900	5450	8100	6870	8400	6530	7250	4730	6860	No change
1/3-31/3	7930	6760	8090	5620	8310	7120	8650	6660	7410	4890	7110**	No change
1/4-30/4	7990	6790	8180	5640	8240	7100	8580	6670	7390	4860	7000	No change
1/5-31/5	8030	6760	8190	5660	8320	7230	8620	6810**	7500**	4930**	7100	No change
1/6-30/6	7780	6650	8040	5520	8150	7070	8500	6590	7280	4750	6900	No change

Peak hourly throughput on 'A' carriageway (veh/hr)

	J10-11	J11	J11-12	J12	J12-13	J13	J13-14	J14	J14-15	J15	J15-16	Comments
4/1/1999-31/1	*6730*	*5760*	*7310*	*4990*	*7370*	*6280*	*7790*	*6030*	*6710*	-	-	*No change*
1/2-28/2	*6720*	*5650*	*7230*	*4960*	*7440*	*6340*	*7910*	*6160*	*6910*	-	-	*No change*
1/3-1/4	*6990*	*5890*	*7580*	*5260*	*7740*	*6690*	*8350*	*6410*	*7160*	-	-	*No change*
2/4-30/4	*7080*	*6010*	*7660*	*5340*	*7740*	*6690*	*8260*	*6300*	*7040*	-	-	*No change*
1/5-31/5	*7080*	*6030*	*7630*	*5320*	*7850*	*6750*	*8360*	*6420*	*7160*	-	-	*No change*
1/6-2/7	*7060*	*6010*	*7580*	*5230*	*7790*	*6740*	*8300*	*6300*	*7010*	-	-	*No change*
3/7-28/7	*7010*	*6020*	*7520*	*5210*	*7810*	*6730*	*8290*	*6380*	*7090*	-	-	*No change*
29/7/-30/8	*6800*	*5900*	*7370*	*5020*	*7500*	*6500*	*8060*	*6190*	*6940*	-	-	*EMS messages enable*
31/8-1/10	*6920*	*5860*	*7370*	*5060*	*7510*	*6500*	*8150*	*6170*	*6910*	-	-	*No change*
2/10-31/10	*6840*	*5770*	*7340*	*5010*	*7450*	*6400*	*8030*	*6000*	*6700*	-	-	*No change*
1/11-28/11	*6880*	*5750*	*7490*	*5050*	*7550*	*6500*	*8120*	*6130*	*6850*	-	-	*No change*
29/11-31/12	*6510*	*5580*	*7160*	*4830*	*7080*	*6080*	*7550*	*5840*	*6530*	-	-	*No change*
1/1/2000-30/1	*6680*	*5690*	*7310*	*4920*	*7290*	*6210*	*7720*	*5940*	*6610*	-	-	*No change*
31/1-27/2	*6970*	*5850*	*7530*	*5120*	*7540*	*6420*	*7950*	*6250*	*7010*	-	-	*No change*
28/2-31/3	*7060*	*5940*	*7590*	*5180*	*7720*	*6600*	*8130*	*6340*	*7090*	-	-	*No change*
1/4-30/4	*6980*	*5950*	*7600*	*5200*	*7660*	*6680*	*8320*	*6320*	*7090*	-	-	*No change*
1/5-2/6	*7110*	*6090*	*7660*	*5270*	*7810*	*6750*	*8320*	*6380*	*7120*	-	-	*No change*
3/6-30/6	*7120*	*6070*	*7680*	*5260*	*7710*	*6670*	*8200*	*6310*	*7000*	-	-	*No change*
1/7/2000-30/7	7130	6040	7640	5210	7700	6670	8230	6350	7070	4500	6700	J15-16 included
31/7-31/8	7040	6070	7610	5150	7610	6580	8040	6240	6970	4640	6440	No change
1/9-30/9	7030	5930	7540	5170	7650	6540	8140	6300	7070	4490	6640	No change
1/10-31/10	6820	5810	7310	5030	7520	6440	7960	6120	6860	4360	6520	No change
1/11-30/11	6780	5670	7330	5050	7440	6360	7980	6080	6820	4350	6290	No change
1/12-31/12	6580	5630	7160	4890	7250	6210	7680	5880	6570	4170	6110	No change

	J10-11	J11	J11-12	J12	J12-13	J13	J13-14	J14	J14-15	J15	J15-16	Comments
1/1/2001-31/1	6560	5560	7080	4890	7200	6070	7560	5800	6480	4050	6010	No change
1/2-28/2	6780	5760	7330	5070	7520	6400	7900	6040	6760	4240	6190	Roadworks J16-17
1/3-31/3	6870	5720	7420	5110	7630	6520	8100	6130	6850	4320	6310	No change
1/4-30/4	7110	6050	7690	5280	7870	6780	8320	6300	7040	4400	6520	No change
1/5-31/5	**7130**	**6000**	**7670**	**5240**	**7900****	**6800**	**8320**	**6390**	**7080**	**4450**	**6470**	**No change**
1/6-30/6	**7180**	**6110**	**7760****	**5280****	**7890**	**6820****	**8300**	**6310**	**7050**	**4420**	**6450**	**No change**
1/7-31/7	7080	6040	7590	5180	7750	6720	8160	6290	6980	4450	6510	No change
1/8-31/8	6960	6020	7480	5030	7700	6580	8120	6300	6950	4330	6390	No change
1/9-30/9	6960	5890	7450	5070	7670	6530	8100	6200	6900	4380	6430	No change
1/10-31/10	6920	5870	7400	5050	7560	6500	8010	6200	6930	4450	6570	No change
1/11-30/11	6920	5850	7240	4920	7440	6360	7840	6070	6780	4360	6370	No change
1/12-31/12	6960	5840	7000	4720	7280	5950	7430	5630	6330	4090	6060	No change
1/1/2002-31/1	6720	5720	7230	4850	7350	6200	7740	5930	6600	4200	6270	No change
1/2-28/2	7030	5960	7550	5090	7710	6510	8070	6220	6980	4460	6510	No change
1/3-31/3	7150	6050	7610	5180	7860	6730	8310	6370	7120	4630	6770	No change
1/4-30/4	7140	6090	7610	5210	7830	6690	8240	6340	7080	4590	6670	No change
1/5-31/5	7230**	6120**	7710	5250	7840	6810	8340**	6480**	7200**	4660**	6760**	No change
1/6-30/6	7020	6010	7540	5130	7670	6620	8060	6210	6920	4480	6620	No change

Total throughput (5 hours) on 'B' carriageway

	J16-15	J15	J15-14	J14	J14-13	J13	J13-12	J12	J12-11	J11	J11-10	Comments
4/1-31/1	-	-	*27100*	*24100*	*30800*	*26100*	*30400*	*20300*	*29700*	*24000*	*27300*	*No change*
1/2-28/2	-	-	*28700*	*25300*	*32300*	*27500*	*32100*	*21400*	*31200*	*25400*	*28800*	*No change*
1/3-1/4	-	-	*29000*	*25200*	*32700*	*27400*	*32100*	*21500*	*31600*	*25700*	*29300*	*No change*
2/4-30/4	-	-	*28600*	*24900*	*32400*	*27300*	*32300*	*21600*	*31700*	*26000*	*29700*	*No change*
1/5-31/5	-	-	*28900*	*25100*	*32700*	*27700***	*32600***	*21800*	*31900*	*26100*	*29800*	*No change*
1/6-1/7	-	-	*29000*	*25200*	*32700*	*27300*	*32600***	*21900***	*32300***	*26600***	*30500*	*No change*
3/7-28/7	-	-	*28400*	*24600*	*32000*	*27300*	*32100*	*21700*	*32200*	*26500*	*30300*	*No change*
29/7-30/8	-	-	*28300*	*24500*	*31500*	*27200*	*31900*	*21500*	*31700*	*26100*	*29700*	*EMS messages enable*
31/8-1/10	-	-	*28100*	*24200*	*31900*	*26900*	*31900*	*21600*	*31800*	*26300*	*30100*	*No change*
2/10-31/10	-	-	*27700*	*23700*	*31400*	*26000*	*31300*	*21100*	*31800*	*25800*	*29600*	*No change*
1/11-28/11	-	-	*27000*	*23300*	*30900*	*25700*	*30600*	*20600*	*31100*	*25100*	*28900*	*No change*
29/11-31/12	-	-	*26200*	*22700*	*29900*	*25300*	*30000*	*20100*	*30200*	*24600*	*27500*	*No change*
1/1/2000-30/1	-	-	*26600*	*23500*	*30300*	*25700*	*30400*	*20100*	*29900*	*24000*	*27600*	*No change*
31/1-27/2	-	-	*28200*	*24600*	*31400*	*26800*	*31700*	*21200*	*31700*	*25600*	*29400*	*No change*
28/2-31/3	-	-	*28300*	*24900*	*32100*	*27200*	*31800*	*21200*	*31600*	*25600*	*29300*	*No change*
1/4-30/4	-	-	*27900*	*24000*	*31600*	*26600*	*31000*	*21200*	*31800*	*26100*	*29900*	*No change*
1/5-2/6	-	-	*28400*	*24300*	*32100*	*27000*	*32000*	*21400*	*32000*	*26300*	*30200*	*No change*
3/6-30/6	-	-	*27900*	*24000*	*31100*	*26500*	*31400*	*21000*	*31200*	*24700*	*29100*	*No change*
1/7/2000-30/7	25800	16600	28200	24300	31900	26900	31700	21500	32200	26600	30600**	J16-15 included
31/7-31/8	*24900*	*16200*	27500	23900	30900	26100	30900	21000	31300	25900	29700	No change
1/9-30/9	*25700*	*16500*	28200	24400	32100	27200	32000	21500	31800	26300	30200	No change
1/10-31/10	*25100*	*16300*	27800	23700	31700	26600	31600	21300	31500	26100	30000	No change
1/11-30/11	*23900*	*15600*	26700	23100	30900	26200	31100	20700	30800	25300	29300	No change
1/12-31/12	*23500*	*15400*	26000	22400	30200	25500	30700	20500	30800	24900	28600	No change

	J16-15	J15	J15-14	J14	J14-13	J13	J13-12	J12	J12-11	J11	J11-10	Comments
1/1/2001-31/1	22900	15200	25700	22800	29900	25500	30000	19900	29400	23200	27100	No change
1/2-28/2	24600	16000	27000	23100	31300	26400	31600	21200	31200	25400	29400	Roadworks J16-17
1/3-31/3	23800	15400	26400	22800	30800	26000	31200	20700	30700	25100	29100	No change
1/4-30/4	25100	16400	27500	23800	31600	26800	32000	21100	31500	26000	30000	No change
1/5-31/5	**24600**	**16100**	**27400**	**23800**	**31600**	**26900**	**31900**	**21100**	**31500**	**25800**	**30000**	**No change**
1/6-30/6	**24600**	**16000**	**27100**	**24000**	**31200**	**26500**	**31700**	**20900**	**31400**	**25700**	**29900**	**No change**
1/7-31/7	24700	16100	27000	23100	31000	26300	31600	21100	31700	26200	30300	No change
1/8-31/8	24800	16200	26900	23400	30600	26000	31100	20900	31400	26030	30000	No change
1/9-30/9	24900	16200	26900	23100	30800	26100	31200	21000	31400	26000	30000	No change
1/10-31/10	24500	16100	26800	23100	30200	25400	30600	20300	30500	25000	29000	No change
1/11-30/11	24000	16000	27000	23000	30300	25700	30800	20400	30500	25000	29100	No change
1/12-31/12	23600	15700	26200	22900	30100	25600	30600	20200	29900	25400	29500	No change
1/1/2002-31/1	23700	15500	26000	22600	29800	25200	30100	20000	29500	24000	27700	No change
1/2-28/2	24500	16000	27100	23400	31200	26470	31740	21300	31600	25800	29800	No change
1/3-31/3	25200	16500	27700	24100	31300	26800	31900	21300	31600	25900	30000	No change
1/4-30/4	25100	16900	27400	24000	31100	26600	31600	21300	31500	25700	29900	No change
1/5-31/5	26000**	17300**	28100	24200	32100	27300	32400	21600	32000	26100	30300	No change
1/6-30/6	25300	17000	27800	24100	31600	26900	32000	21400	32000	26300	30600**	No change

Peak 15-minute throughput on 'B' carriageway (veh/hr)

	J16-15	J15	J15-14	J14	J14-13	J13	J13-12	J12	J12-11	J11	J11-10	Comments
4/1/1999-31/1	-	-	*6780*	*6070*	*7530*	*6420*	*7490*	*4970*	*7380*	*5890*	*6910*	*No change*
1/2-28/2	-	-	*7190*	*6320*	*7710*	*6560*	*7610*	*5140*	*7490*	*6070*	*7060*	*No change*
1/3-1/4	-	-	*7230*	*6390*	*7840*	*6700*	*7680*	*5110*	*7390*	*6080*	*7050*	*No change*
2/4-30/4	-	-	*7180*	*6300*	*7850*	*6730*	*7770*	*5220*	*7480*	*6140*	*7110*	*No change*
1/5-31/5	-	-	*7270*	*6420*	*7950*	*6770*	*7790*	*5180*	*7450*	*6080*	*7090*	*No change*
1/6-2/7	-	-	*7210*	*6340*	*7820*	*6690*	*7680*	*5130*	*7360*	*6050*	*7120*	*No change*
3/7-28/7	-	-	*7230*	*6390*	*7810*	*6690*	*7680*	*5110*	*7380*	*6020*	*7150*	*No change*
29/7-30/8	-	-	*6990*	*6040*	*7490*	*6510*	*7490*	*5020*	*7250*	*5990*	*6910*	*EMS messages enable*
31/8-1/10	-	-	*7020*	*6060*	*7500*	*6430*	*7500*	*5040*	*7310*	*6000*	*7100*	*No change*
2/10-31/10	-	-	*6960*	*6090*	*7530*	*6310*	*7470*	*5050*	*7450*	*6050*	*7100*	*No change*
1/11-28/11	-	-	*6850*	*5970*	*7450*	*6280*	*7310*	*4950*	*7570***	*6080*	*7090*	*No change*
29/11-31/12	-	-	*6650*	*5840*	*7190*	*6110*	*7060*	*4820*	*7310*	*5900*	*6730*	*No change*
1/1/2000-30/1	-	-	*6600*	*5880*	*7340*	*6260*	*7330*	*4910*	*7440*	*5950*	*7000*	*No change*
31/1-27/2	-	-	*7050*	*6250*	*7530*	*6500*	*7520*	*5110*	*7510*	*6120*	*7080*	*No change*
28/2-31/3	-	-	*7060*	*6310*	*7810*	*6690*	*7710*	*5170*	*7580*	*6160*	*7130*	*No change*
1/4-30/4	-	-	*7020*	*6170*	*7670*	*6550*	*7500*	*5070*	*7430*	*6090*	*7120*	*No change*
1/5-2/6	-	-	*7170*	*6310*	*7760*	*6640*	*7630*	*5140*	*7410*	*6070*	*7120*	*No change*
3/6-30/6	-	-	*7200*	*6300*	*7660*	*6650*	*7680*	*5100*	*7290*	*6050*	*7070*	*No change*
1/7/2000-30/7	6720	4490	7140	6330	7740	6590	7530	5120	7350	6080	7100	J16-15 included
31/7-31/8	6480	4250	6940	6100	7500	6360	7410	5100	7380	6040	7110	No change
1/9-30/9	6480	4320	6980	6160	7590	6570	7530	5120	7440	6110	7240	No change
1/10-31/10	6590	4480	7200	6260	7670	6580	7520	5060	7290	6020	7060	No change
1/11-30/11	6150	4090	6750	5990	7350	6250	7240	4960	7260	6020	7080	No change
1/12-31/12	6270	4160	6620	5780	7190	6080	7270	4900	7310	5900	6920	No change

	J16-15	J15	J15-14	J14	J14-13	J13	J13-12	J12	J12-11	J11	J11-10	Comments
1/1/2001-31/1	5990	3980	6430	5790	7140	6080	7120	4800	7160	5780	6730	No change
1/2-28/2	6460	4300	6870	6060	7440	6360	7490	5020	7300	5980	7020	Roadworks J16-17
1/3-31/3	6420	4210	6900	6080	7580	6510	7610	4990	7300	6000	7010	No change
1/4-30/4	6630	4420	6980	6240	7710	6660	7680	5160	7390	6140	7120	No change
1/5-31/5	**6430**	**4240**	**7060**	**6270**	**7770**	**6690**	**7660**	**5120**	**7430**	**6060**	**7110**	**No change**
1/6-30/6	**6440**	**4280**	**6960**	**6290**	**7740**	**6660**	**7690**	**5090**	**7420**	**6070**	**7130**	**No change**
1/7-31/7	6520	4330	6900	6120	7600	6560	7510	5040	7330	5980	7090	No change
1/8-31/8	6480	4640	6870	6170	7510	6510	7490	5010	7260	5980	7000	No change
1/9-30/9	6580	4370	6940	6120	7510	6490	7560	5020	7300	6020	7150	No change
1/10-31/10	6540	4430	7030	6170	7490	6460	7520	5000	7270	6030	7040	No change
1/11-30/11	6380	4340	6940	6140	7420	6330	7380	4980	7390	6070	7170	No change
1/12-31/12	6440	4370	6850	5910	7250	6150	7250	4860	7200	6090	7210	No change
1/1/2002-31/1	6250	4170	6640	5900	7310	6260	7350	4930	7240	5900	6910	No change
1/2-28/2	6400	4290	6860	6060	7390	6330	7430	5050	7370	6050	7100	No change
1/3-31/3	6680	4460	7120	6270	7610	6650	7710	5140	7530	6180**	7180	No change
1/4-30/4	6540	4470	7040	6260	7760	6740	7810	5240	7500	6180**	7280**	No change
1/5-31/5	6680	4650	7240	6370	7730	6650	7650	5210	7410	6130	7230	No change
1/6-30/6	6470	4500	7190	6390	7770	6650	7720	5120	7370	6110	7230	No change

Peak hourly throughput on 'B' carriageway (veh/hr)

	J16-15	J15	J15-14	J14	J14-13	J13	J13-12	J12	J12-11	J11	J11-10	Comments
4/1/1999-31/1	-	-	*6450*	*5750*	*7260*	*6180*	*7220*	*4740*	*7110*	*5660*	*6640*	*No change*
1/2-28/2	-	-	*6760*	*5970*	*7430*	*6340*	*7410*	*4900*	*7270*	*5860*	*6810*	*No change*
1/3-1/4	-	-	*6820*	*6020*	*7490*	*6360*	*7370*	*4860*	*7150*	*5850*	*6800*	*No change*
2/4-30/4	-	-	*6660*	*5910*	*7450*	*6420*	*7500*	*4940*	*7210*	*5910*	*6880*	*No change*
1/5-31/5	-	-	*6820*	*6040*	*7550*	*6420*	*7450*	*4930*	*7240*	*5880*	*6880*	*No change*
1/6-2/7	-	-	*6760*	*5970*	*7490*	*6340*	*7390*	*4880*	*7160*	*5840*	*6900*	*No change*
3/7-28/7	-	-	*6730*	*5980*	*7400*	*6330*	*7320*	*4860*	*7150*	*5820*	*6870*	*No change*
29/7-30/8	-	-	*6500*	*5670*	*7180*	*6250*	*7200*	*4770*	*7010*	*5800*	*6680*	*EMS messages enable*
31/8-1/10	-	-	*6480*	*5640*	*7160*	*6130*	*7150*	*4770*	*7070*	*5790*	*6830*	*No change*
2/10-31/10	-	-	*6550*	*5700*	*7210*	*6010*	*7180*	*4790*	*7250*	*5870*	*6880*	*No change*
1/11-28/11	-	-	*6480*	*5640*	*7150*	*6050*	*7070*	*4750*	*7320*	*5830*	*6850*	*No change*
29/11-31/12	-	-	*6230*	*5470*	*6920*	*5840*	*6870*	*4620*	*7070*	*5700*	*6530*	*No change*
1/1/2000-30/1	-	-	*6280*	*5540*	*7030*	*5970*	*7080*	*4720*	*7170*	*5720*	*6730*	*No change*
31/1-27/2	-	-	*6690*	*5910*	*7220*	*6200*	*7240*	*4850*	*7270*	*5900*	*6860*	*No change*
28/2-31/3	-	-	*6750*	*5990*	*7500*	*6420*	*7410*	*4920*	*7330***	*5930*	*6900*	*No change*
1/4-30/4	-	-	*6590*	*5800*	*7290*	*6220*	*7140*	*4820*	*7190*	*5880*	*6860*	*No change*
1/5-2/6	-	-	*6720*	*5910*	*7420*	*6330*	*7270*	*4830*	*7160*	*5840*	*6860*	*No change*
3/6-30/6	-	-	*6750*	*5910*	*7380*	*6340*	*7300*	*4830*	*7070*	*5800*	*6800*	*No change*
1/7/2000-30/7	6370**	4530**	6710	5950	7380	6290	7170	4830	7120	5870	6880	J16-15 included
31/7-31/8	6000	3880	6380	5590	7050	6020	7050	4760	7070	5810	6800	No change
1/9-30/9	6140	4020	6570	5820	7300	6280	7190	4820	7190	5920	6970	No change
1/10-31/10	6230	4110	6630	5800	7250	6180	7120	4780	7050	5820	6840	No change
1/11-30/11	5860	3800	6320	5540	7020	5920	6980	4700	7030	5800	6820	No change
1/12-31/12	5900	3860	6260	5430	6880	5790	7080	4680	7110	5690	6670	No change

	J16-15	J15	J15-14	J14	J14-13	J13	J13-12	J12	J12-11	J11	J11-10	Comments
1/1/2001-31/1	5640	3690	6060	5400	6840	5790	6880	4590	6890	5550	6500	No change
1/2-28/2	6090	3970	6480	5650	7150	6080	7150	4780	7100	5760	6770	Roadworks J16-17
1/3-31/3	5980	3880	6420	5620	7190	6160	7240	4750	7040	5760	6770	No change
1/4-30/4	6190	4070	6570	5850	7340	6320	7350	4820	7110	5880	6870	No change
1/5-31/5	**6090**	**3950**	**6590**	**5860**	**7370**	**6290**	**7310**	**4830**	**7140**	**5840**	**6890**	**No change**
1/6-30/6	**6130**	**4030**	**6630**	**5970**	**7390**	**6340**	**7330**	**4810**	**7140**	**5840**	**6880**	**No change**
1/7-31/7	6180	3960	6420	5690	7130	6130	7110	4720	7080	5780	6890	No change
1/8-31/8	6120	4010	6460	5720	7110	6100	7020	4690	7040	5760	6800	No change
1/9-30/9	6200	4050	6480	5680	7160	6150	7160	4750	7060	5800	6870	No change
1/10-31/10	6100	4050	6520	5680	7060	6030	7150	4710	7010	5790	6780	No change
1/11-30/11	6030	4000	6490	5660	7060	6030	7100	4740	7140	5870	6900	No change
1/12-31/12	5900	3930	6290	5550	6930	5910	7010	4660	6930	5890	6980	No change
1/1/2002-31/1	5830	3850	6270	5550	7000	5980	7080	4690	7020	5680	6690	No change
1/2-28/2	6090	3920	6440	5600	7090	6050	7140	4810	7150	5860	6870	No change
1/3-31/3	6280	4090	6660	5850	7300	6330	7370	4880	7270	5940**	6950	No change
1/4-30/4	6180	4170	6600	5870	7380	6340	7430	4960	7250	5940**	7030**	No change
1/5-31/5	6330	4280	6610	5800	7290	6260	7270	4860	7170	5890	6960	No change
1/6-30/6	6170	4190	6630	5890	7370	6320	7340	4860	7170	5890	6990	No change

<u>SUMMARY OF WEEKDAY JUNCTION-TO-JUNCTION JOURNEY TIMES</u>

The average journey time from the midpoint of one junction to the midpoint of the next junction of the Controlled Motorways section of the M25 has been estimated for the morning and afternoon peaks of each weekday. For each minute of the peak period, the passage of an imaginary car is followed through the section. The imaginary car is assumed to travel at the average speed of the outside 3 lanes for each loop site.

Using this method, the average total journey time between Junctions 11 and 15 in uncongested conditions is 8.0 minutes, representing a speed of 73 mph. The average journey time between Junctions 10 and 11 has been estimated separately.

For each peak period (0600-1100, 1530-2030), the average journey time and the journey time variability (the standard deviation) has been calculated. Friday evenings, bank holidays and days with bad weather or accidents have been excluded. The figures have been split according to the dates of changes to the MIDAS configuration data; where the MIDAS configuration is stable, the figures have been split into months. Summaries are provided below. This document shows the journey times since the start of July 2000.

The results are presented in the form JT (V), where JT is the journey time and V is the journey time variability (both in minutes). The figures for an uncongested weekend day are provided for comparison.

Uncongested Day

J10-11	J11-12	J12-13	J13-14	J14-15	J15-16	Total (J11-15)
2.8 (0.1)	1.8 (0.1)	2.6 (0.1)	1.6 (0.1)	2.1 (0.1)	2.5 (0.1)	8.0 (0.3)

AM peak on 'A' carriageway

	J10-11	J11-12	J12-13	J13-14	J14-15	J15-16	Total (J11-15)	Comments
4/1/1999-31/1	*5.8 (2.8)*	*3.6 (1.7)*	*5.0 (1.7)*	*2.6 (0.7)*	*2.7 (0.3)*	-	*13.9 (3.9)*	*No change*
1/2-28/2	*6.2 (3.0)*	*3.7 (1.6)*	*4.8 (1.6)*	*2.5 (0.6)*	*2.6 (0.2)*	-	*13.6 (3.6)*	*No change*
1/3-1/4	*5.7 (2.5)*	*3.4 (1.3)*	*4.5 (1.3)*	*2.5 (0.6)*	*2.6 (0.2)*	-	*13.0 (3.0)*	*No change*
2/4-30/4	*5.8 (2.3)*	*3.6 (1.4)*	*4.6 (1.2)*	*2.5 (0.5)*	*2.6 (0.2)*	-	*13.3 (2.8)*	*No change*
1/5-31/5	*6.0 (2.6)*	*3.6 (1.5)*	*4.9 (1.5)*	*2.6 (0.7)*	*2.6 (0.3)*	-	*13.8 (3.3)*	*No change*
1/6-2/7	*5.8 (2.5)*	*3.4 (1.4)*	*4.6 (1.5)*	*2.6 (0.8)*	*2.8 (0.4)*	-	*13.4 (3.4)*	*No change*
3/7-28/7	*5.4 (2.4)*	*3.2 (1.2)*	*4.5 (1.3)*	*2.5 (0.7)*	*2.8 (0.5)*	-	*13.0 (3.1)*	*No change*
29/7-30/8	*4.5 (1.4)*	*2.8 (0.9)*	*3.9 (0.9)*	*2.3 (0.5)*	*2.6 (0.3)*	-	*11.7 (2.2)*	*EMS messages enabled (He*
31/8-1/10	*6.4 (2.7)*	*3.8 (1.7)*	*5.1 (1.8)*	*2.7 (0.7)*	*2.8 (0.4)*	-	*14.4 (3.7)*	*No change*
2/10-30/10	*6.1 (2.5)*	*3.5 (1.3)*	*5.0 (1.6)*	*2.7 (0.8)*	*2.9 (0.5)*	-	*14.1 (3.5)*	*No change*
1/11-28/11	*5.1 (2.0)*	*3.1 (1.0)*	*4.4 (1.1)*	*2.4 (0.5)*	*2.7 (0.3)*	-	*12.5 (2.4)*	*No change*
29/11-31/12	*4.9 (1.8)*	*3.0 (0.9)*	*4.3 (1.2)*	*2.5 (0.5)*	*2.7 (0.3)*	-	*12.4 (2.4)*	*No change*
1/1/2000-30/1	*5.3 (2.1)*	*3.3 (1.1)*	*4.6 (1.3)*	*2.5 (0.6)*	*2.7 (0.5)*	-	*13.1 (3.1)*	*No change*
31/1-27/2	*5.4 (2.3)*	*3.1 (1.0)*	*4.3 (1.1)*	*2.5 (0.6)*	*2.7 (0.3)*	-	*12.6 (2.5)*	*No change*
28/2-31/3	*5.4 (2.4)*	*3.2 (1.2)*	*4.5 (1.2)*	*2.5 (0.5)*	*2.7 (0.3)*	-	*12.9 (2.8)*	*No change*
1/4-30/4	*5.4 (1.9)*	*3.3 (1.2)*	*4.6 (1.2)*	*2.5 (0.6)*	*2.7 (0.3)*	-	*13.1 (2.8)*	*No change*
1/5-2/6	*5.9 (2.5)*	*3.4 (1.3)*	*4.5 (1.2)*	*2.5 (0.6)*	*2.8 (0.4)*	-	*13.2 (2.8)*	*No change*
3/6-30/6	*5.4 (2.4)*	*3.3 (1.4)*	*4.5 (1.4)*	*2.4 (0.6)*	*2.8 (0.5)*	-	*13.0 (3.1)*	*No change*
1/7/2000-30/7	5.5 (2.2)	3.2 (1.1)	4.4 (1.1)	2.5 (0.6)	2.7 (0.3)	3.0 (0.3)	12.8 (2.6)	J15-16 included
31/7-31/8	4.7 (1.7)	2.9 (1.0)	4.2 (1.1)	2.4 (0.6)	2.7 (0.3)	3.0 (0.4)	12.2 (2.5)	No change
1/9-30/9	5.7 (2.1)	3.3 (1.1)	4.5 (1.2)	2.5 (0.6)	2.7 (0.3)	3.0 (0.2)	13.1 (2.6)	No change
1/10-31/10	5.9 (2.4)	3.5 (1.3)	4.7 (1.4)	2.5 (0.6)	2.8 (0.4)	3.2 (0.7)	13.5 (3.0)	No change
1/11-30/11	4.8 (2.1)	3.2 (1.1)	4.6 (1.3)	2.6 (0.7)	2.7 (0.5)	3.1 (0.5)	13.2 (2.8)	No change
1/12-31/12	6.0 (2.5)	3.4 (1.1)	4.5 (1.4)	2.6 (0.8)	3.1 (0.6)	3.7 (0.9)	13.6 (3.2)	No change

	J10-11	J11-12	J12-13	J13-14	J14-15	J15-16	Total (J11-15)	Comments
1/1/2001-31/1	6.2 (2.5)	3.6 (1.4)	4.7 (1.3)	2.5 (0.6)	2.7 (0.3)	3.0 (0.2)	13.5 (3.0)	No change
1/2-28/2	5.1 (1.9)	3.3 (1.1)	4.5 (1.2)	2.5 (0.6)	2.7 (0.3)	2.9 (0.2)	12.9 (2.6)	Roadworks J16-17
1/3-31/3	5.5 (2.2)	3.2 (1.0)	4.4 (1.0)	2.4 (0.5)	2.7 (0.2)	3.0 (0.3)	12.6 (2.3)	No change
1/4-30/4	5.4 (2.2)	3.3 (1.1)	4.5 (1.3)	2.5 (0.7)	2.7 (0.5)	3.2 (0.6)	12.9 (2.7)	No change
1/5-31/5	**5.5 (2.2)**	**3.2 (1.1)**	**4.3 (1.1)**	**2.4 (0.5)**	**2.7 (0.3)**	**3.2 (0.4)**	**12.6 (2.4)**	**No change**
1/6-30/6	**5.3 (2.0)**	**3.0 (1.0)**	**4.0 (0.9)**	**2.3 (0.4)**	**2.7 (0.2)**	**3.1 (0.3)**	**11.9 (2.1)**	**No change**
1/7-31/7	5.6 (2.0)	3.2 (1.0)	4.3 (1.1)	2.4 (0.5)	2.8 (0.4)	3.0 (0.2)	12.7 (2.3)	No change
1/8-31/8	3.8 (1.2)	2.6 (0.6)	3.7 (0.7)	2.2 (0.4)	2.6 (0.2)	2.9 (0.2)	11.1 (1.6)	No change
1/9-30/9	5.6 (2.4)	3.4 (1.3)	4.5 (1.2)	2.3 (0.5)	2.7 (0.4)	3.0 (0.3)	12.9 (2.8)	No change
1/10-31/10	5.7 (2.4)	3.4 (1.2)	4.4 (1.2)	2.3 (0.4)	2.7 (0.2)	3.0 (0.2)	12.7 (2.5)	No change
1/11-30/11	6.0 (2.6)	3.4 (1.3)	4.6 (1.2)	2.4 (0.5)	2.7 (0.3)	3.1 (0.4)	13.2 (2.8)	No change
1/12-31/12	5.0 (1.8)	3.0 (0.9)	4.3 (1.1)	2.4 (0.5)	2.8 (0.3)	3.2 (0.3)	12.4 (2.3)	No change
1/1/2002-31/1	5.0 (2.0)	2.9 (1.0)	4.1 (1.0)	2.2 (0.4)	2.6 (0.3)	3.1 (0.4)	11.8 (2.3)	No change
1/2-28/2	5.1 (2.0)	3.0 (1.0)	4.3 (1.1)	2.4 (0.5)	2.8 (0.4)	3.1 (0.3)	12.5 (2.3)	No change
1/3-31/3	5.6 (2.1)	3.3 (1.1)	4.3 (1.0)	2.3 (0.4)	2.7 (0.3)	3.1 (0.3)	12.6 (2.2)	No change
1/4-30/4	5.6 (2.3)	3.3 (1.3)	4.4 (1.4)	2.4 (0.5)	2.7 (0.3)	3.1 (0.3)	12.8 (2.9)	No change
1/5-31/5	5.4 (2.0)	3.3 (1.2)	4.5 (1.5)	2.4 (0.7)	2.7 (0.2)	3.1 (0.3)	12.8 (3.0)	No change
1/5-30/6	5.2 (1.8)	3.0 (1.0)	4.2 (1.1)	2.4 (0.5)	2.7 (0.3)	3.1 (0.3)	12.3 (2.3)	No change

PM peak on 'B' carriageway

	J16-15	J15-14	J14-13	J13-12	J12-11	J11-10	Total (J15-11)	Comments
4/1-31/1	-	*2.9 (0.8)*	*2.3 (0.5)*	*3.5 (0.6)*	*2.4 (0.4)*	*3.3 (0.3)*	*11.0 (2.1)*	*No change*
1/2-28/2	-	*3.5 (1.3)*	*2.5 (0.7)*	*3.6 (0.7)*	*2.6 (0.6)*	*3.4 (0.4)*	*12.2 (2.9)*	*No change*
1/3-1/4	-	*4.2 (1.7)*	*2.7 (0.8)*	*4.1 (1.0)*	*2.9 (0.8)*	*3.7 (0.6)*	*14.0 (3.9)*	*No change*
2/4-30/4	-	*4.3 (1.8)*	*2.8 (1.0)*	*4.3 (1.3)*	*3.1 (0.9)*	*3.5 (0.4)*	*14.5 (4.2)*	*No change*
1/5-31/5	-	*4.2 (1.7)*	*2.7 (0.9)*	*3.8 (0.8)*	*2.8 (0.7)*	*3.4 (0.3)*	*13.5 (3.5)*	*No change*
1/6-2/7	-	*4.5 (1.8)*	*2.8 (0.9)*	*4.3 (1.2)*	*3.1 (0.8)*	*3.5 (0.4)*	*14.6 (4.0)*	*No change*
3/7-28/7	-	*4.9 (2.0)*	*2.9 (1.1)*	*4.6 (1.4)*	*3.3 (0.9)*	*3.5 (0.4)*	*15.7 (4.5)*	*No change*
29/7-30/8	-	*4.6 (1.6)*	*2.7 (0.8)*	*4.2 (1.0)*	*3.0 (0.7)*	*4.1 (0.7)*	*14.5 (3.6)*	*EMS messages enabled (He*
31/8-1/10	-	*4.9 (1.9)*	*3.0 (1.0)*	*4.4 (1.2)*	*3.1 (0.8)*	*3.5 (0.2)*	*15.5 (4.0)*	*No change*
2/10-31/10	-	*4.8 (1.9)*	*3.2 (1.2)*	*4.5 (1.4)*	*3.0 (0.8)*	*3.6 (0.5)*	*15.3 (4.3)*	*No change*
1/11-28/11	-	*4.8 (2.0)*	*3.2 (1.1)*	*4.1 (0.9)*	*2.6 (0.5)*	*3.5 (0.4)*	*14.6 (4.0)*	*No change*
29/11-31/12	-	*5.0 (2.5)*	*3.0 (1.2)*	*3.9 (0.9)*	*2.8 (0.7)*	*3.6 (0.4)*	*14.6 (4.6)*	*No change*
1/1/2000-30/1	-	*3.1 (0.7)*	*2.3 (0.5)*	*3.4 (0.6)*	*2.5 (0.5)*	*3.4 (0.4)*	*11.3 (2.1)*	*No change*
31/1-27/2	-	*3.9 (1.6)*	*2.7 (0.9)*	*4.0 (1.0)*	*2.8 (0.7)*	*3.6 (0.5)*	*13.5 (3.8)*	*No change*
28/2-31/3	-	*3.4 (1.0)*	*2.5 (0.7)*	*3.9 (1.0)*	*2.8 (0.7)*	*3.5 (0.5)*	*12.6 (3.0)*	*No change*
1/4-30/4	-	*5.1 (2.5)*	*3.1 (1.2)*	*4.6 (1.4)*	*3.2 (0.9)*	*3.6 (0.4)*	*16.0 (5.1)*	*No change*
1/5-2/6	-	*4.8 (2.0)*	*2.9 (1.1)*	*4.5 (1.4)*	*3.3 (1.0)*	*3.5 (0.4)*	*15.4 (4.8)*	*No change*
3/6-30/6	-	*4.4 (1.9)*	*2.7 (0.9)*	*4.3 (1.2)*	*3.1 (0.9)*	*3.5 (0.4)*	*14.6 (3.9)*	*No change*
1/7/2000-30/7	4.9 (2.1)	5.1 (2.3)	3.1 (1.1)	4.8 (1.4)	3.4 (1.0)	3.5 (0.3)	16.3 (5.0)	J16-15 included
31/7-31/8	4.1 (1.3)	4.5 (1.8)	2.8 (1.0)	4.2 (1.1)	3.0 (0.8)	3.5 (0.3)	14.5 (3.9)	No change
1/9-30/9	3.6 (1.0)	4.3 (1.9)	2.9 (1.0)	4.2 (1.1)	3.0 (0.8)	3.6 (0.4)	14.4 (4.0)	No change
1/10-31/10	5.3 (2.2)	5.7 (2.4)	3.3 (1.2)	4.8 (1.4)	3.3 (0.9)	3.6 (0.3)	17.0 (5.1)	No change
1/11-30/11	4.3 (1.7)	4.9 (2.1)	3.0 (1.0)	4.0 (0.9)	2.8 (0.7)	3.6 (0.4)	14.7 (4.1)	No change
1/12-31/12	3.8 (1.1)	4.8 (2.4)	3.2 (1.2)	4.2 (1.1)	3.1 (0.9)	3.6 (0.4)	15.3 (5.1)	No change

	J16-15	J15-14	J14-13	J13-12	J12-11	J11-10	Total (J15-11)	Comments
1/1/2001-31/1	3.5 (0.9)	3.8 (1.5)	2.6 (0.7)	3.5 (0.6)	2.5 (0.5)	3.5 (0.4)	12.5 (2.9)	No change
1/2-28/2	4.4 (1.8)	5.4 (2.6)	3.2 (1.1)	4.1 (1.0)	3.1 (0.8)	3.4 (0.5)	15.8 (5.0)	Roadworks J16-17
1/3-31/3	4.5 (1.5)	4.9 (2.0)	3.1 (1.0)	4.4 (1.3)	3.3 (1.1)	3.6 (0.4)	15.6 (4.4)	No change
1/4-30/4	3.5 (0.9)	4.3 (1.9)	2.9 (1.0)	4.4 (1.3)	3.3 (0.4)	3.7 (0.4)	14.9 (4.3)	No change
1/5-31/5	**3.9 (1.3)**	**4.4 (1.7)**	**2.6 (0.9)**	**4.1 (1.1)**	**3.1 (0.8)**	**3.5 (0.4)**	**14.1 (3.9)**	**No change**
1/6-30/6	**3.4 (0.9)**	**4.3 (2.0)**	**2.9 (1.2)**	**4.3 (1.2)**	**3.3 (1.0)**	**4.1 (0.6)**	**14.8 (4.7)**	**No change**
1/7-31/7	4.2 (1.5)	4.9 (2.2)	3.0 (1.1)	4.5 (1.3)	3.2 (0.9)	3.6 (0.4)	15.7 (4.7)	No change
1/8-31/8	3.9 (1.4)	4.7 (2.1)	2.8 (1.1)	4.7 (1.5)	3.3 (1.0)	3.3 (0.3)	15.6 (4.9)	No change
1/9-30/9	4.1 (1.5)	5.0 (2.3)	3.0 (1.2)	4.4 (1.3)	3.3 (0.9)	3.6 (0.4)	15.7 (5.1)	No change
1/10-31/10	4.2 (1.4)	4.7 (2.0)	3.0 (1.1)	4.8 (1.6)	3.4 (1.1)	4.0 (1.0)	15.8 (4.8)	No change
1/11-30/11	3.8 (1.3)	4.9 (2.5)	2.9 (1.1)	4.2 (1.3)	2.9 (0.9)	3.7 (0.7)	14.9 (5.1)	No change
1/12-31/12	3.8 (1.2)	4.4 (1.9)	2.8 (0.9)	3.8 (0.8)	2.6 (0.6)	3.5 (0.4)	13.5 (3.8)	No change
1/1/2002-31/1	3.2 (0.7)	3.8 (1.8)	2.8 (1.1)	3.6 (0.6)	2.5 (0.4)	3.5 (0.5)	12.7 (3.5)	No change
1/2-28/2	4.5 (1.8)	5.1 (2.2)	3.1 (1.1)	4.1 (1.0)	3.0 (0.8)	3.6 (0.4)	15.2 (4.8)	No change
1/3-31/3	3.4 (0.9)	4.3 (1.9)	2.8 (1.0)	4.1 (1.0)	2.9 (0.8)	3.5 (0.3)	14.0 (4.1)	No change
1/4-30/4	3.4 (0.9)	3.7 (1.5)	2.6 (1.0)	4.2 (1.3)	2.9 (0.9)	3.6 (0.6)	13.4 (3.9)	No change
1/5-31/5	4.5 (1.9)	5.3 (2.7)	3.1 (1.3)	4.6 (1.5)	3.4 (1.2)	4.1 (0.9)	16.4 (5.6)	No change
1/6-30/6	4.3 (1.6)	4.8 (2.2)	2.9 (1.1)	4.4 (1.3)	3.1 (0.9)	3.6 (0.5)	15.2 (4.6)	No change

SUMMARY OF WEEKDAY JUNCTION-TO-JUNCTION FLOW BREAKDOWNS

The extent of flow breakdown on the Controlled Motorways section of the M25 has been estimated for the morning and afternoon peaks of each weekday. Flow breakdown was defined as the average traffic speed in the outside 3 lanes falling below 25 mph. The duration of the flow breakdown is multiplied by the length of road affected to give a measure in kilometre hours (kmh).

The total amount of flow breakdown for each junction-to-junction section has been calculated for the morning peak and afternoon peak (0600-1100, 1530-2030). Friday evenings, bank holidays and days with bad weather or accidents have been excluded. The figures have been split according to the dates of changes to the MIDAS configuration data; where the MIDAS configuration is stable, the figures have been split into months. The results are expressed as the average flow breakdown per peak period (kmh); summaries are provided below. This document shows the amount of flow breakdown since the start of July 2000.

Section Lengths (km)

J10-11	J11-12	J12-13	J13-14	J14-15	J15-16	Total (J11-15)
5.5	3.5	5.0	3.0	4.0	5.0	15.5

AM peak on 'A' carriageway

	J10-11	J11-12	J12-13	J13-14	J14-15	J15-16	Total (J11-15)	Comments
4/1/1999-31/1	*5.0*	*2.5*	*3.1*	*1.1*	*0.1*	-	*6.8*	*No change*
1/2-28/2	*6.1*	*2.9*	*3.0*	*0.7*	*0.0*	-	*6.6*	*No change*
1/3-1/4	*5.3*	*2.3*	*2.2*	*0.6*	*0.0*	-	*5.1*	*No change*
2/4-30/4	*5.2*	*2.5*	*2.4*	*0.6*	*0.0*	-	*5.5*	*No change*
1/5-31/5	*5.3*	*2.5*	*3.0*	*1.1*	*0.1*	-	*6.7*	*No change*
1/6-2/7	*5.3*	*2.2*	*2.6*	*0.8*	*0.1*	-	*5.7*	*No change*
3/7-28/7	*4.3*	*1.6*	*2.2*	*0.8*	*0.3*	-	*4.9*	*No change*
29/7-30/8	*2.9*	*1.2*	*1.2*	*0.5*	*0.0*	-	*2.9*	*EMS messages enabled (He*
31/8-1/10	*6.4*	*3.0*	*3.5*	*1.0*	*0.1*	-	*7.6*	*No change*
2/10-31/10	*6.2*	*2.4*	*3.3*	*1.0*	*0.1*	-	*6.8*	*No change*
1/11-28/11	*4.3*	*1.6*	*2.1*	*0.7*	*0.0*	-	*4.4*	*No change*
29/11-31/12	*3.4*	*1.2*	*1.8*	*0.7*	*0.0*	-	*3.7*	*No change*
1/1/2000-30/1	*4.3*	*1.9*	*2.6*	*0.9*	*0.2*	-	*5.6*	*No change*
31/1-27/2	*4.4*	*1.5*	*1.7*	*0.7*	*0.0*	-	*3.9*	*No change*
28/2-31/3	*4.3*	*1.7*	*2.0*	*0.8*	*0.1*	-	*4.6*	*No change*
1/4-30/4	*4.4*	*1.9*	*2.4*	*0.8*	*0.2*	-	*5.3*	*No change*
1/5-2/6	*5.3*	*2.2*	*2.2*	*0.6*	*0.0*	-	*5.0*	*No change*
3/6-30/6	*4.6*	*1.8*	*2.1*	*0.8*	*0.3*	-	*5.0*	*No change*
1/7/2000-30/7	4.2	1.6	2.0	0.6	0.0	0.0	4.2	J15-16 included
31/7-31/8	2.9	1.3	1.9	0.9	0.1	0.1	4.2	No change
1/9-30/9	5.4	2.1	2.4	0.9	0.1	0.0	5.5	No change
1/10-31/10	5.3	2.2	2.4	0.8	0.2	0.5	5.6	No change
1/11-30/11	4.8	1.6	2.3	1.1	0.2	0.3	5.2	No change
1/12-31/12	5.8	2.0	2.1	1.1	0.8	1.2	6.0	No change

	J10-11	J11-12	J12-13	J13-14	J14-15	J15-16	Total (J11-15)	Comments
1/1/2001-31/1	6.3	2.7	2.6	0.8	0.1	0.0	6.2	No change
1/2-28/2	4.6	1.8	1.9	0.8	0.1	0.0	4.6	Roadworks J16-17
1/3-31/3	4.6	1.6	1.7	0.5	0.1	0.1	3.9	No change
1/4-30/4	4.3	2.0	2.4	0.9	0.2	0.4	5.5	No change
1/5-31/5	**4.4**	**1.5**	**1.6**	**0.5**	**0.1**	**0.2**	**3.7**	**No change**
1/6-30/6	**3.6**	**1.2**	**1.2**	**0.2**	**0.0**	**0.1**	**2.6**	**No change**
1/7-31/7	4.4	1.3	1.6	0.6	0.2	0.0	3.7	No change
1/8-31/8	1.8	0.5	0.6	0.2	0.0	0.0	1.3	No change
1/9-30/9	4.4	2.1	2.1	0.5	0.4	0.2	5.1	No change
1/10-31/10	4.8	2.0	2.0	0.4	0.1	0.0	4.5	No change
1/11-30/11	5.3	2.2	2.2	0.5	0.1	0.3	5.0	No change
1/12-31/12	3.3	1.2	1.5	0.5	0.1	0.0	3.3	No change
1/1/2002-31/1	3.3	1.1	1.2	0.3	0.0	0.2	2.6	No change
1/2-28/2	3.6	1.2	1.8	0.6	0.2	0.1	3.8	No change
1/3-31/3	4.4	1.2	1.7	0.3	0.0	0.0	3.2	No change
1/4-30/4	5.0	2.2	2.5	0.7	0.1	0.1	5.5	No change
1/5-31/5	3.9	1.7	1.8	0.5	0.0	0.0	4.0	No change
1/6-30/6	3.5	1.3	1.5	0.6	0.1	0.0	3.5	No change

PM peak on 'B' carriageway

	J16-15	J15-14	J14-13	J13-12	J12-11	J11-10	Total (J15-11)	Comments
4/1/1999-31/1	-	*0.9*	*0.6*	*0.3*	*0.2*	*0.0*	*2.0*	*No change*
1/2-28/2	-	*2.2*	*0.7*	*0.4*	*0.6*	*0.0*	*3.9*	*No change*
1/3-1/4	-	*3.5*	*1.4*	*1.5*	*1.5*	*0.2*	*7.9*	*No change*
2/4-30/4	-	*3.8*	*1.8*	*2.1*	*1.8*	*0.1*	*9.5*	*No change*
1/5-31/5	-	*3.4*	*1.4*	*0.9*	*1.2*	*0.0*	*6.9*	*No change*
1/6-2/7	-	*4.1*	*1.6*	*2.1*	*2.0*	*0.0*	*9.8*	*No change*
3/7-28/7	-	*4.8*	*2.2*	*3.0*	*2.4*	*0.0*	*12.4*	*No change*
29/7-30/8	-	*4.6*	*1.5*	*1.9*	*1.9*	*0.0*	*9.9*	*EMS messages enabled (He*
31/8-1/10	-	*4.9*	*2.1*	*2.1*	*2.0*	*0.0*	*11.1*	*No change*
2/10-31/10	-	*4.5*	*2.5*	*2.2*	*1.5*	*0.1*	*10.7*	*No change*
1/11-28/11	-	*4.4*	*2.5*	*1.3*	*0.4*	*0.0*	*8.6*	*No change*
29/11-31/12	-	*5.2*	*2.2*	*0.8*	*0.7*	*0.0*	*8.9*	*No change*
1/1/2000-30/1	-	*1.4*	*0.7*	*0.2*	*0.4*	*0.1*	*2.7*	*No change*
31/1-27/2	-	*3.0*	*1.4*	*1.2*	*1.1*	*0.1*	*6.7*	*No change*
28/2-31/3	-	*1.8*	*0.9*	*1.3*	*1.2*	*0.3*	*5.2*	*No change*
1/4-30/4	-	*5.4*	*2.3*	*2.5*	*1.9*	*0.0*	*12.1*	*No change*
1/5-2/6	-	*4.9*	*2.1*	*2.6*	*2.5*	*0.2*	*12.1*	*No change*
3/6-30/6	-	*4.2*	*1.6*	*2.1*	*2.2*	*0.1*	*10.1*	*No change*
1/7/2000-30/7	4.1	5.3	2.3	3.4	2.8	0.0	13.8	J16-15 included
31/7-31/8	2.8	4.4	1.9	2.2	1.9	0.0	10.4	No change
1/9-30/9	1.4	3.5	1.8	1.8	1.7	0.1	8.8	No change
1/10-31/10	4.5	6.3	2.9	3.3	2.4	0.0	14.9	No change
1/11-30/11	3.1	5.0	2.4	1.3	1.3	0.0	10.0	No change
1/12-31/12	0.7	4.9	3.1	1.3	1.8	0.1	11.1	No change

	J16-15	J15-14	J14-13	J13-12	J12-11	J11-10	Total (J15-11)	Comments
1/1/2001-31/1	1.6	3.0	1.4	0.3	0.5	0.1	6.8	No change
1/2-28/2	3.8	6.4	2.8	2.0	2.1	0.4	13.3	Roadworks J16-17
1/3-31/3	3.2	4.7	2.4	2.1	2.4	0.0	11.6	No change
1/4-30/4	1.6	3.7	2.2	2.5	2.6	0.0	11.0	No change
1/5-31/5	**2.5**	**3.8**	**1.5**	**1.9**	**2.0**	**0.1**	**9.2**	**No change**
1/6-30/6	**0.7**	**3.4**	**2.1**	**1.9**	**2.2**	**1.5**	**9.6**	**No change**
1/7-31/7	3.1	4.9	2.3	2.6	2.4	0.0	12.2	No change
1/8-31/8	1.9	4.2	1.9	3.0	2.7	0.1	11.8	No change
1/9-30/9	2.5	4.7	2.3	2.5	2.4	0.1	11.9	No change
1/10-31/10	2.6	4.2	2.2	3.2	2.7	0.9	12.3	No change
1/11-30/11	1.9	4.8	2.2	1.7	1.3	0.3	10.0	No change
1/12-31/12	1.5	5.1	1.7	0.6	0.6	0.0	8.0	No change
1/1/2002-31/1	0.8	3.0	1.9	0.4	0.3	0.1	5.6	No change
1/2-28/2	3.3	5.7	2.4	1.2	1.4	0.0	10.7	No change
1/3-31/3	1.0	3.4	1.8	1.3	1.3	0.0	7.8	No change
1/4-30/4	1.3	2.5	1.4	1.7	1.4	0.5	7.0	No change
1/5-31/5	2.9	5.6	2.4	2.4	2.5	1.0	12.9	No change
1/6-30/6	2.6	4.6	2.1	2.3	2.0	0.1	11.0	No change

Figure 1: Five Hour Throughputs for the A carriageway for J10-11 section

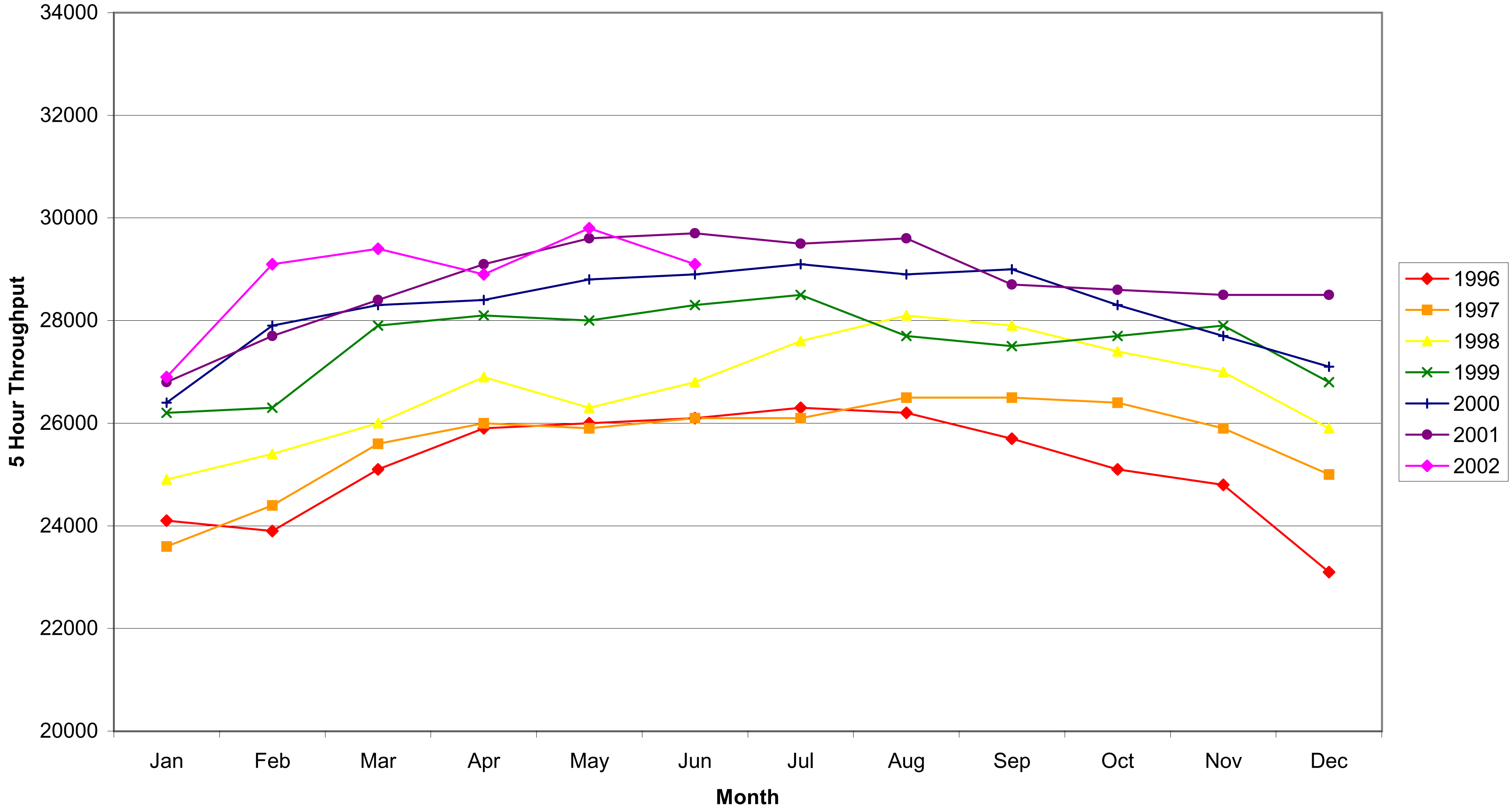


Figure 2: Five Hour Throughputs for the B carriageway for J11-10 section

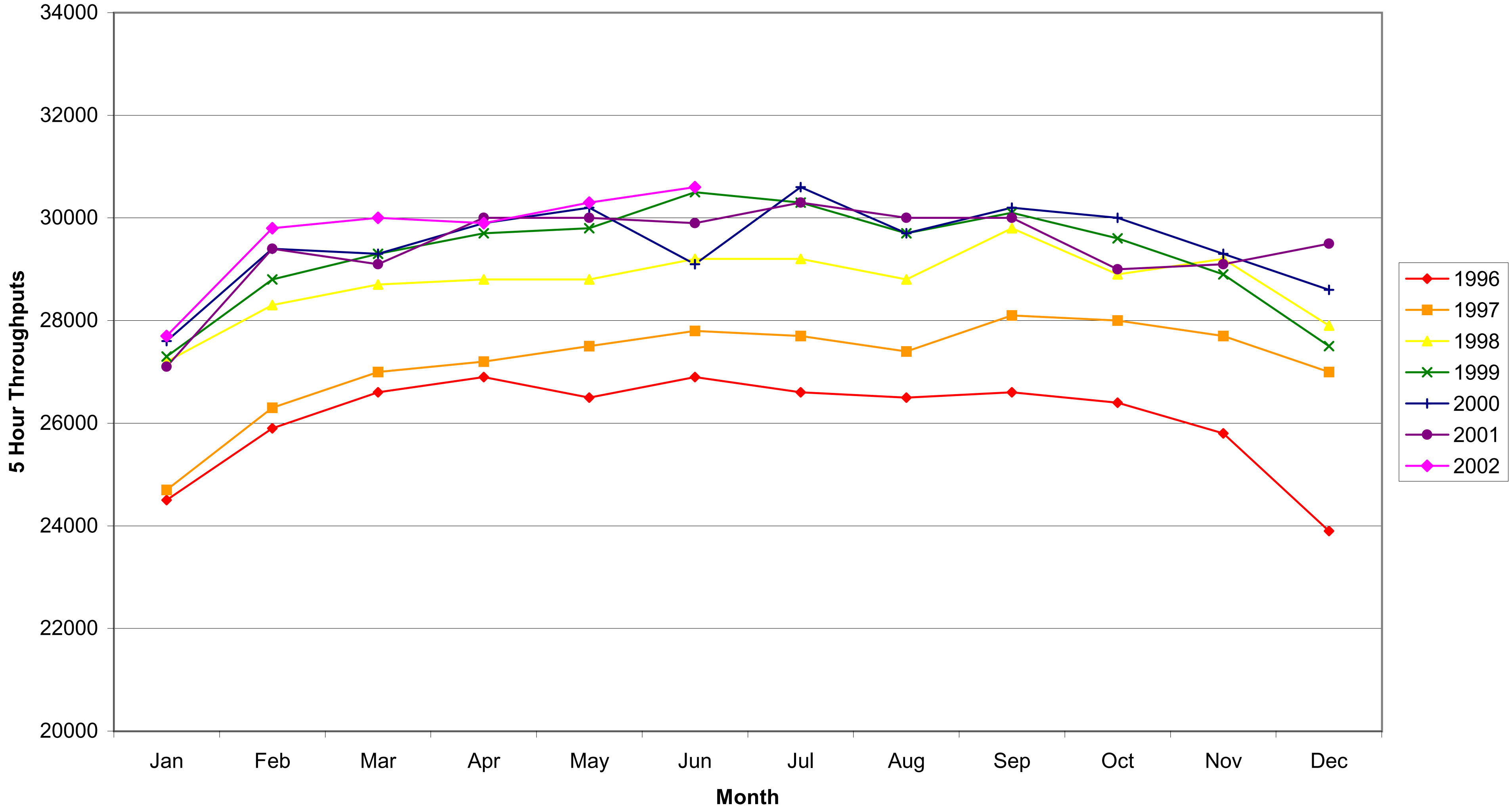


Figure 3: Five Hour Throughputs for the A carriageway for J14-15 section

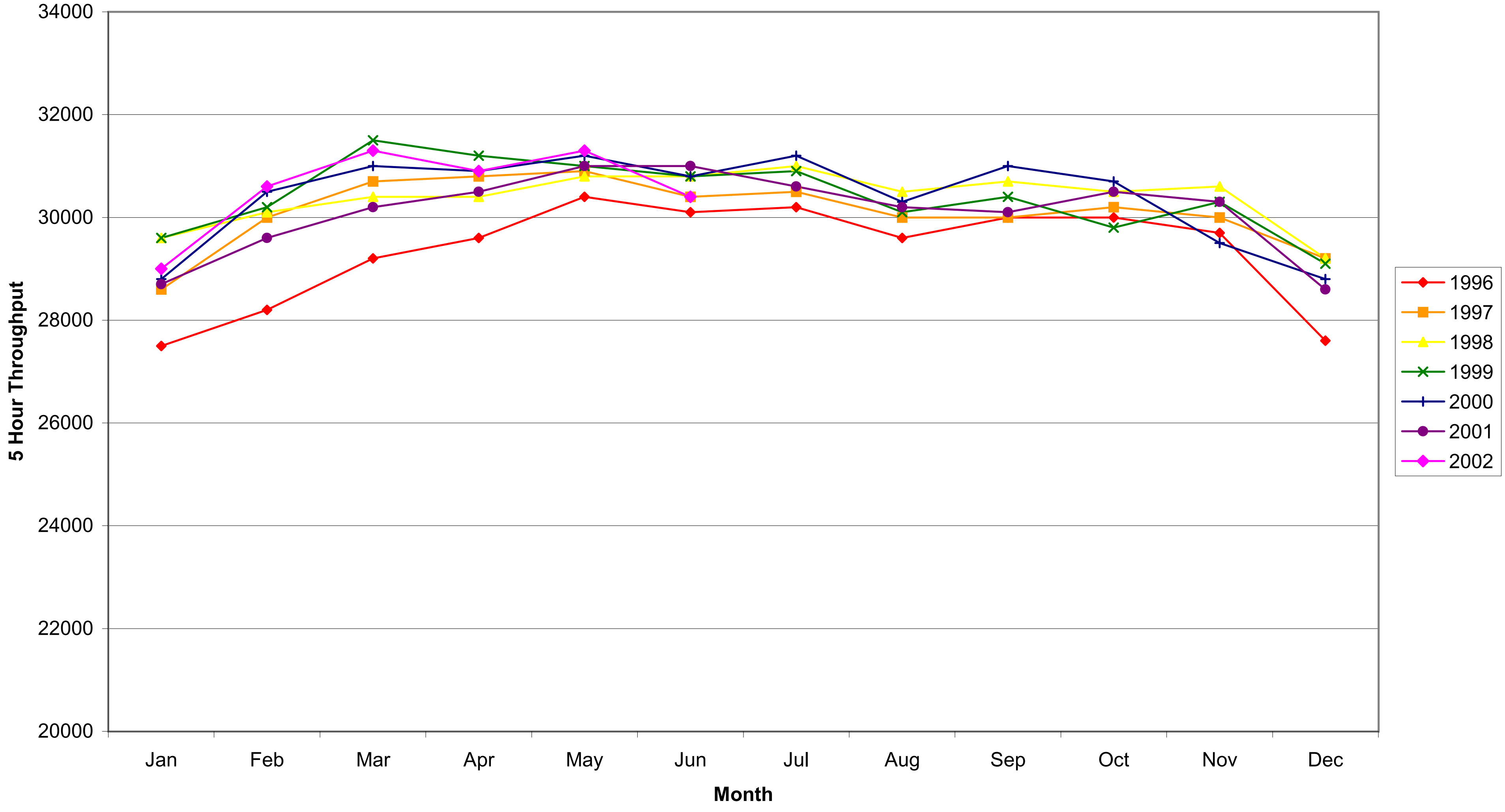


Figure 4: Five Hour Throughputs for the B carriageway for J15-14 section

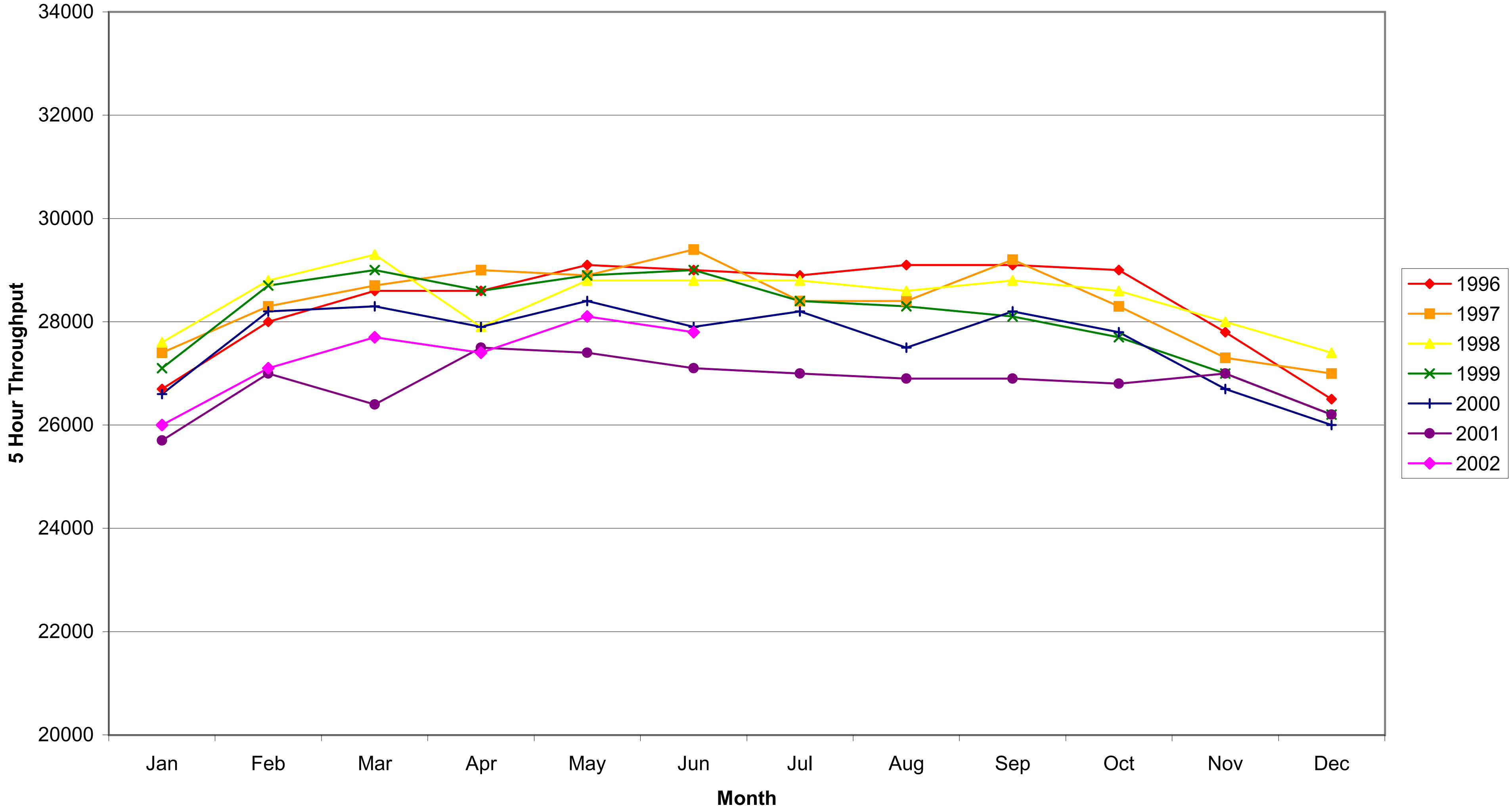


Figure 5: Peak 15 Minute Throughput for the A carriageway for J13-14 section

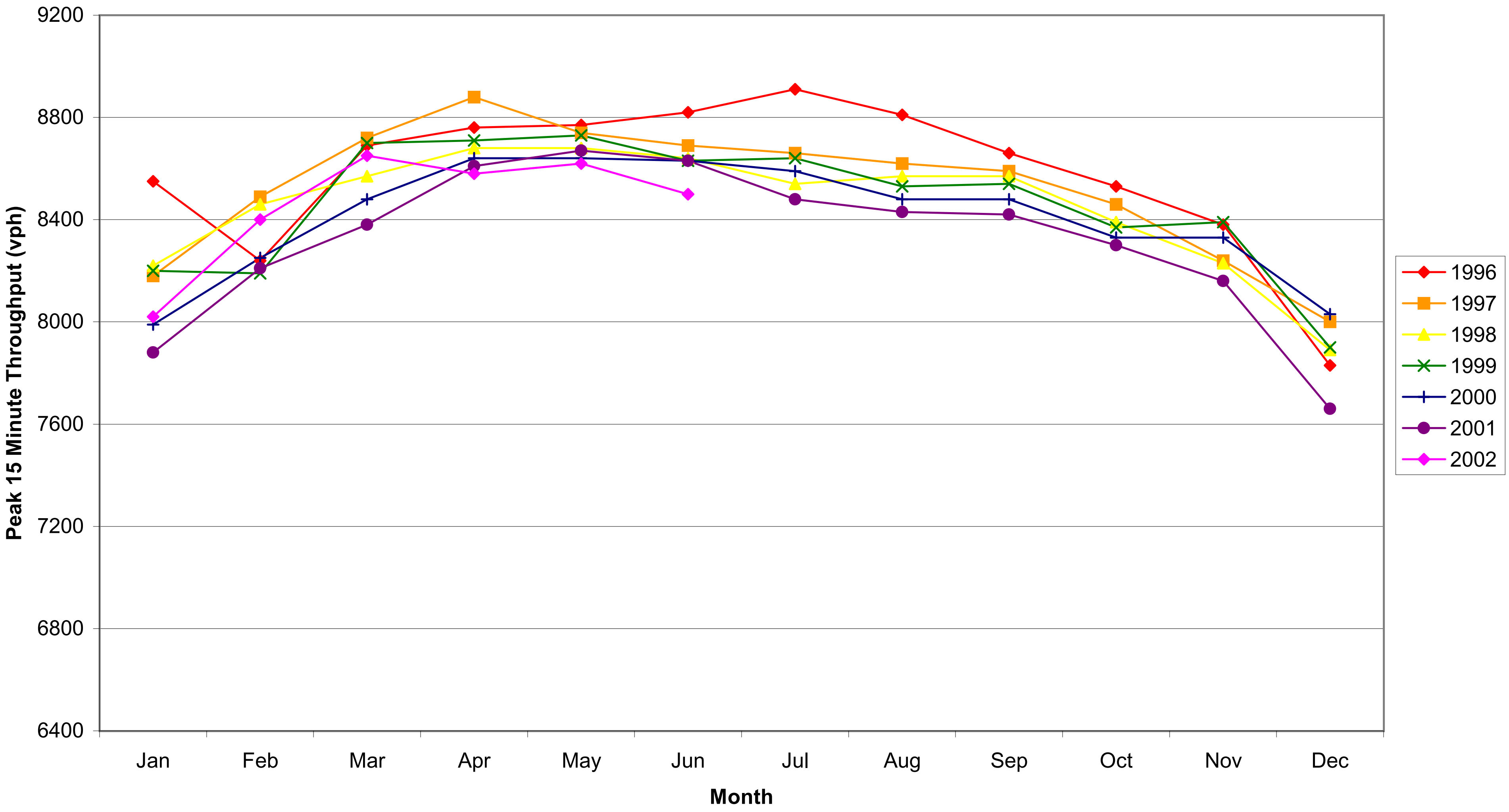


Figure 6: Peak 15 Minute Throughput for the B carriageway for J12-11 section

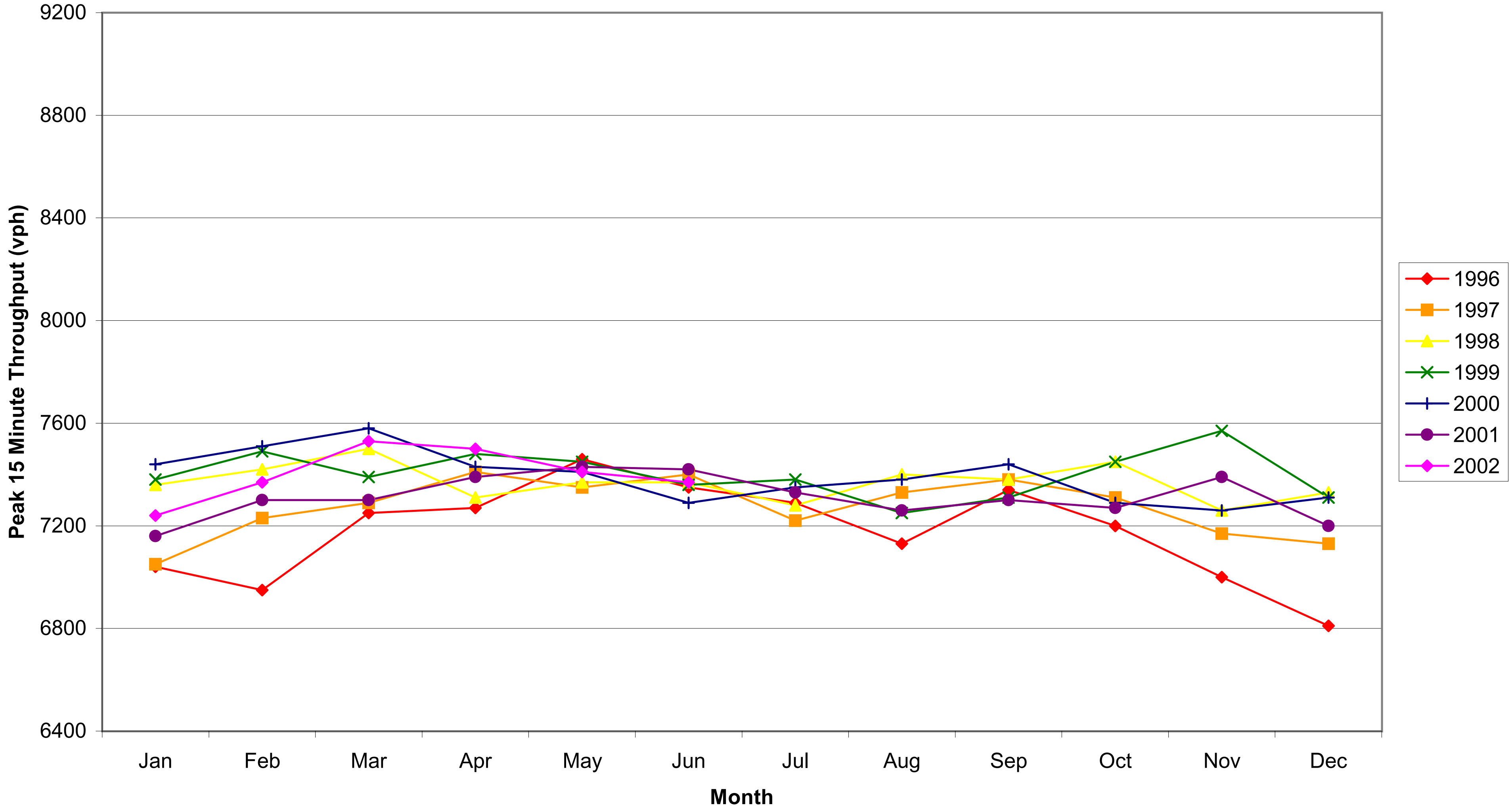


Figure 7: Peak 1 Hour Throughput for the A carriageway for J13-14 section

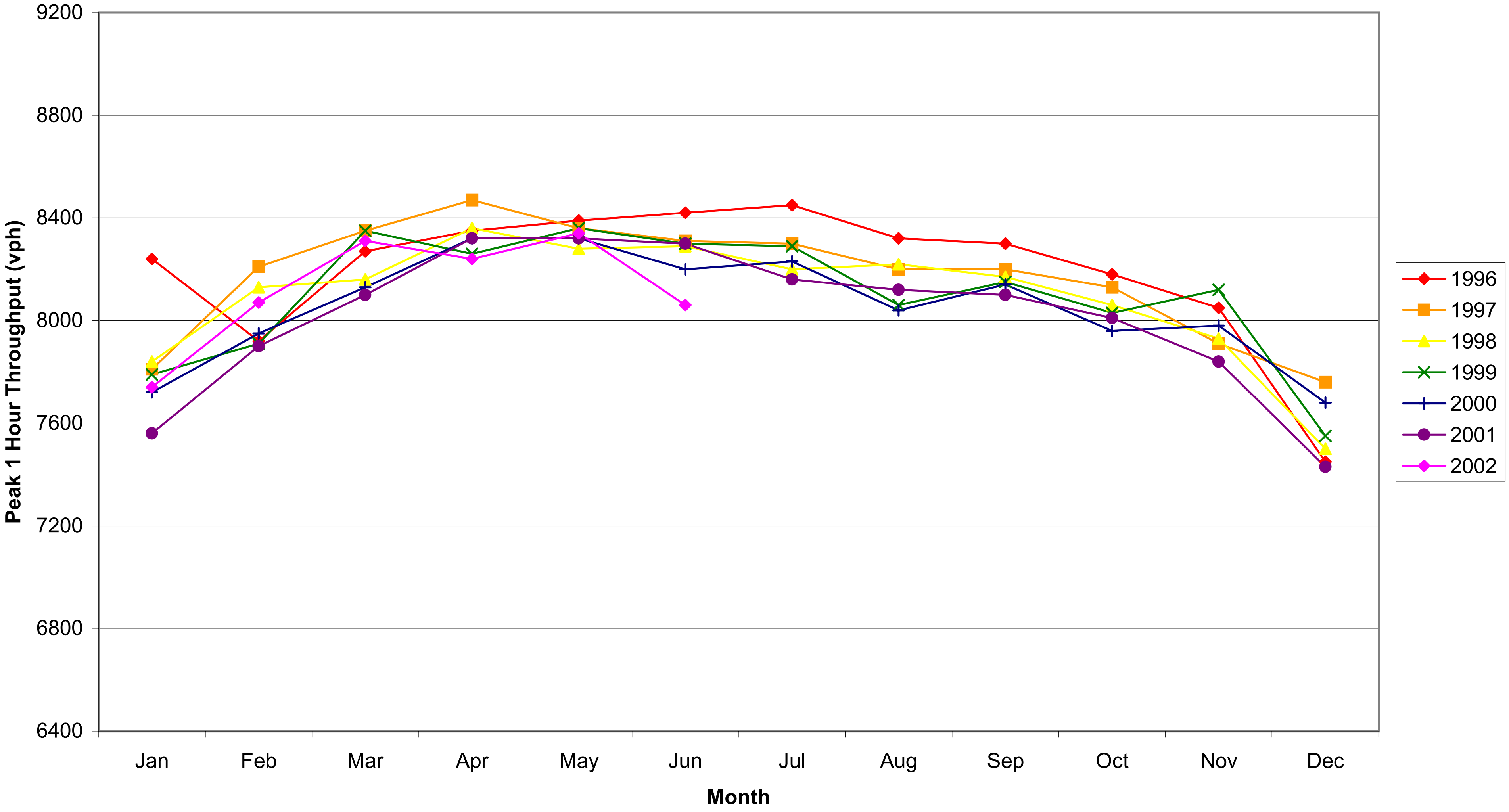


Figure 8: Peak 1 Hour Throughput for the B carriageway for J12-11 section

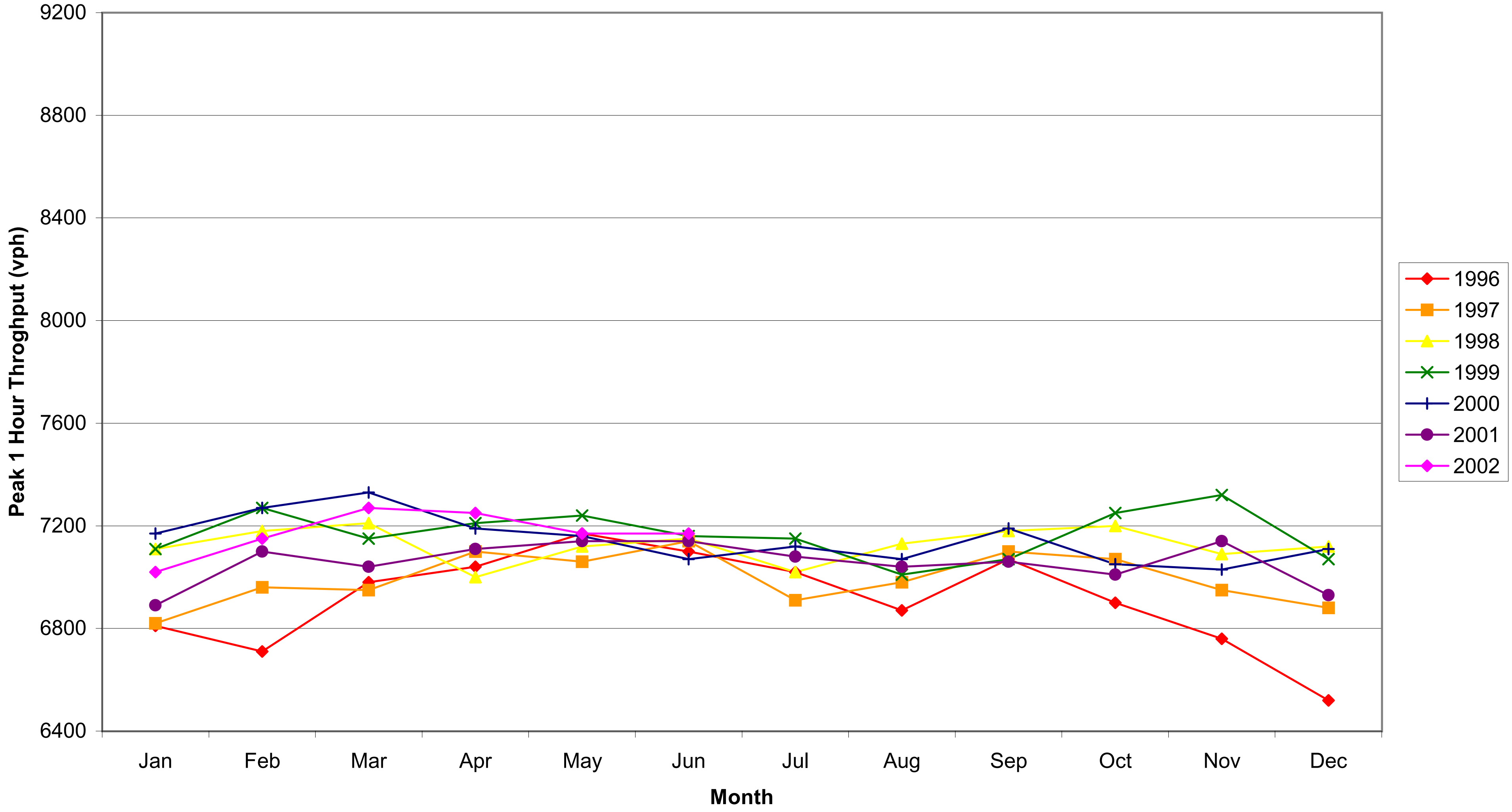


Figure 9: Journey Times for the A carriageway for J11-15 section

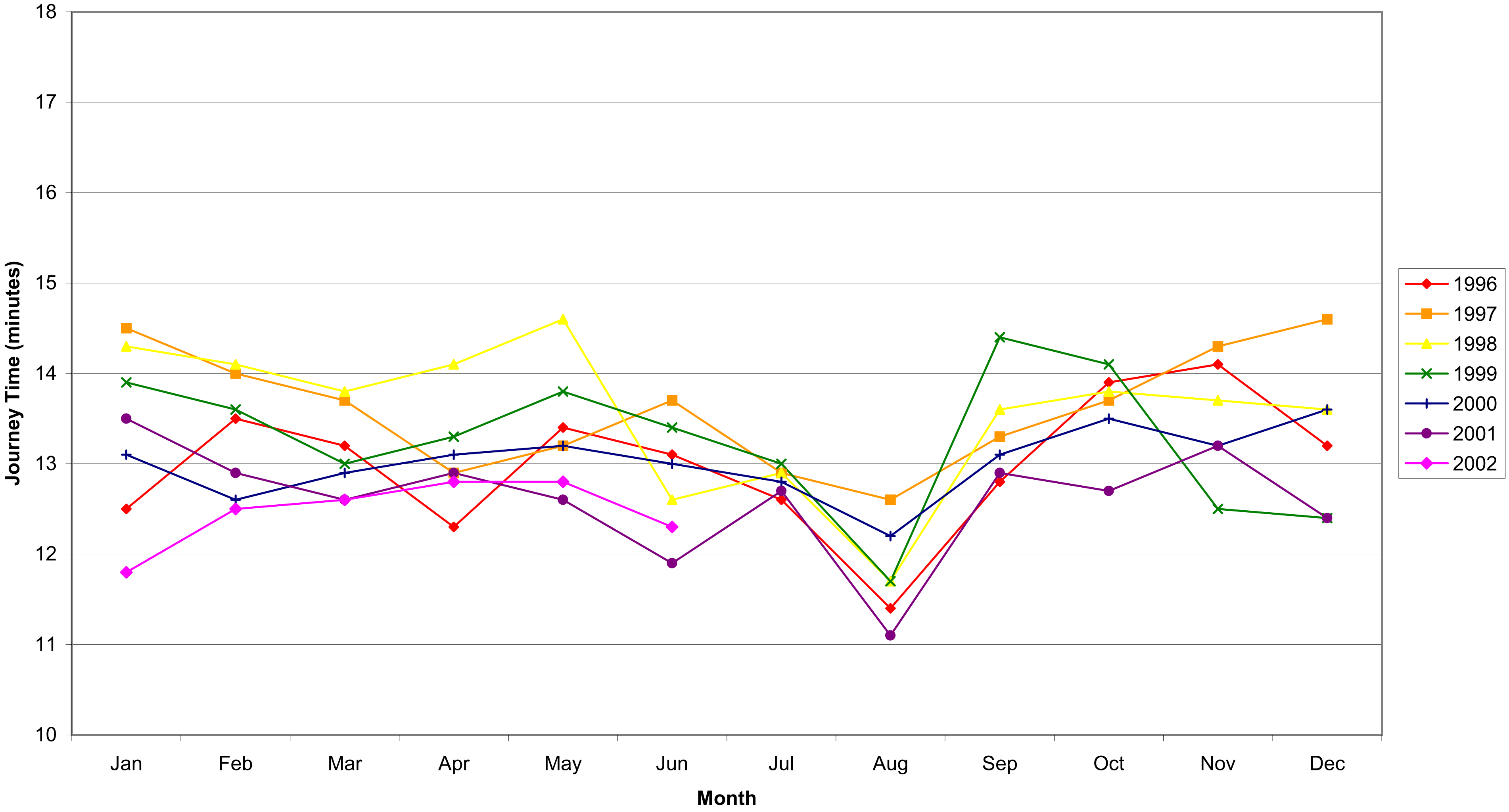


Figure 10: Journey Times for the B carriageway for J15-11 section

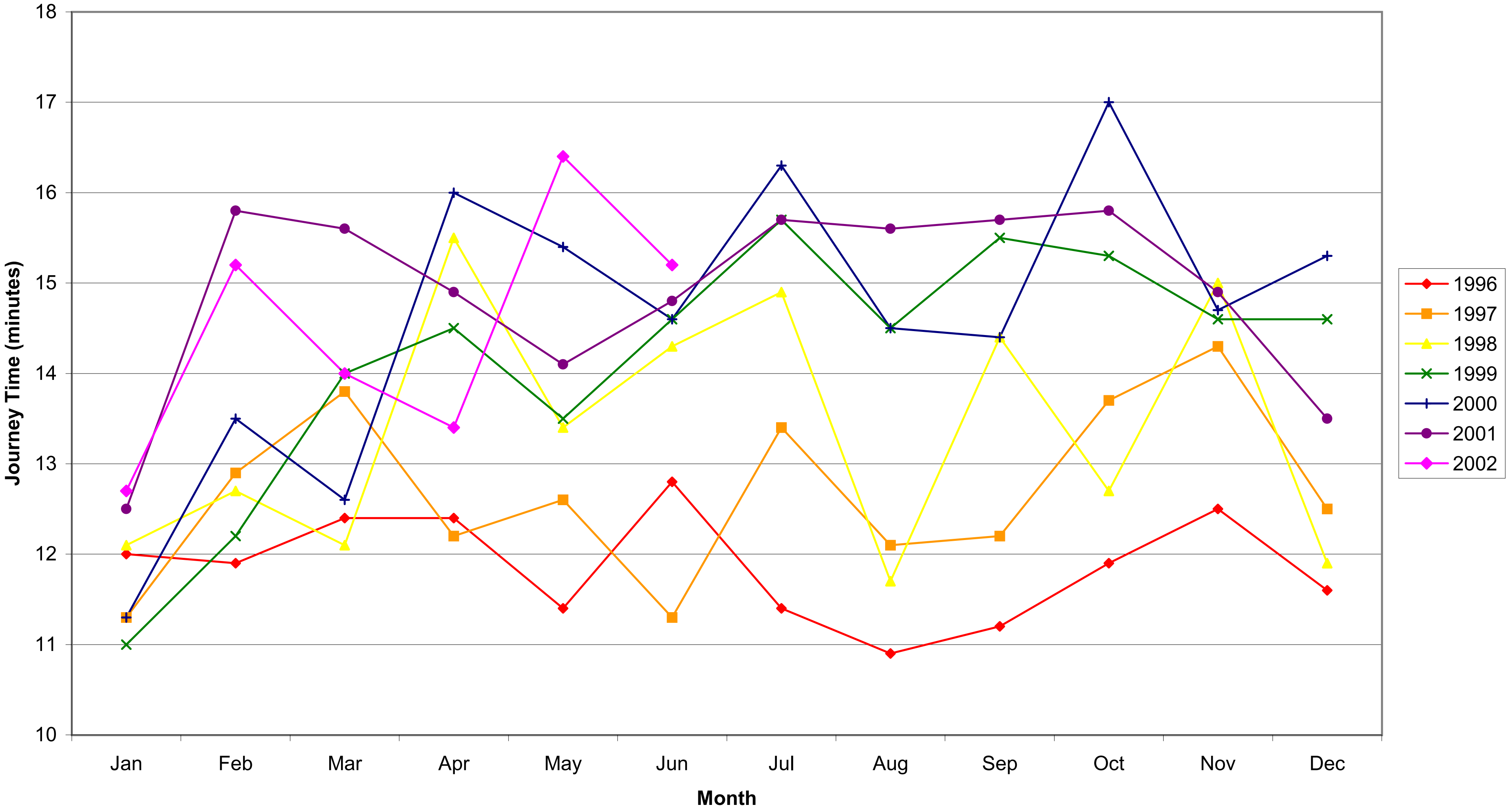


Figure 11: Flow Breakdown for the A carriageway between Junctions 11 to 15

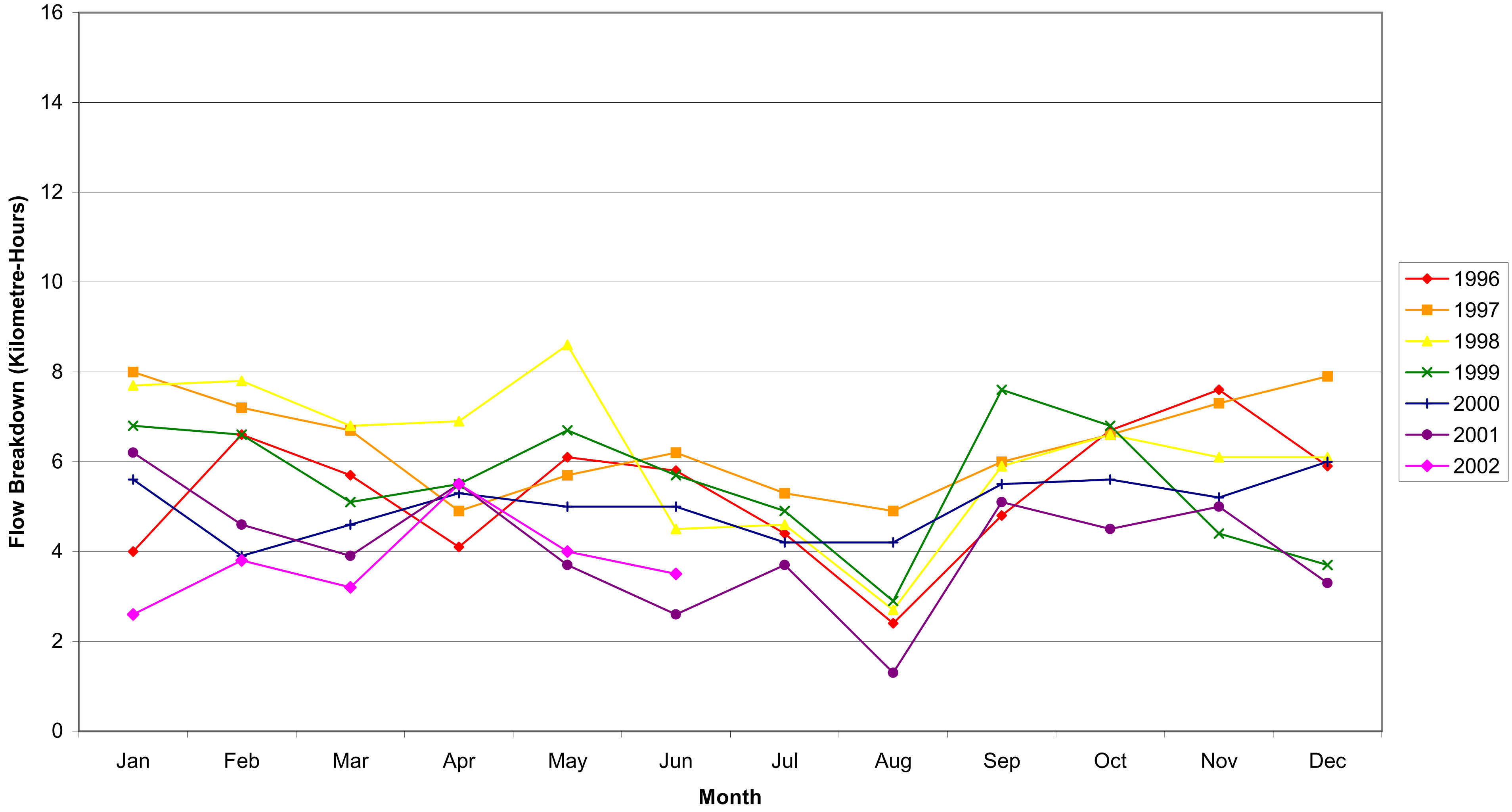
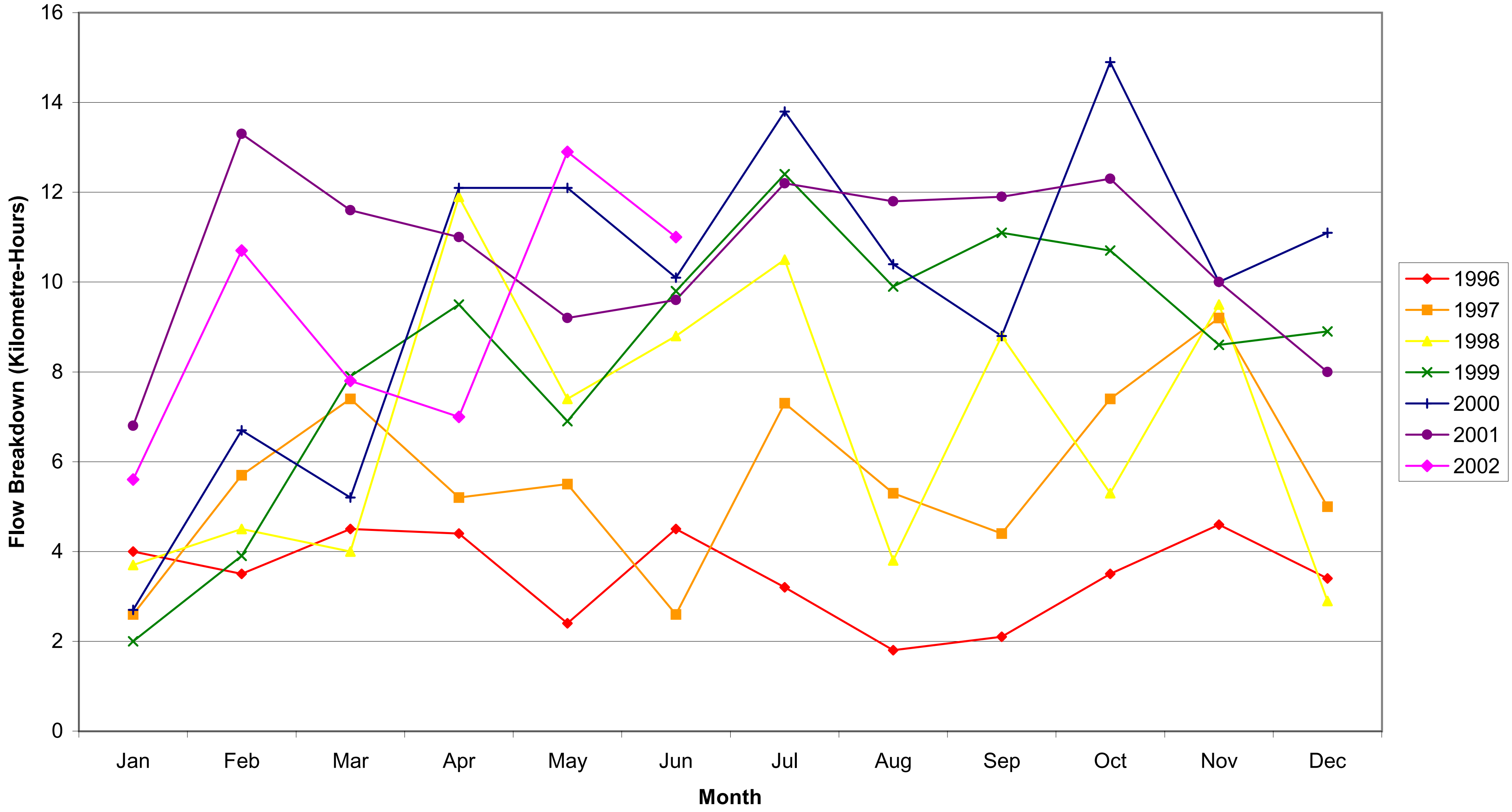


Figure 12: Flow Breakdown for the B carriageway between Junctions 15 to 11



APPENDIX B

THE ROLE OF THE MOTORWAY TRAFFIC VIEWER IN REGULAR MONITORING

B. The Role of MTV in Regular Monitoring

Monitoring activity makes use of a series of graphical utilities, prepared and developed within TRL, and collectively known as the Motorway Traffic Viewer (MTV). This utility is not limited to the M25, but has also been modified to examine traffic patterns on other motorways (e.g. the M60 around Manchester). Traffic patterns observed on the M60 were found to be quite similar in nature to those observed on the M25.

The monitoring tools can be used both for examining traffic and signal data, and gaining insight into the specific problems of a particular motorway. This Appendix seeks to explain the layout of some of the MTV outputs, and how they relate to the motorway traffic.

B.1 The Daily Speed Plot

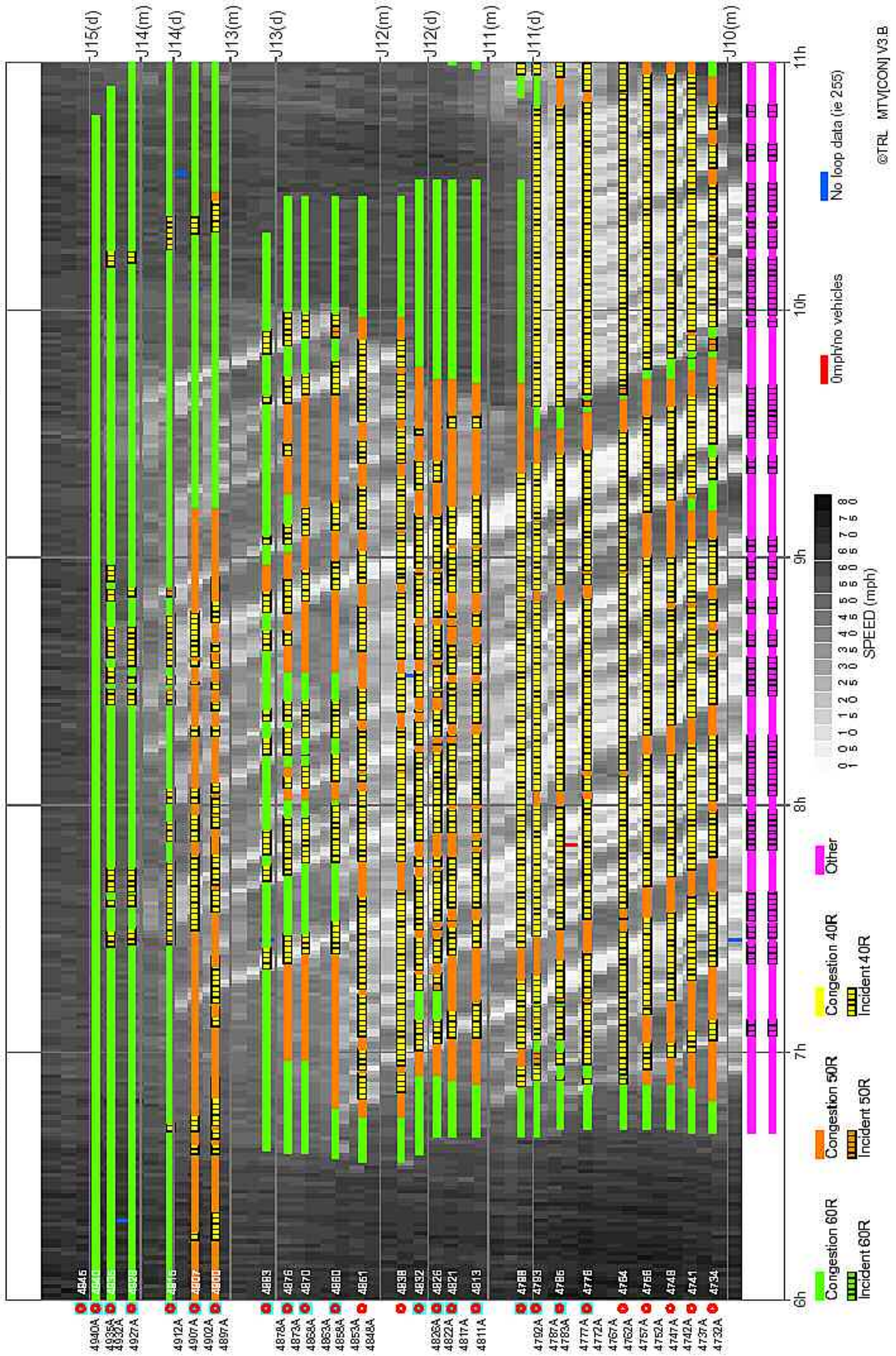
Figure B.1 shows the Daily Speed Plot used as part of the regular monitoring particularly for peak periods. The plot consists of a Signal Setting display superimposed on a ‘Speed Background’. The horizontal axis gives time (in this case, the morning peak from 06:00 to 11:00), and the vertical axis is location (Junction 10 to Junction 15). The left hand axis gives the loop numbers (referenced to nearest marker post), with blue numbers indicating a ‘three lane section’ and black numbers indicating a 'four lane section’. The red circles indicate the location of the MIDAS signs (denoted by an appropriate marker post number) and a blue square indicates the presence of direction signs at that gantry.

The background is defined by the traffic data using a grey scale, allowing the backward propagating region of low speed (known as a ‘shockwave’) to be identified. The shockwaves move upstream through time at a near-constant speed, and are not impeded by the presence of junctions.

With regard to the speed limits, the speed setting at an individual site through time is shown by a horizontal coloured bar. The green colour indicates 60mph, the orange colour indicates 50mph, and the yellow colour indicates 40mph. A solid colour indicates that the signal was set by MIDAS. The addition of a cross-hatching pattern to the colour code indicates that the speed limit was generated by HIOCC instead of MIDAS. When the limits are set manually (e.g. when there is an incident), MTV uses a magenta colour.

The plot has a number of additional features. Red blocks indicate regions where the average speed is between 0 and 1 mph, signifying a complete standstill. Blue regions denote missing data or faulty loop readings. In addition, the plot has the ability to display the actual cause of manual signal settings.

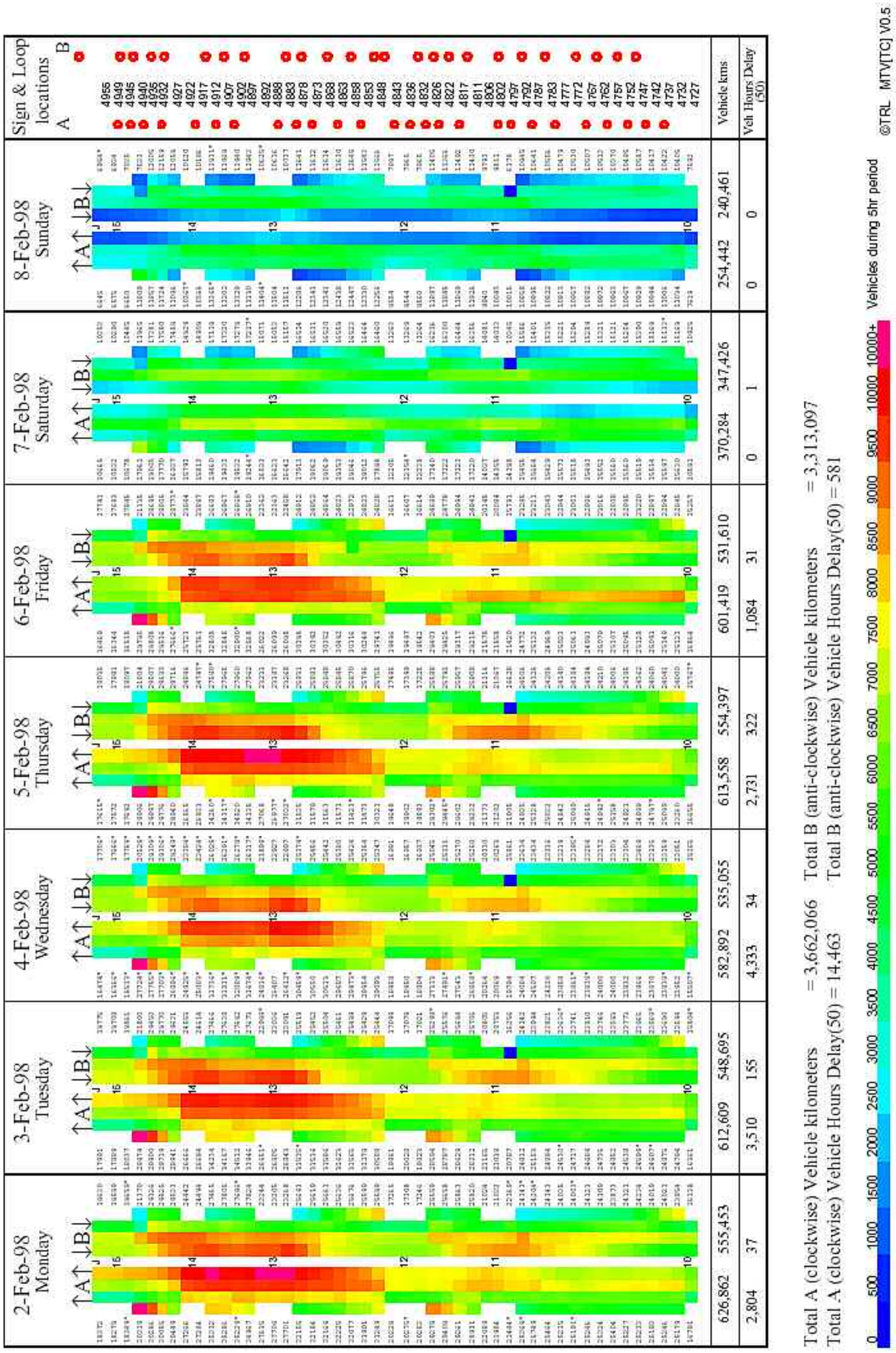
Figure B.1 - Illustration Showing How The Signs Change
M25 Clockwise(A) speeds. Thursday 22-Oct-1998



B.2 The Weekly Traffic Count Plot

Figure B.2 shows the average flows recorded by every loop in the Controlled section for the morning peak period of each day of the week. The nature of traffic distribution across the lanes can be clearly seen, with the two offside lanes sustaining the highest traffic volume. Traffic can also be seen moving into lane 1 as it approaches busy junctions (in particular, Junction 15 on the A carriageway). This plot has the added advantage of being able to monitor the integrity of the data collection system. Anomalies in the colour progression can reveal potential problems with the loops.

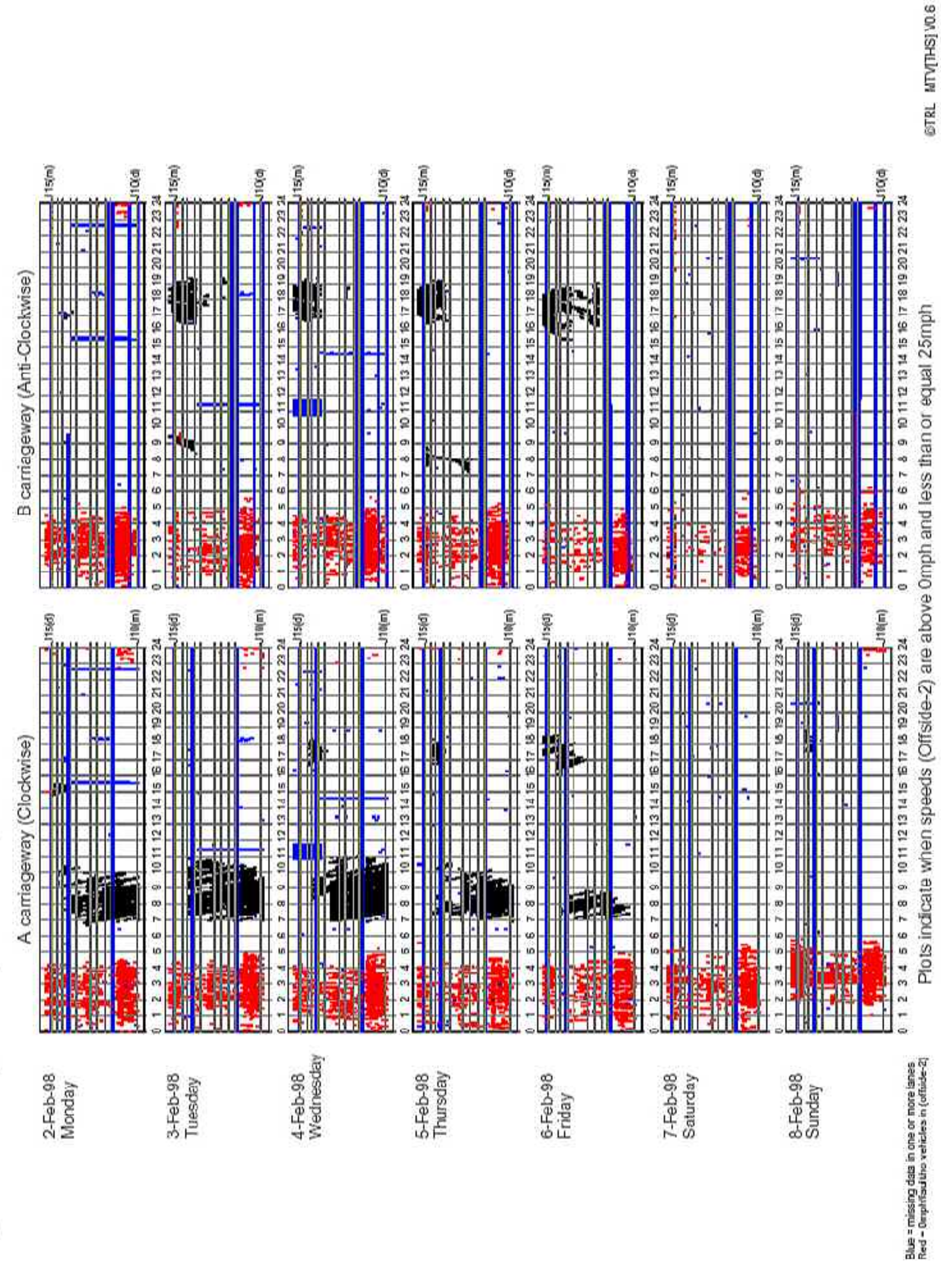
Figure B.2
M25 Traffic Counts and Summary Statistics 6:00hr to 11:00hr



B.3 The Weekly Thumbnail Speed Summary

Figure B.3 shows all the regions of low speed during a particular week on the M25 in a thumbnail sketch format. Monitoring already involves close investigation of the peak periods, but this plot helps identify any other problems occurring outside the peaks. It is used in conjunction with the signal thumbnail plot (see Section B.4) to provide a snapshot of significant events during the week. Black regions denote where speeds were between 0 and 25 mph. Blocks of red indicate instances for which there were no vehicles in that lane during that minute. Prolonged periods of this kind could be due to lane closures. Blue blocks indicate where loops were faulty.

Figure B.3 - Weekly Summary Of Traffic Speeds



B.4 The Weekly Thumbnail Signals Summary

Figure B.4 shows, in thumbnail sketch format, the times for which signals were set during the day. MIDAS speed limits are denoted by the same colour scheme as the daily speed plot (see Section B.1), and HIOCC settings are shown in black. The corresponding speed patterns can be compared and the stability of the signal regime (particularly outside of peak hours) can be monitored.

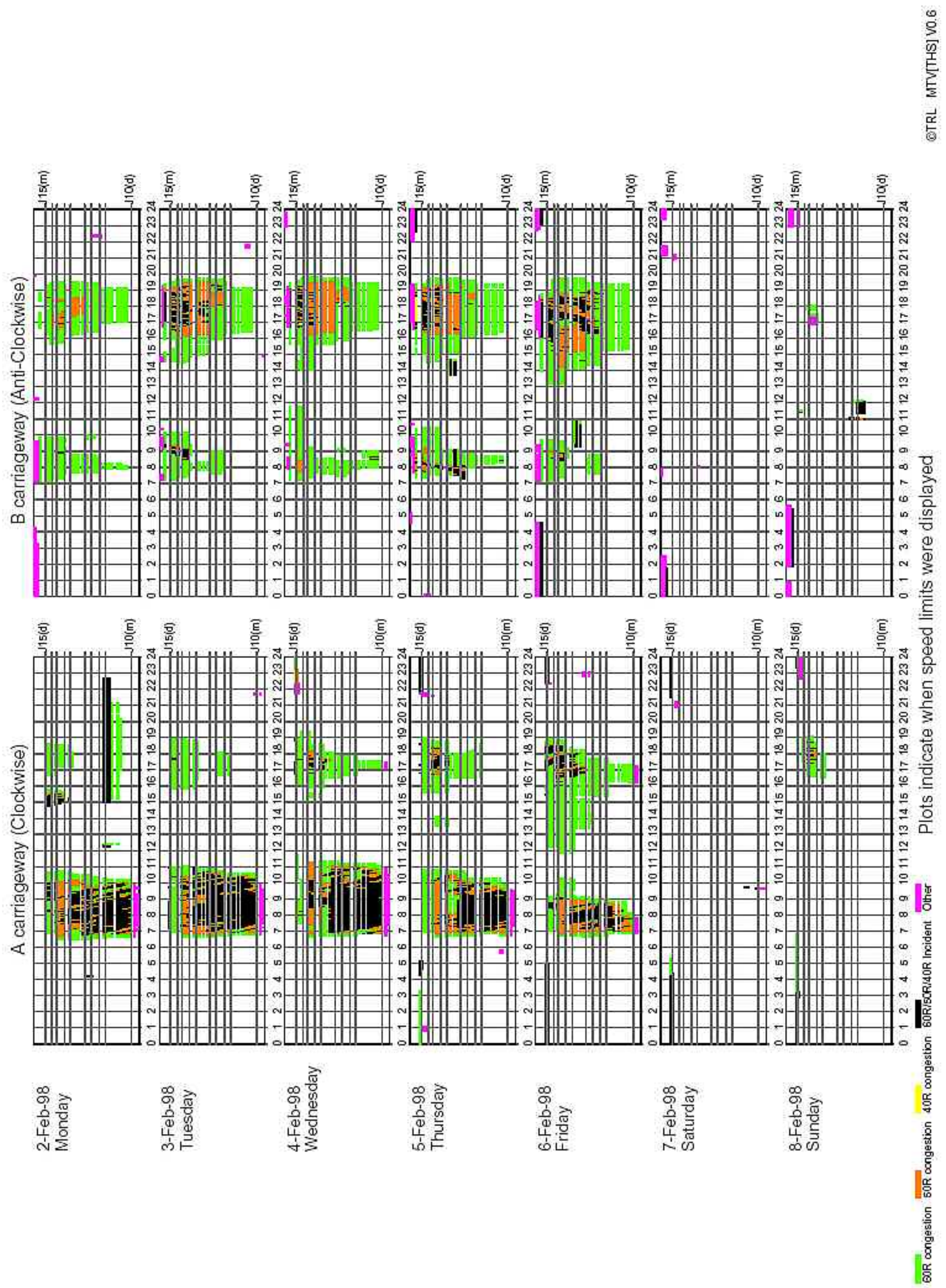


Figure B.4 - Weekly Summary Of Signal Settings

B.5 Final Comments

The extent and the variety of the tools developed for analysing and evaluating the continuous data stream from the MIDAS system gives some indication of the complexity of the relationships and the interaction between signal settings, traffic and local features (such as junctions).

It is evident that the versatility of this approach has continued to provide deeper insight into what is actually happening on the motorway, and an effective means of examining the raw data. There remains much potential within the MTV suite to facilitate a deeper level of research into such areas as compliance and junction effects, as well as a continued ability to provide guidance for the monitoring programme both for the M25 and for other motorways.