Monitoring of the M4 Bus Lane: 2000 to 2002

by T Rees

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MONITORING OF THE M4 BUS LANE: 2000 TO 2002

ISSUE 1

by T Rees (TRL Limited)

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CONTENTS

EXECUTIVE SUMMARY 1

1. INTRODUCTION AND BACKGROUND 2

2. JOURNEY TIMES 4

2.1 THE EFFECT OF INCIDENTS ON JOURNEY TIMES 4
2.2 JOURNEY TIME PROFILES 5
2.3 COMPARISON OF JOURNEY TIMES 6
2.4 JOURNEY TIME RELIABILITY 8
2.4.1 Day to day reliability 8
2.4.2 Within day reliability 8
2.5 JOURNEY TIME TRENDS 9
2.6 CONCLUSIONS 11

3. TRAFFIC SPEEDS 13

3.1 EFFECT OF NEW SPEED LIMIT ON TRAFFIC SPEEDS 13
3.2 SPEED COMPLIANCE 13
3.2.1 Results eighteen months after bus lane opened 14
3.2.2 Results three years after bus lane opened 14
3.2.3 Comparison of speed compliance since 1998 14
3.3 CONCLUSIONS 16

4. USE OF BUS LANE 18

4.1 MOTORCYCLES IN THE BUS LANE 18
4.2 CONCLUSIONS 18

5. CONCLUSIONS 19

6. RECOMMENDATIONS 21

7. REFERENCES 22

MONITORING OF THE M4 BUS LANE: 2000 TO 2002

EXECUTIVE SUMMARY

During 1999, the Highways Agency installed approximately 6km of bus lane on the eastbound M4 between Junctions 3 and 2 into London to encourage the use of public transport. The bus lane was reserved exclusively for buses, coaches and taxis, and its primary aim was to reduce the journey times of buses, coaches and taxis without significantly affecting other vehicles.

The bus lane scheme included new road layouts at the start and end of the bus lane, and new lower speed limits of 50mph through Junctions 4 and 3, and 40mph approaching the start of the elevated section into London.

To determine whether the objectives were met and whether any undesirable side effects were produced, traffic conditions before and after the opening of the bus lane were compared (Rees, White & Quick, 2000). The principal effects were on journey times:

- During peak periods, both buses and cars were benefiting from the bus lane scheme. On average, each bus was saving 3.5 minutes and each car was saving 1 minute during each peak period.
- During off-peak periods, journey times for both buses and cars increased by 1 minute as a result of the lower speed limits along the section.
- Journey times for all vehicles became more reliable following the introduction of the bus lane.

The reduced speed limits were imposed for safety reasons. The Highways Agency felt that the 50mph speed limit through Junctions 4 and 3 could be increased to 60mph, and still provide safety benefits. The new speed limit was introduced on 23rd July 2002. At the same time, motorcycles were allowed to use the bus lane.

The bus lane scheme continues to meet most of the objectives set out before the scheme was installed. The saving in journey times during peak periods is still present, although it varies considerably from year to year.

The increase in the speed limit from 50mph to 60mph has had only a small impact during off-peak periods, as traffic speeds between Junctions 4 and 2 were already close to 60mph. During peak periods, it was not expected that journey times would benefit from the increase in speed limits, as drivers cannot usually travel in excess of 50mph.

There has been little change in journey time reliability in the years following the introduction of the bus lane. The current journey time reliability is very similar to that in 1999.

Following the opening of the bus lane to motorcycles, 100 motorcycles per day have been detected using the bus lane. The presence of the motorcycles has had no impact on the operation of the bus lane.

It is recommended that a further study should be carried out into the causes of congestion on the elevated section, as this congestion is increasing, causing additional congestion on the bus lane section.

It is also recommended that the current speed limits and enforcement levels should not be changed, as they are appropriate for the traffic conditions.

MONITORING OF THE M4 BUS LANE: 2000 TO 2002

1. INTRODUCTION AND BACKGROUND

During 1999, the Highways Agency installed approximately 6km of bus lane on the eastbound M4 between Junctions 3 and 2 into London to encourage the use of public transport. The bus lane was reserved exclusively for buses, coaches and taxis, and its primary aim was to reduce the journey times of buses, coaches and taxis without significantly affecting other vehicles.

The bus lane scheme included new road layouts at the start and end of the bus lane, and new lower speed limits of 50mph through Junctions 4 and 3, and 40mph approaching the start of the elevated section into London.

To determine whether the objectives were met and whether any undesirable side effects were produced, traffic conditions before and after the opening of the bus lane were compared (Rees, White & Quick, 2000). The principal effects were on journey times:

- During peak periods, both buses and cars were benefiting from the bus lane scheme. On average, each bus was saving 3.5 minutes and each car was saving 1 minute during each peak period.
- During off-peak periods, journey times for both buses and cars increased by 1 minute as a result of the lower speed limits along the section.
- Journey times for all vehicles became more reliable following the introduction of the bus lane.

The reduced speed limits were imposed for safety reasons. The Highways Agency felt that the 50mph speed limit through Junctions 4 and 3 could be increased to 60mph, and still provide safety benefits. The new speed limit was introduced on 23rd July 2002. At the same time, motorcycles were allowed to use the bus lane.

This report describes the operation of the bus lane from 2000 to 2002, with particular emphasis on the effects of the changes made during July 2002. The report concentrates on the operation of the scheme during October, November and the start of December for each year, as this was the period that was examined in detail during 1998 and 1999.

Traffic data, comprising speeds and flows, have been collected from the eastbound M4 into London from west of Junction 4 (the Heathrow junction) to the start of the elevated section (leading to Junction 2). The performance of the M4 between Junctions 4 and 2 has been measured by estimating journey times throughout each day. The journey times for both buses and cars have been compared to determine the effect of the scheme on all types of traffic.

The analysis of the effects of the bus lane has been performed in two ways. Typical days (days without incidents) have been compared to determine the effect of the bus lane on an average day. The random effect of incidents is therefore excluded. An analysis of all weekdays has also been carried out to account for the effect of incidents.

Other aspects of traffic behaviour and composition have also been analysed to determine whether the bus lane scheme has been effective. These include compliance with speed limits and an analysis of bus lane usage. Analyses of safety and general traffic flows are outside the scope of this report; they are being reported by Mouchel Consulting Limited as part of the M25 Sphere contract.

Recommendations have been made about the suitability of the speed limits and the enforcement levels, and a further study into reducing congestion on the bus lane section.

Most of this report deals with traffic conditions on weekdays, as these are the days with the highest flows and the worst congestion. Weekends have been analysed separately, as traffic patterns are different to weekdays.

2. JOURNEY TIMES

Journey times are an important indicator of the performance of the M4, as they measure what drivers experience as they drive through the section, and they contribute to an estimate of the economic effect of the bus lane scheme. Benefits can be achieved by a reduction in the journey time, and also by making the journey time more reliable, so that drivers can better predict how long their journeys will take.

Journey times have been calculated for the section of carriageway between Junction 4 and the start of the elevated section (a distance of 8.4 km) by tracking the progress of typical vehicles through the section. The journey time reliability has also been analysed. The algorithm for calculating the journey times is the same as used for the previous report (Rees, White & Quick, 2000).

Before the bus lane was opened, journey times for typical vehicles were calculated by averaging the journey times in each of the lanes. All vehicle types (eg cars and buses) had similar journey times in congested conditions. After the bus lane was opened, journey times for priority vehicles (buses and taxis) and non-priority vehicles (eg cars) were calculated separately. Buses were assumed to travel in the bus lane. Journey times for cars were calculated by averaging the journey times in each of the available lanes. Taxis were assumed to travel at the quicker of the car and bus journey times: within this report, all references to bus journey times during congested conditions also apply to taxis.

This section describes the journey times for cars and buses, with particular reference to October, November and the start of December. The journey time analysis has been divided into peak and off-peak periods. The peak periods have been selected to be the periods with the greatest congestion. To try to ensure that all regular congestion is included, and that the analysis of peak periods only covers times when congestion is likely to be present, each of the peak periods lasts for three hours. The morning peak period is from 6:30 to 9:30; the evening peak period is from 17:30 to 20:30.

2.1 THE EFFECT OF INCIDENTS ON JOURNEY TIMES

The performance of the bus lane scheme is determined by comparing traffic conditions from year to year. When an incident occurs, it can cause a random variation in the normal traffic behaviour and, in particular, it can cause a large increase in journey times. Incidents can be assumed to occur randomly.

The performance comparisons can cover all days (ie including incidents), or they can only deal with typical days (ie excluding incidents). Both methods of comparison have been used to monitor the M4, and the particular method used at each stage has been made clear in this report.

Most of the journey time comparisons deal with typical days (ie excluding incidents). The most appropriate method to use varies according to the information required and the time period over which the data is being analysed:

- When dealing with short time periods (eg one week), typical days (excluding incidents) are used for comparison. This is because the inclusion of any days on which there was an incident would have an undue effect and would distort the results.
- To identify small differences in the traffic behaviour, typical days are analysed because the inclusion of incidents in the analysis would swamp the small differences. This also applies to the analysis of journey time reliability.

An analysis of all days (including incidents) is performed for two scenarios:

- By analysing all days, the effect of incidents can be included. It is possible that the installation of the bus lane has caused the overall incident rate to change (eg by making the road safer/more dangerous) or affected the traffic delay due to the severity of accidents. Including all days enables any effect to be included in the analysis.

- When comparing long periods (eg the 9-week "before" and "after" periods), the effect of individual incidents will not be as great as for short periods, and the distribution of incidents is likely to be similar. Therefore, for long periods of comparison, all days (including incidents) are used.

2.2 JOURNEY TIME PROFILES

The report on the first year of operation (Rees, White & Quick, 2000) contains the journey time profiles for 1998 and 1999, before and after the bus lane opened.

Figures 1 to 6 show the average journey times on each day of the week for the corresponding periods during 2000, 2001 and 2002 (excluding days with incidents). Figures 1, 3 and 5 show the journey times for cars; Figures 2, 4 and 6 show the journey times for buses (and taxis). These show the following trends:

- The congestion during the morning peak period starts at approximately the same time on each weekday. The congestion patterns up to 9:30 are similar from Mondays to Thursdays, with maximum journey times reaching similar levels. On Friday mornings, the congestion is less severe and lasts for a shorter period.
- By 9:30, the congestion has almost cleared on most mornings. After 9:30 on many days (Thursdays in particular), journey times increase and congestion does not fully clear until approximately 12:00.
- The congestion during the evening peak period starts and finishes at similar times on each weekday. Congestion on Friday evenings is slightly worse than on other weekdays, but not to the extent observed on other motorways (eg the M25 and the M6).
- There is some congestion on Saturday lunchtimes, although there was very little during 2001. There is little congestion on Sunday lunchtimes. Congestion levels on Sunday evenings are similar to weekday evenings, but the congestion lasts slightly longer.
- Buses suffer little congestion, with maximum journey times of under 10 minutes. There is no congestion on the bus lane itself; buses are, however, delayed by congestion before the start of the bus lane.

Figure 7 shows summary profiles for car journey times for typical weekdays (excluding incidents), comparing the "before" period against the corresponding periods during 1999, 2000, 2001 and 2002. Figure 8 shows a similar profile, but including weekdays with incidents. These show that:

- There is considerable variability between years during the "after" period". For most of the day, congestion was lowest during 1999 and 2001, and highest during 2000.
- During off-peak periods, journey times during 2002 are the lowest they have been since the bus lane opened. This is likely to be a result of the increased speed limit through Junctions 4 and 3. Night-time journey times have been reducing from year-to-year since 1999.
- The maximum journey times for cars are lower in almost all cases following the introduction of the bus lane. For typical days, the peak journey times in the morning were lower in 1999, 2001 and 2002, and slightly higher in 2000. In the evening, the peak journey times were lower for all years.
- Journey times for cars are longer on some days between 9:00 and 11:00. Congestion in the morning often takes longer to clear with the bus lane open. When the bus lane opened, the traffic behaviour changed from queueing to shockwaves, and this has made the traffic more susceptible to poor weather. Rain causes traffic within shockwaves to leave larger headways, which results in the congestion lasting longer. Rain has less of an impact on queueing traffic: traffic speeds are slower within the queue, so the headways are less affected.

- There is no major difference in the results between comparing typical days and days with incidents over a long period.

Figures 9 and 10 show summary profiles for bus journey times for typical weekdays (excluding incidents), and for all weekdays (including incidents). These show that:

- There has been little change in bus journey times from year to year. The trends are similar to those for cars: journey times were worse in 2000, and during off-peak periods, journey times during 2002 are the lowest they have been since the bus lane opened.

It is not known why the journey times for cars and buses were highest during 2000, and lowest during 1999 and 2001. This year-to-year pattern has not been observed on nearby motorways such as the M25 (Dixon *et al*, 2002).

2.3 COMPARISON OF JOURNEY TIMES

Tables 1 and 2 compare typical weekday journey times during October/November/December 1998 (before the bus lane opened) with the average journey times for cars and buses during the corresponding periods during 1999, 2000, 2001 and 2002. Days with incidents have been excluded from this table. Values in green indicate that the performance is better now that the bus lane is open, and values in red show that the performance is worse than before the bus lane was installed.

Table 1 – Typical journey times for cars (excluding incidents)

Time of day (weekday)	Percentage of daily flow	Journey time (minutes)				
		"Before"	"After"			
		1998	1999	2000	2001	2002
0630-0930	19%	10.1	9.4	11.7	9.7	10.8
0930-1730	45%	5.1	6.1	6.8	5.8	5.9
1730-2030	19%	9.9	9.2	9.8	8.0	8.3
2030-0630	17%	4.7	5.8	5.6	5.4	5.2

Table 2 – Typical journey times for buses (excluding incidents)

Time of day (weekday)	Percentage of daily flow	Journey time (minutes)				
		"Before"	"After"			
		1998	1999	2000	2001	2002
0630-0930	19%	10.1	7.2	7.9	7.5	7.6
0930-1730	45%	5.1	6.1	6.2	6.0	5.8
1730-2030	19%	9.9	7.2	7.4	6.9	6.9
2030-0630	17%	4.7	5.9	5.8	5.7	5.5

During the night-time period, journey times for both cars and buses have been decreasing over the years. This is likely to be a result of drivers choosing to travel at the speed they think is appropriate for the conditions, rather than complying with the speed limit. When the new speed limits were originally installed in 1999, compliance was better, as drivers were more cautious following the introduction of a new scheme. As drivers have become more familiar with the scheme, and as the speed limits have not been rigorously enforced, the average speeds have increased. Therefore, the increase in the speed limit from 50mph to 60mph has only had a small impact.

The night-time journey time for cars of 5.8 minutes during 1999 represents an average speed of 54mph (just in excess of the speed limit). By 2001, the night-time journey time for cars had reduced to 5.4 minutes (an average speed of 58mph). Following the increase in the speed limit to 60mph, the night-time journey time for cars reduced to 5.2 minutes (an average speed of 60mph). As part of the measured journey is within a 40mph speed limit area, drivers are still exceeding the speed limit.

Journey times for buses and taxis during the night-time period have similarly reduced.

During the inter-peak period, there is occasional congestion that delays traffic (especially cars). Journey times are more variable than during the night-time period, but journey times have generally been reducing from year to year.

During the peak periods, buses are continuing to save time compared to before the bus lane was open. Cars are saving time during the evening peak periods, but during the mornings, the typical journey times are sometimes longer than they were in 1998. This is likely to be a result of the general unpredictability of traffic conditions on the elevated section during the mornings.

It was not expected that journey times during the peak periods would benefit from the increase in speed limits from 50mph to 60mph, as drivers cannot usually travel in excess of 50mph.

Tables 3 and 4 compare the average weekday journey times for cars and buses for all days (including those with incidents).

Table 3 – Average journey times for cars (including incidents)

Time of day (weekday)	Percentage of daily flow	Journey time (minutes)				
		"Before"	"After"			
		1998	1999	2000	2001	2002
0630-0930	19%	11.5	10.2	12.1	10.1	11.3
0930-1730	45%	5.4	6.4	7.6	6.0	6.5
1730-2030	19%	10.2	9.6	11.5	9.6	9.8
2030-0630	17%	4.7	5.9	5.7	5.5	5.3

Table 4 – Average journey times for buses (including incidents)

Time of day (weekday)	Percentage of daily flow	Journey time (minutes)				
		"Before"	"After"			
		1998	1999	2000	2001	2002
0630-0930	19%	11.5	7.4	8.0	7.6	7.7
0930-1730	45%	5.4	6.1	6.4	6.0	5.9
1730-2030	19%	10.2	7.3	7.8	7.4	7.3
2030-0630	17%	4.7	5.9	5.8	5.7	5.5

The time savings are broadly comparable with those in Tables 1 and 2. Journey times for cars are showing a benefit during the mornings of 2002, and a disbenefit during the evenings of 2000, in contrast to the "typical" days. This is because each incident has a different effect: the incidents in the mornings of 2002 were relatively minor, and the incidents in the evenings of 2000 were more severe.

Buses achieve greater savings in the analysis of all days (compared to those for typical days) because the buses obtain an additional benefit from the bus lane when an incident occurs, as they can avoid the congestion between Junction 3 and the start of the elevated section.

2.4 JOURNEY TIME RELIABILITY

Reliability of journey times is important as it enables drivers and passengers to predict their arrival times. This is especially important for bus companies, who are running scheduled services to a timetable. The main measure of reliability is the day to day reliability, which shows how well drivers will be able to predict their arrival times if they leave at the same time each day.

2.4.1 Day to day reliability

Figure 11 shows the variability (measured by the standard deviation) of the journey times for cars for typical weekdays (excluding incidents), comparing the "before" period against the corresponding periods during 1999, 2000, 2001 and 2002. Figure 12 shows a similar profile, but including weekdays with incidents. A low variability indicates greater reliability. These show that:

- The journey times for all vehicles are very reliable before 7:00, as suggested in Figures 1 to 6. Drivers arriving at the same time each day should be able to predict their journey time over this stretch of road to within a minute (provided there are no incidents).
- The journey time reliability for cars between 7:00 and 9:00 has remained unchanged since 1998.
- The reliability for cars between 9:00 and 13:00 became worse following the introduction of the bus lane, as the time that the congestion clears is now more variable.
- The poor reliability in the evenings before the bus lane opened indicates that, although congestion levels was lower than in the mornings, they were also less predictable. Once the bus lane opened, the reliability improved, indicating that car journey times during the evening peak are more predictable than they used to be.
- There has been little change in journey time reliability in the years following the introduction of the bus lane. The current journey time reliability is very similar to that in 1999.
- The inclusion of incidents results in a large increase in variability (see Figure 12), as journey times can be very large if an incident occurs, and the extent of the delay depends on the details of the incident. The variability from year to year varies according to the distribution of incidents, but the overall reliability has not changed much since 1998.

Figures 13 and 14 show the variability of the journey times for buses for typical weekdays (excluding incidents), and for all weekdays (including incidents). These show that:

- The journey time reliability for buses has improved throughout the day since the bus lane opened.
- There has been little change in journey time reliability in the years following the introduction of the bus lane. The current journey time reliability is very similar to that in 1999.
- Now that the bus lane is open, bus journey times are reliable even when an incident occurs.

2.4.2 Within day reliability

Another measure of journey time reliability is the reliability within a day. This shows how well drivers will be able to predict their journey time if they vary their departure time by up to an hour on a particular day.

Tables 5 and 6 show the variability (standard deviation) of these journey times for cars and buses for typical weekdays during October/November/December 1998 (before the bus lane opened) and for the corresponding periods during 1999, 2000, 2001 and 2002. Values in green indicate that the variability is smaller now that the bus lane is open, values in yellow show that there has been little or no change (0.1 minute or less), and values in red show that the variability is larger.

Table 5 – Journey time reliability for cars by time period (typical weekdays)

Time period (weekday)	Percentage of daily flow	Variability (minutes)				
		"Before"	"After"			
		1998	1999	2000	2001	2002
0630-0730	7%	3.4	2.5	3.1	2.6	2.6
0730-0830	6%	2.2	1.5	1.8	1.4	1.3
0830-0930	6%	1.7	1.2	1.9	1.3	1.7
0930-1630	38%	0.6	0.7	1.3	0.3	1.0
1630-1730	6%	0.6	0.5	0.7	0.5	0.5
1730-1830	7%	1.9	1.4	1.4	1.0	1.3
1830-1930	7%	2.0	1.8	1.3	1.2	1.4
1930-2030	6%	2.2	1.2	1.3	0.6	1.0
2030-0630	17%	0.3	0.3	0.2	0.2	0.2

Table 6 – Journey time reliability for buses by time period (typical weekdays)

Time period (weekday)	Percentage of daily flow	Variability (minutes)				
		"Before"	"After"			
		1998	1999	2000	2001	2002
0630-0730	7%	3.4	1.2	1.2	1.3	1.2
0730-0830	6%	2.2	0.7	1.0	0.8	1.0
0830-0930	6%	1.7	0.4	0.8	0.6	0.7
0930-1630	38%	0.6	0.4	0.4	0.3	0.4
1630-1730	6%	0.6	0.3	0.4	0.4	0.4
1730-1830	7%	1.9	0.7	0.6	0.5	0.7
1830-1930	7%	2.0	0.9	0.8	0.7	0.9
1930-2030	6%	2.2	0.5	0.6	0.4	0.5
2030-0630	17%	0.3	0.4	0.2	0.2	0.2

Tables 5 and 6 show how much the congestion varied within each time period:

- The reliability for cars has improved during most of the periods since the bus lane opened. The intermittent stop-start traffic behaviour results in a more reliable journey time than the queueing behaviour, as each driver stops once or twice within the section, instead of joining the back of a queue of varying length.
- The reliability for buses has improved throughout the day since the bus lane opened.
- There do not appear to be any year-to-year trends in journey time reliability.

2.5 JOURNEY TIME TRENDS

To compare journey times, day-to-day trends have been examined. Tables 7 and 8 show the average journey time for cars in each peak period, by the day of the week, for days without incidents (as shown in Figures 1, 3 and 5), for each year from 1998 to 2002. Values in green indicate that journey times are lower now that the bus lane is open, values in red indicate that journey times are worse and values in yellow show that there has been little or no change (0.1 minute or less). (Saturdays have not been included in these tables as, due to equipment constraints, no data was collected on Saturdays during 1998 and 1999.)

Before the bus lane opened, there was a consistent trend throughout the week. In the mornings, Mondays had the worst congestion and Fridays had the least. In the evenings, Mondays were the least congested and congestion on Fridays was much worse than other peak periods.

Now that the bus lane is open, the daily trend is less pronounced. In the mornings, the journey times are similar on all weekdays except for Friday mornings, where journey times are lower. In the evenings, Mondays are still the least congested of the weekdays and congestion on Fridays is worse than other peak periods. The biggest percentage improvement in journey times occurs for Friday evenings.

Table 7 – Journey times for cars by day of week (AM peak)

Day of week	Average journey time (AM peak) (min)				
	"Before"	"After"			
	1998	1999	2000	2001	2002
Sunday	4.7	5.6	5.5	5.3	5.1
Monday	11.8	10.1	12.2	10.8	11.9
Tuesday	10.2	9.9	12.4	10.5	11.3
Wednesday	10.4	10.2	11.9	10.6	11.2
Thursday	9.9	10.0	12.7	10.5	11.4
Friday	8.3	7.2	10.3	7.4	8.4

Table 8 – Journey times for cars by day of week (PM peak)

Day of week	Average journey time (PM peak) (min)				
	"Before"	"After"			
	1998	1999	2000	2001	2002
Sunday	8.3	8.8	9.8	8.9	8.4
Monday	7.5	8.0	9.2	7.2	7.3
Tuesday	8.2	9.2	9.0	7.6	7.7
Wednesday	10.7	10.0	10.4	8.5	9.1
Thursday	10.5	8.9	9.7	8.3	8.6
Friday	12.8	9.9	11.8	8.7	10.1

The introduction of the bus lane has had the greatest beneficial effect during the busiest peak periods, ie Monday mornings and Friday evenings. These peak periods now have the same pattern of congestion as other days.

The congestion levels during weekday mornings have increased since 1999. Most of the congestion is caused by shockwaves propagating back along the section. The origins of the shockwaves (the "seed points") vary. Some of the shockwaves start at the merge area at the end of bus lane, but most of the seed points for the shockwaves are further downstream, on the elevated section or further towards London. The congestion levels during the mornings have increased due to more shockwaves propagating back from the elevated section.

Tables 9 and 10 show the average journey time for buses in each peak period, by the day of the week, for days without incidents (as shown in Figures 2, 4 and 6), for each year from 1998 to 2002.

Table 9 – Journey times for buses by day of week (AM peak)

Day of week	Average journey time (AM peak) (min)				
	"Before"	"After"			
	1998	1999	2000	2001	2002
Sunday	4.7	5.9	5.8	5.7	5.1
Monday	11.8	7.4	8.0	7.9	8.0
Tuesday	10.2	7.4	8.3	7.8	7.9
Wednesday	10.4	7.5	8.0	7.7	7.7
Thursday	9.9	7.4	8.3	7.8	7.6
Friday	8.3	6.5	7.4	6.6	6.7

Table 10 – Journey times for buses by day of week (PM peak)

Day of week	Average journey time (PM peak) (min)				
	"Before"	"After"			
	1998	1999	2000	2001	2002
Sunday	8.3	6.9	7.2	7.1	8.4
Monday	7.5	6.8	7.6	6.6	6.5
Tuesday	8.2	7.3	7.1	6.8	6.6
Wednesday	10.7	7.6	7.6	7.0	7.0
Thursday	10.5	7.0	7.2	7.1	6.9
Friday	12.8	7.4	7.8	7.1	7.5

Journey times for buses have improved following the introduction of the bus lane. Bus journey times are now similar on all weekdays. The introduction of the bus lane has had the greatest beneficial effect during the busiest peak periods, ie Monday mornings and Friday evenings. These peak periods now have the same pattern of congestion as other days.

Before the bus lane was installed, there was congestion during some Sunday lunchtimes. This congestion has been reduced now that the bus lane is open; Sunday lunchtimes are now generally uncongested.

2.6 CONCLUSIONS

Congestion occurs on the eastbound M4 into London during the morning and evening peak periods. There is some congestion during the late morning, and little during the rest of the day. The journey time profiles for cars before and after the bus lane opened are similar, although the traffic is behaving differently. The shape of the journey time profiles are similar from year to year, although there is considerable variability between years during the "after" period. For most of the day, congestion levels were lowest during 1999 and 2001, and highest during 2000.

When the scheme opened, both cars and buses saved time during peak periods (when 39% of the traffic travels). This saving is still present, although it varies considerably from year to year.

During off-peak periods, journey times increased as a result of the lower speed limits installed as part of the scheme. Over the years since the bus lane opened, the off-peak journey times for both cars and buses have been decreasing. This is likely to be a result of drivers choosing to travel at the speed they think is appropriate for the conditions, rather than complying with the speed limit. When the new speed limits were originally installed in 1999, compliance was better, as drivers were more cautious following the introduction of a new scheme. As drivers have become more familiar with the scheme, and as the speed limits have not been rigorously enforced, the average speeds have increased. The average off-peak speed in 1999 was 54mph (in excess of the speed limit). By 2001, this had increased

to 58mph. Following the increase in the speed limit to 60mph, the average speed increased to 60mph. As part of the measured journey is within a 40mph speed limit area, drivers are still exceeding the speed limit.

As traffic speeds between Junctions 4 and 2 were already close to 60mph, the increase in the speed limit from 50mph to 60mph has had only a small impact during off-peak periods. It is likely that average off-peak speeds will continue to rise following the introduction of the new speed limit.

During peak periods, it was not expected that journey times would benefit from the increase in speed limits, as drivers cannot usually travel in excess of 50mph.

Bus journey times are more reliable throughout the day since the bus lane opened. Car journey times are more reliable during the evening peak period, and have become slightly worse during the end of the morning peak period, as the congestion takes longer to clear on some days. There has been little change in journey time reliability in the years following the introduction of the bus lane. The current journey time reliability is very similar to that in 1999.

The bus lane scheme has improved conditions on days that previously had the worst congestion. Before the bus lane opened, Monday mornings and Friday evenings had significantly worse congestion than other days. Now the bus lane is open, the congestion is similar to other peak periods. This pattern has been consistent over the four years the bus lane has been open.

The congestion levels during weekday mornings have increased since 1999. Most of the congestion is caused by shockwaves propagating back along the section. The origins of the shockwaves (the “seed points”) vary. Some of the shockwaves start at the merge area at the end of bus lane, but most of the seed points for the shockwaves are further downstream, on the elevated section or further towards London. The congestion levels during the mornings have increased due to more shockwaves propagating back from the elevated section.

During incidents, buses achieve the greatest time savings, as they are able to reach the start of the elevated section without queueing.

3. TRAFFIC SPEEDS

Traffic speeds have been monitored since before the bus lane opened. The 1-minute average speeds have been collected continuously, and have been used to determine the immediate effect of major changes to the scheme (eg to the speed limits). Individual vehicle speeds have been collected at regular intervals, and have been used to analyse compliance with the speed limits over longer periods.

3.1 EFFECT OF NEW SPEED LIMIT ON TRAFFIC SPEEDS

On 23rd July 2002, the speed limit along the M4 into London between Junction 4 and the end of the bus lane was increased from 50mph to 60mph. An analysis has been performed to determine the revised limit's impact on traffic speeds. The 1-minute average speeds through Junction 3 have been studied for each day in July 2002 during times of the day when drivers can choose their own speed. Peak periods have been excluded as speeds may be restricted by congestion. Night-time periods have been excluded as there may be a preponderance of lorries that are unable to travel at 60mph. The average speeds have been categorised into three different speed bins and presented in Figure 15.

Figure 15 shows that there is a change in average speeds following the introduction of the revised speed limit on 23rd July 2002. With a 50mph limit, approximately 40% of average speeds exceeded 60mph and almost all exceeded 50mph (so all drivers were exceeding the speed limit). With the increased 60mph limit, approximately 50% of average speeds exceeded 60mph.

3.2 SPEED COMPLIANCE

Before the bus lane opened, the national speed limit covered the eastbound M4 until the elevated section, and there was a 50mph limit from the start of the elevated section. When the bus lane was first opened, there were new speed limits of 50mph just before Junction 4 and 40mph just before the merge area at the end of the bus lane. On 23rd July 2002, the 50mph speed limit was raised to 60mph (the 40mph limit remained unchanged).

Compliance with the speed limits has been directly measured by analysing the speed of each vehicle at the four sites described in Table 11. A speed limit of 60mph now covers the first two locations, whilst there is a speed limit of 40mph near the merge area of the bus lane and at the start of the elevated section. For the pre-bus lane monitoring period, site 16/2 was after the bottleneck where three lanes reduced to two. Following the road redesign, this site is just before the merge area; there are three lanes of traffic, including the bus lane.

Table 11 – Sites chosen for speed investigation

Site	Speed limit before	Speed limit after	Current speed limit
23/2 (between J4 and J3)	70	50	60
18/7 (middle of bus lane)	70	50	60
16/2 (near merge)	70	40	40
15/6 (before elevated section)	50	40	40

Traffic speeds have been monitored for five time periods: the early morning, the morning peak, the midday period, the evening peak and the late evening. To assess speed compliance, free flow traffic data from 20:00 to 06:00 has been analysed, so that traffic is not constrained at a particular speed.

The report on the first year of operation (Rees, White & Quick, 2000) contains the speed compliance results for the pre-bus lane monitoring period and for one month, six months and one year after the bus lane opened. The following sections describe the speed compliance for 18 months and three years after the bus lane opened, and a comparison of compliance over the last four years.

3.2.1 Results eighteen months after bus lane opened

Table 12 shows the 85th percentile speed[1] and the average (mean) speed for each of the four sites under free-flow conditions 18 months after the bus lane opened (ie during November 2000). In addition, the table shows the percentage of traffic exceeding a threshold speed of (110% * speed limit + 2)[2].

Table 12 – Speeds under free-flow conditions 18 months after the bus lane opened

Site	Speed limit	85th percentile speed	Average speed	Percentage exceeding threshold
23/2 (J4-3)	50mph	70mph	59mph	49%
18/7 (J3-2)	50mph	65mph	57mph	42%
16/2 (near elevated section)	40mph	57mph	48mph	59%
15/6 (elevated section)	40mph	46mph	40mph	12%

3.2.2 Results three years after bus lane opened

Table 13 shows the 85th percentile and average (mean) speeds, during free flow conditions three years after the bus lane opened (ie during November 2002), and the percentage of traffic exceeding a threshold speed of (110% * speed limit + 2). No data was available from site 15/6, as this site was not accessible for data collection.

Table 13 – Speeds under free-flow conditions three years after the bus lane opened

Site	Speed limit	85th percentile speed	Average speed	Percentage exceeding threshold
23/2 (J4-3)	60mph	69mph	60mph	13%
18/7 (J3-2)	60mph	69mph	58mph	8%
16/2 (near elevated section)	40mph	58mph	48mph	59%

3.2.3 Comparison of speed compliance since 1998

Tables 14 to 17 compare the speed compliance at each site over the last four years. Samples of individual vehicle speeds have been taken during six separate months.

[1] 85% of traffic travels at or below this speed. This is the standard measurement used by traffic engineers with regards to speed limits.
[2] This threshold speed is the speed limit, plus a tolerance. It is likely that drivers exceeding this speed are consciously exceeding the speed limit.

Table 14 – Summary of speed compliance between Junctions 4 and 3 since 1998

Time period	Speed limit	85th percentile speed	Average speed	Percentage exceeding threshold
Pre-bus lane	70mph	78mph	66mph	11%
One month after	50mph	65mph	57mph	41%
Six months after	50mph	64mph	56mph	35%
One year after	50mph	64mph	56mph	47%
Eighteen months after	50mph	70mph	59mph	49%
Three years after	60mph	69mph	60mph	13%

Table 14 shows that, at site 23/2, compliance with the 50mph limit gradually became worse, with average speeds rising to 59mph by November 2000. The introduction of the 60mph limit has had little effect on the average speed at this site. Consequently, compliance with the 60mph limit is noticeably better than with the previous 50mph limit.

Table 15 – Summary of speed compliance between Junctions 3 and 2 since 1998

Time period	Speed limit	85th percentile speed	Average speed	Percentage exceeding threshold
Pre-bus lane	70mph	78mph	68mph	10%
One month after	50mph	64mph	58mph	48%
Six months after	50mph	63mph	57mph	41%
One year after	50mph	68mph	61mph	73%
Eighteen months after	50mph	65mph	57mph	42%
Three years after	60mph	69mph	58mph	8%

Table 15 shows that, at site 18/7, compliance with the 50mph limit has been poor. The introduction of the 60mph limit has had little effect on the average speed at this site. Consequently, compliance with the 60mph limit is noticeably better than with the previous 50mph limit.

Table 16 – Summary of speed compliance near elevated section since 1998

Time period	Speed limit	85th percentile speed	Average speed	Percentage exceeding threshold
Pre-bus lane	70mph	70mph	62mph	2%
One month after	40mph	57mph	50mph	73%
Six months after	40mph	55mph	48mph	55%
One year after	40mph	57mph	49mph	62%
Eighteen months after	40mph	57mph	48mph	59%
Three years after	40mph	58mph	48mph	59%

Table 16 shows that, at site 16/2, compliance with the 40mph limit has been poor, with over half the drivers exceeding the threshold speed. The drivers have just entered the 40mph speed limit area, but have only reduced their speed by 9mph. There has been little change in compliance during the three years since the new speed limit was imposed.

Table 17 – Summary of speed compliance at elevated section since 1998

Time period	Speed limit	85th percentile speed	Average speed	Percentage exceeding threshold
Pre-bus lane	50mph	50mph	45mph	4%
One month after	40mph	46mph	41mph	14%
Six months after	40mph	45mph	40mph	12%
One year after	40mph	47mph	41mph	16%
Eighteen months after	40mph	46mph	40mph	12%
Three years after	40mph	N/A	N/A	N/A

Table 17 shows that, at site 15/6, compliance with the 40mph limit is very good, with average speeds below 41mph. The better compliance at site 15/6 compared to the other sites is likely to be due to the presence of an operational speed camera. There has been little change in compliance during the three years since the new speed limit was imposed.

3.3 CONCLUSIONS

The introduction of the 60mph speed limit resulted in an increase in speed in the days immediately following the change. Average speeds were close to 60mph prior to the change, so the increase in speed was not as great as it would have been had drivers been complying with the previous 50mph speed limit.

Speed compliance has been measured with the 70mph and 50mph limits in place before the bus lane opened, with the 50mph and 40mph limits implemented when the bus lane opened, and with the 60mph limits implemented in July 2002. The number of vehicles exceeding the speed limit rose following the introduction of the lower speed limits in 1999. The number of vehicles exceeding the 50mph speed limit was double the number that exceeded the national speed limit before the bus lane scheme was installed. This was likely to be because the drivers did not feel that a fixed 50mph limit was appropriate. Drivers tend to have less respect for fixed speed limits – there is better compliance with the variable speed limits on the M25, as the drivers know that the limits have been set for a reason. There is also greater enforcement on the M25.

There has also been poor compliance with the 40mph limit near the merge area at the end of the bus lane, with average speeds close to 50mph. This is likely to be because the drivers did not feel that the fixed 40mph limit was appropriate.

There were very few speed-related incidents during the first year of monitoring. Assuming that this is still the case, then the poor compliance with the 50mph and 40mph speed limits does not have any safety implications. However, it is not recommended that the 40mph limit be increased, as drivers would then be likely to travel closer to 60mph, as observed with the 50mph speed limits between Junctions 4 and 2.

Speed compliance just after drivers passed into the 50mph speed limit area became worse during the period after the speed limits were installed. Levels of compliance further downstream have been unchanged.

The introduction of the 60mph speed limits to replace the existing 50mph limits has not had much effect on traffic speeds, with average speeds typically rising by 1mph. Consequently, compliance with the 60mph limit is noticeably better than with the previous 50mph limit.

Speed cameras were installed on the M4 between Junctions 4 and 2, but they were not operational and did not flash. The only site where compliance with the speed limit was good was just before the start of the elevated section, where there is an operational speed camera. A study of speeds on the

M25 (Rees *et al*, 1996) has shown that neither the introduction of camera signs nor the presence of speed cameras has a great effect on speed compliance. It is necessary for the cameras to flash before drivers obey the speed limits.

4. USE OF BUS LANE

When the M4 bus lane opened in 1999, three main classes of vehicle were allowed to use it: buses/coaches, minibuses and taxis. From 23rd July 2002, motorcycles were also allowed to use the bus lane. Vehicle length data has been collected from loops to analyse bus lane usage in terms of each of these vehicle classes. Motorcycles are defined as having vehicle length under 3 metres. Taxis are defined as having vehicle length between 3 metres and 5.5 metres. The categories of minibuses and buses/coaches from the length data have been calibrated using observations of vehicles in the bus lane obtained from video footage.

Figure 16 shows the typical daily profile of vehicles using the bus lane during 2002. The profile for taxis is slightly different to that for minibuses and buses/coaches. Taxi use of the bus lane is highest in the morning and evening peak period, with the peak flow occurring at approximately 7:00. There are more minibuses and buses/coaches in the bus lane during the morning, with a peak flow occurring around 11:00.

The number of minibuses and buses/coaches that use the bus lane has remained constant since the bus lane was opened: approximately 100 minibuses and 500 buses/coaches use the bus lane each day.

On average, 3700 vehicles per day use the bus lane, which is 7% of the total traffic on the eastbound M4. The daily total using the bus lane has varied between 3000 and 4750 and is greatly affected by the number of taxis using the bus lane: between 2400 and 4100 per day. A typical peak hour flow comprises 230 taxis and 50 buses/minibuses.

4.1 MOTORCYCLES IN THE BUS LANE

Identification of motorcycles using the bus lane is not always possible from the vehicle length data, as motorcycles often do not ride directly over the loops. When the bus lane first opened, video data was collected on several occasions during peak periods. During a typical 3-hour morning peak period, up to 25 motorcycles were observed using the bus lane, although they were not legally allowed to do so.

Now that motorcycles are allowed to use the bus lane, more are doing so. On a typical day, 100 motorcycles were detected by the loops; it is likely that the actual number of motorcycles using the bus lane is greater than this. More motorcycles use the bus lane during peak periods, to avoid congestion in the general purpose lanes.

4.2 CONCLUSIONS

The number of vehicles that use the bus lane has remained relatively constant since the bus lane was opened. Approximately 3100 taxis, 100 minibuses and 500 buses/coaches use the bus lane each day.

Following the opening of the bus lane to motorcycles, 100 motorcycles per day have been detected using the bus lane. The actual number of motorcycles is likely to be greater than this, as some motorcycles will not pass over the loops.

5. CONCLUSIONS

This report has examined the performance of the eastbound M4 between Junctions 4B and 2 from 2000 to 2002, with particular emphasis on the effects of the changes made during July 2002 to the speed limits and motorcycle use of the bus lane. The report concentrates on the operation of the scheme during October, November and the start of December for each year, as this was the period that was examined in detail during 1998 and 1999 and previously reported (Rees, White & Quick, 2000).

Journey times

Congestion occurs on the eastbound M4 into London during the morning and evening peak periods. There is some congestion during the late morning, and little during the rest of the day. The journey time profiles for cars before and after the bus lane opened are similar, although the traffic is behaving differently. The shape of the journey time profiles are similar from year to year, although there is considerable variability between years during the "after" period". For most of the day, congestion levels were lowest during 1999 and 2001, and highest during 2000.

When the scheme opened, both cars and buses saved time during peak periods (when 39% of the traffic travels). This saving is still present, although it varies considerably from year to year.

During off-peak periods, journey times increased as a result of the lower speed limits installed as part of the scheme. Over the years since the bus lane opened, the off-peak journey times for both cars and buses have been decreasing. This is likely to be a result of drivers choosing to travel at the speed they think is appropriate for the conditions, rather than complying with the speed limit. When the new speed limits were originally installed in 1999, compliance was better, as drivers were more cautious following the introduction of a new scheme. As drivers have become more familiar with the scheme, and as the speed limits have not been rigorously enforced, the average speeds have increased. The average off-peak speed in 1999 was 54mph (in excess of the speed limit). By 2001, this had increased to 58mph. Following the increase in the speed limit to 60mph, the average speed increased to 60mph. As part of the measured journey is within a 40mph speed limit area, drivers are still exceeding the speed limit.

As traffic speeds between Junctions 4 and 2 were already close to 60mph, the increase in the speed limit from 50mph to 60mph has had only a small impact during off-peak periods. It is likely that average off-peak speeds will continue to rise following the introduction of the new speed limit.

During peak periods, it was not expected that journey times would benefit from the increase in speed limits, as drivers cannot usually travel in excess of 50mph.

Bus journey times are more reliable throughout the day since the bus lane opened. Car journey times are more reliable during the evening peak period, and have become slightly worse during the end of the morning peak period, as the congestion takes longer to clear on some days. There has been little change in journey time reliability in the years following the introduction of the bus lane. The current journey time reliability is very similar to that in 1999.

The congestion levels during weekday mornings have increased since 1999. Most of the congestion is caused by shockwaves propagating back along the section. The origins of the shockwaves (the "seed points") vary. Some of the shockwaves start at the merge area at the end of bus lane, but most of the seed points for the shockwaves are further downstream, on the elevated section or further towards London. The congestion levels during the mornings have increased due to more shockwaves propagating back from the elevated section.

Traffic Speeds

On the day the speed limits were raised from 50mph to 60mph, there was a corresponding increase in average speeds. As the average speeds were already close to 60mph, the increase was only a few miles per hour, but it was distinguishable.

Speed compliance

Speed compliance just after drivers passed into the 50mph speed limit area became worse during the period after the speed limits were installed. Levels of compliance further downstream have been unchanged.

The introduction of the 60mph speed limits to replace the existing 50mph limits has not had much effect on traffic speeds, with average speeds typically rising by 1mph. Consequently, compliance with the 60mph limit is noticeably better than with the previous 50mph limit.

Bus lane use

The number of vehicles that use the bus lane has remained relatively constant since the bus lane was opened. Approximately 3100 taxis, 100 minibuses and 500 buses/coaches use the bus lane each day.

Following the opening of the bus lane to motorcycles, 100 motorcycles per day have been detected using the bus lane. The actual number of motorcycles is likely to be greater than this, as some motorcycles will not pass over the loops.

Summary

The bus lane scheme continues to meet most of the objectives set out before the scheme was installed. The savings in journey times during peak periods is still present, although it varies considerably from year to year.

The increase in the speed limit from 50mph to 60mph has had only a small impact during off-peak periods, as traffic speeds between Junctions 4 and 2 were already close to 60mph. During peak periods, it was not expected that journey times would benefit from the increase in speed limits, as drivers cannot usually travel in excess of 50mph.

There has been little change in journey time reliability in the years following the introduction of the bus lane. Bus journey times are more reliable throughout the day since the bus lane opened. Car journey times are more reliable during the evening peak period, and have become slightly worse during the end of the morning peak period, as the congestion takes longer to clear on some days. The current journey time reliability is very similar to that in 1999.

Following the opening of the bus lane to motorcycles, 100 motorcycles per day have been detected using the bus lane. The presence of the motorcycles has had no impact on the operation of the bus lane.

6. RECOMMENDATIONS

The congestion on the eastbound M4 into London is generally caused by shockwaves propagating back along the section and by congestion at Junctions 3 and 4. The origins of the shockwaves (the "seed points") vary. Some of the shockwaves start at the merge area at the end of bus lane, but most of the seed points for the shockwaves are further downstream. As no speed and flow data is available from the elevated section, it has not been possible to identify these seed points. They may be on the elevated section itself, or further towards London (eg at the Chiswick roundabout).

The congestion levels during weekday mornings are increasing, as more shockwaves are propagating back from the elevated section. The performance of the bus lane section would improve if some of these shockwaves were eliminated. Therefore, **it is recommended that the locations of the seed points on the elevated section and further towards London should be identified, and ways of alleviating the congestion at these points considered.**

The new 60mph speed limit has not resulted in a large increase in vehicle speeds, so there should not be any safety implications associated with the increase in speed limit to 60mph. If the speed limit were to be increased to 70mph, traffic in lane 2 would be travelling faster than the buses in the bus lane, as buses are limited to 65mph. This might adversely affect safety. Therefore, **it is recommended that the 60mph limit should remain in place.**

Traffic in the 40mph speed limit area is currently travelling at an average speed of 48mph. Although drivers appear to consider that the speed limit is inappropriate, increasing the speed limit to 50mph would be likely to result in average speeds close to 60mph at the merge area. These speeds would be likely to adversely affect safety. Therefore, **it is recommended that the 40mph limit should remain in place.**

The current speeds in the 40mph speed limit area do not seem to have adversely affected safety. Therefore, reducing these speeds would delay traffic without providing significant safety benefits. Consequently, **it is recommended that enforcement levels in the 40mph speed limit area should not change.**

7. REFERENCES

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Rees T R, White J K & Quick J I (2000). Monitoring of the M4 Bus Lane: The First Year. *Unpublished Report PR/T/125/2000*. TRL Limited.

Dixon C, Harbord B & Abou-Rahme N (2002). Speed-control and incident-detection on the M25 Controlled Motorway (Summary of Results 1995-2002). *Unpublished Report PR/T/095/02*. TRL Limited.

Figure 1
Car journey time (M4 J4 - start of elevated section)
(8.4 km)
Average of typical days (8 October - 9 December 2000): bus lane in operation

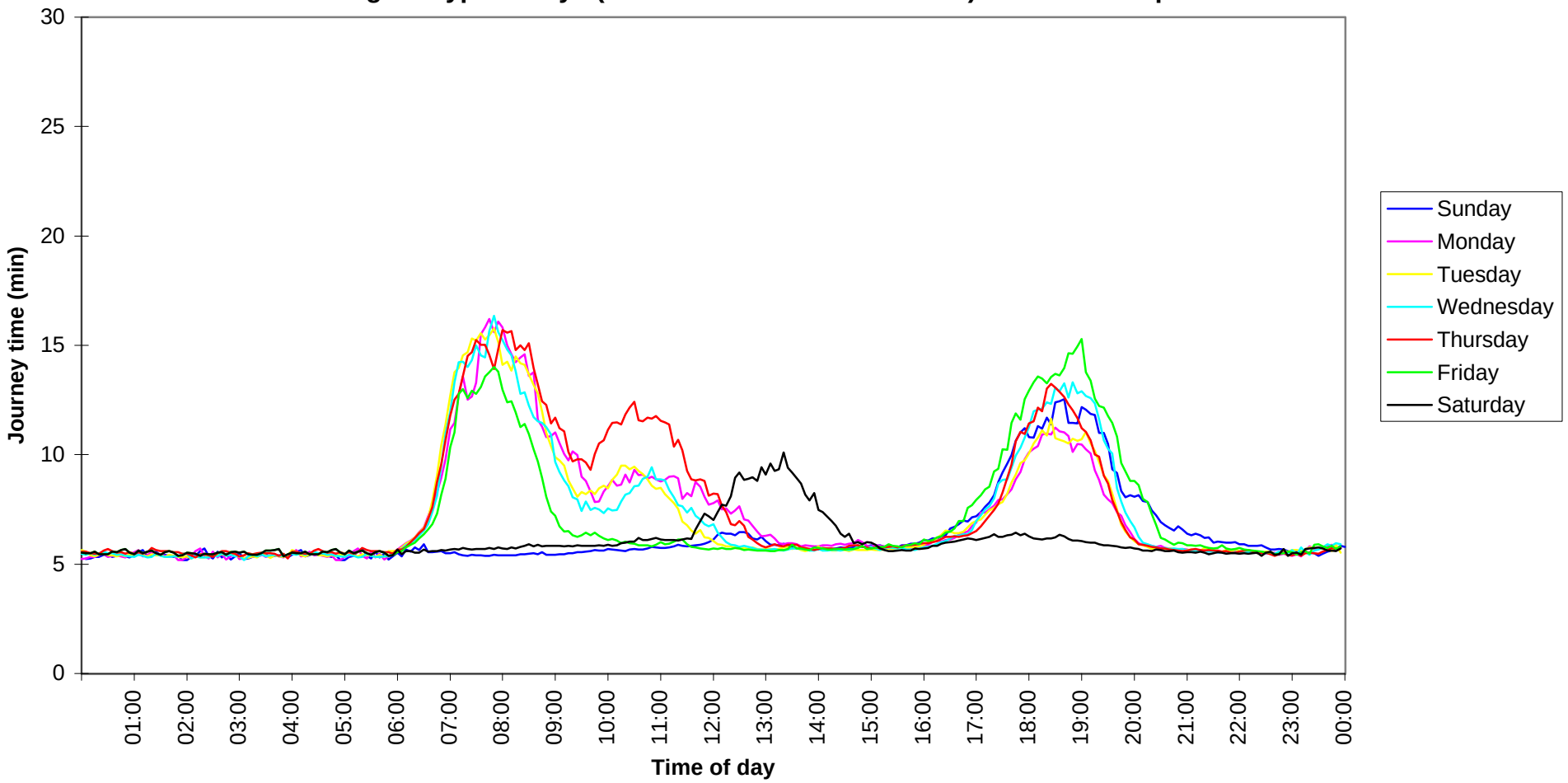

Figure 2
Bus journey time (M4 J4 - start of elevated section)
(8.4 km)
Average of typical days (8 October - 9 December 2000): bus lane in operation

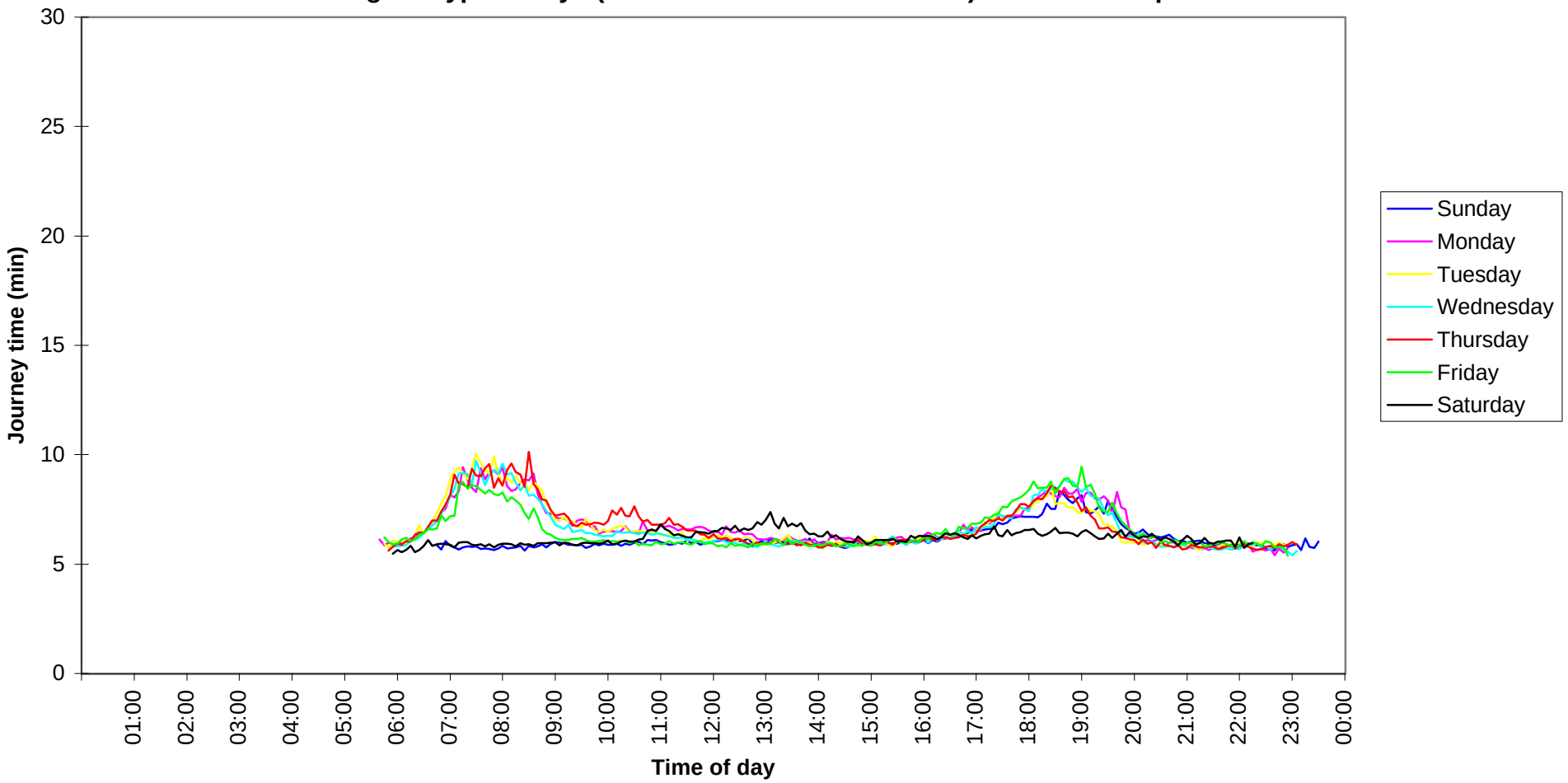

Figure 3
Car journey time (M4 J4 - start of elevated section)
(8.4 km)
Average of typical days (7 October - 8 December 2001): bus lane in operation

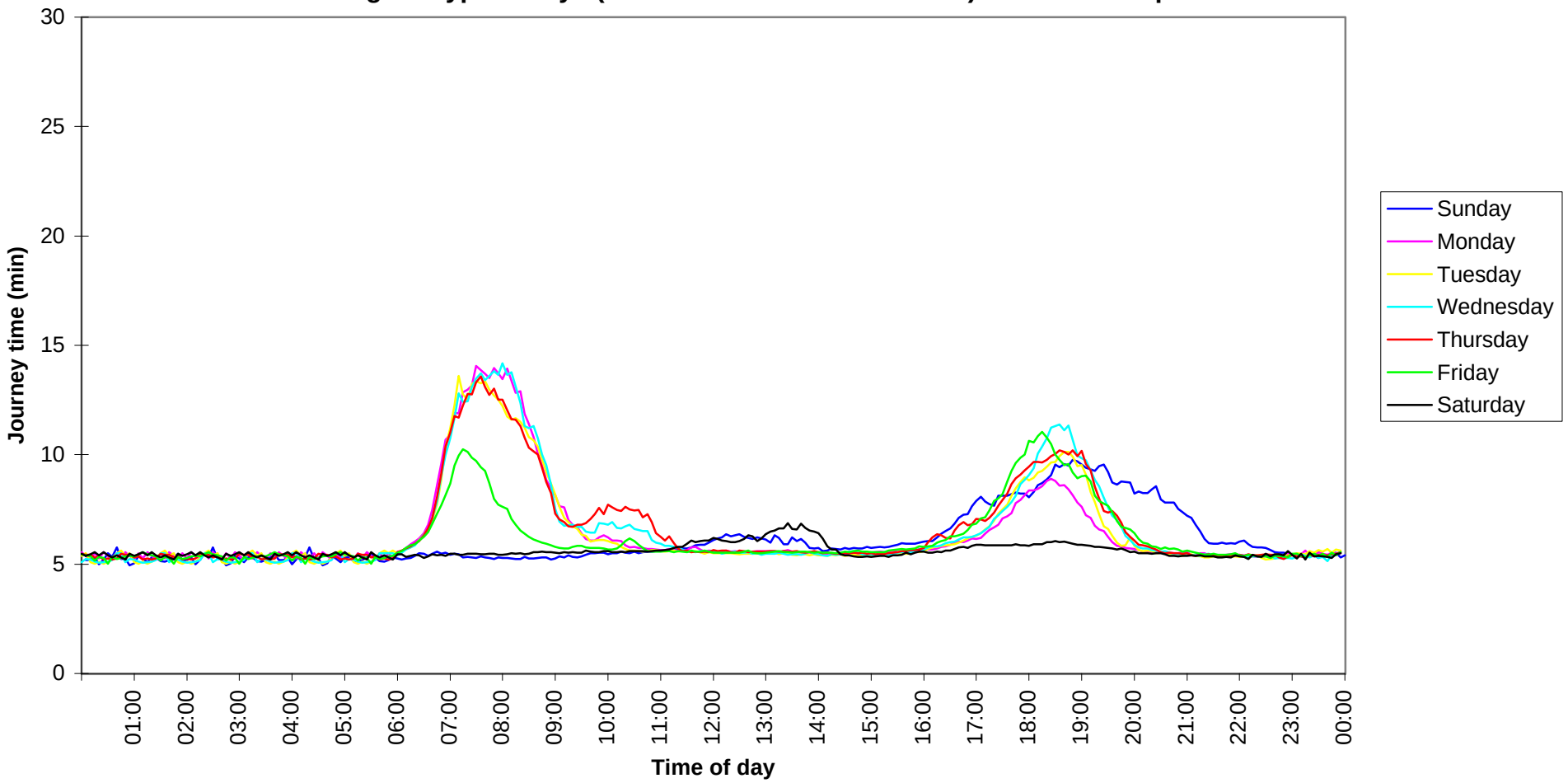

Figure 4
Bus journey time (M4 J4 - start of elevated section)
(8.4 km)
Average of typical days (7 October - 8 December 2001): bus lane in operation

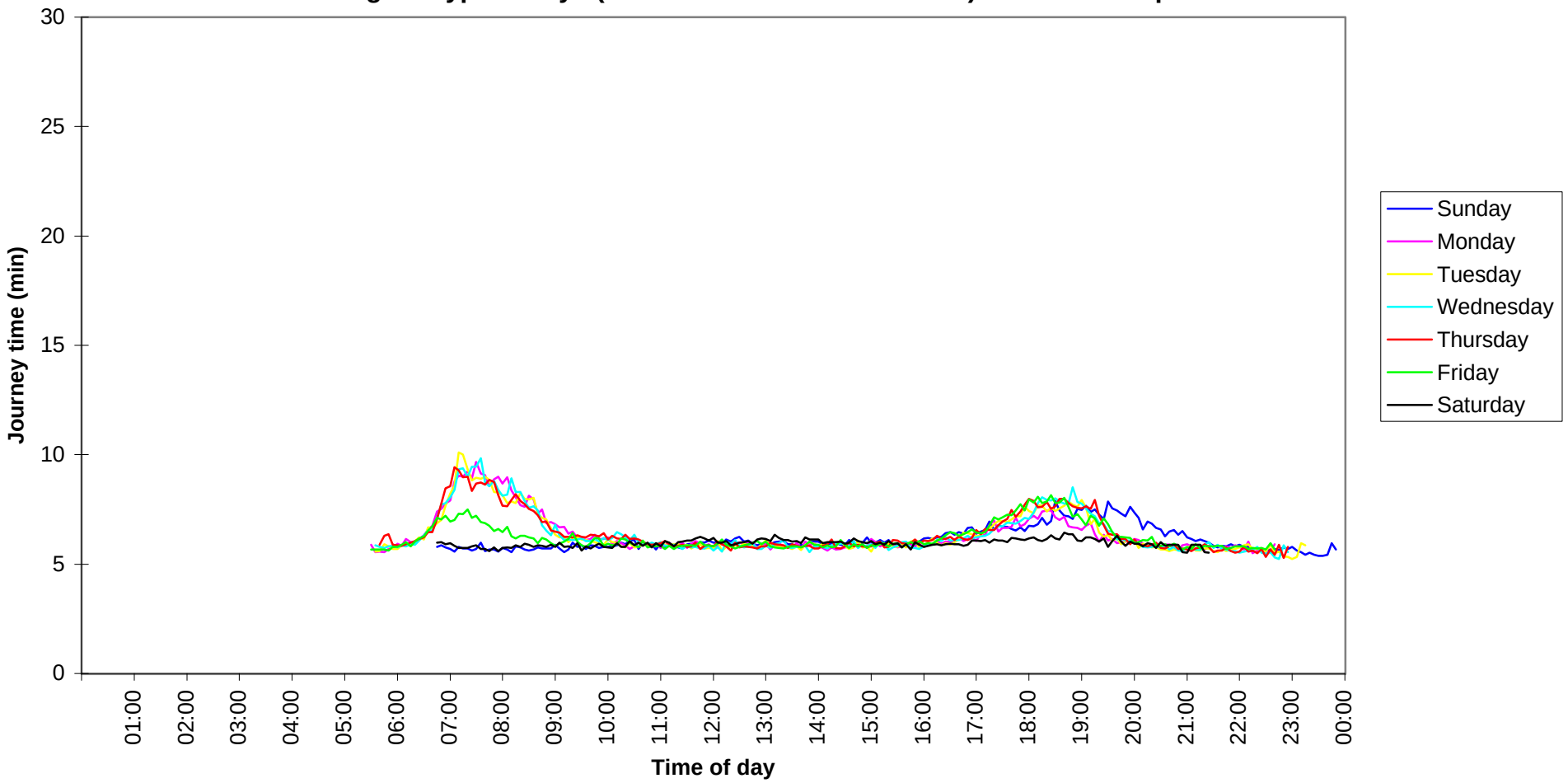

Figure 5
Car journey time (M4 J4 - start of elevated section)
(8.4 km)
Average of typical days (6 October - 7 December 2002): bus lane in operation

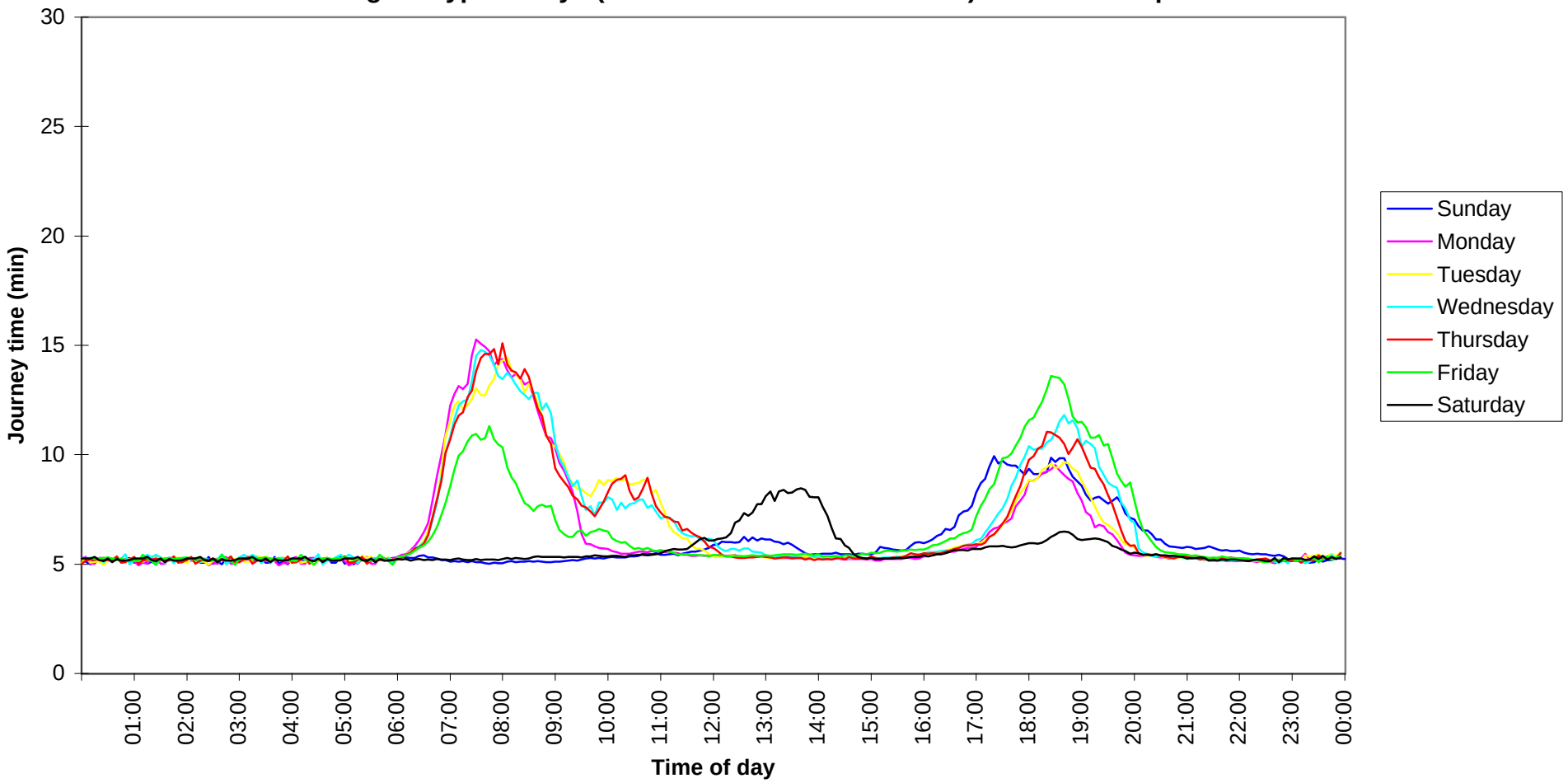

Figure 6
Bus journey time (M4 J4 - start of elevated section)
(8.4 km)
Average of typical days (6 October - 7 December 2002): bus lane in operation

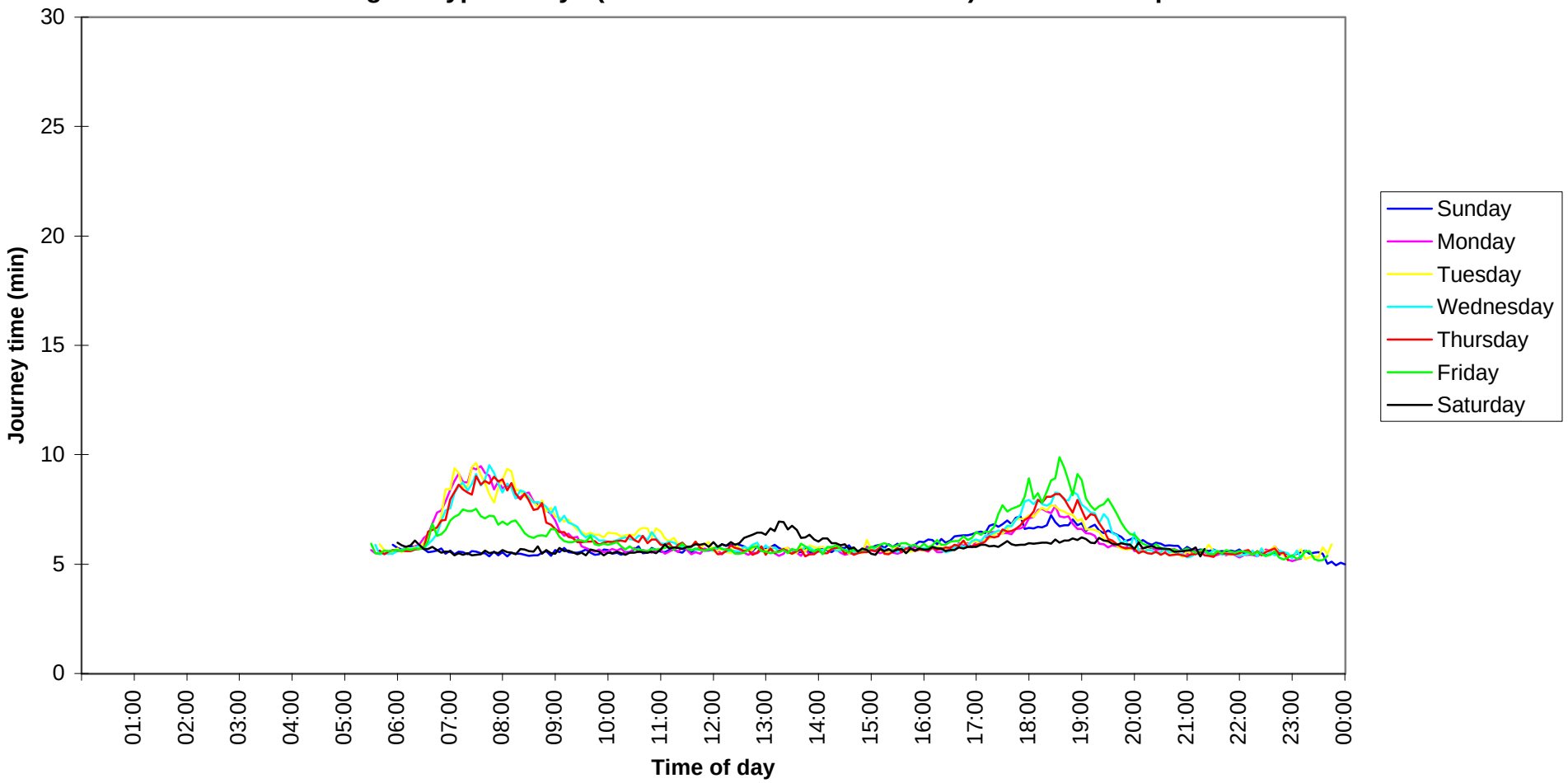

Figure 7
Journey time (M4 J4 - start of elevated section)
(8.4 km)
Weekdays excluding incidents

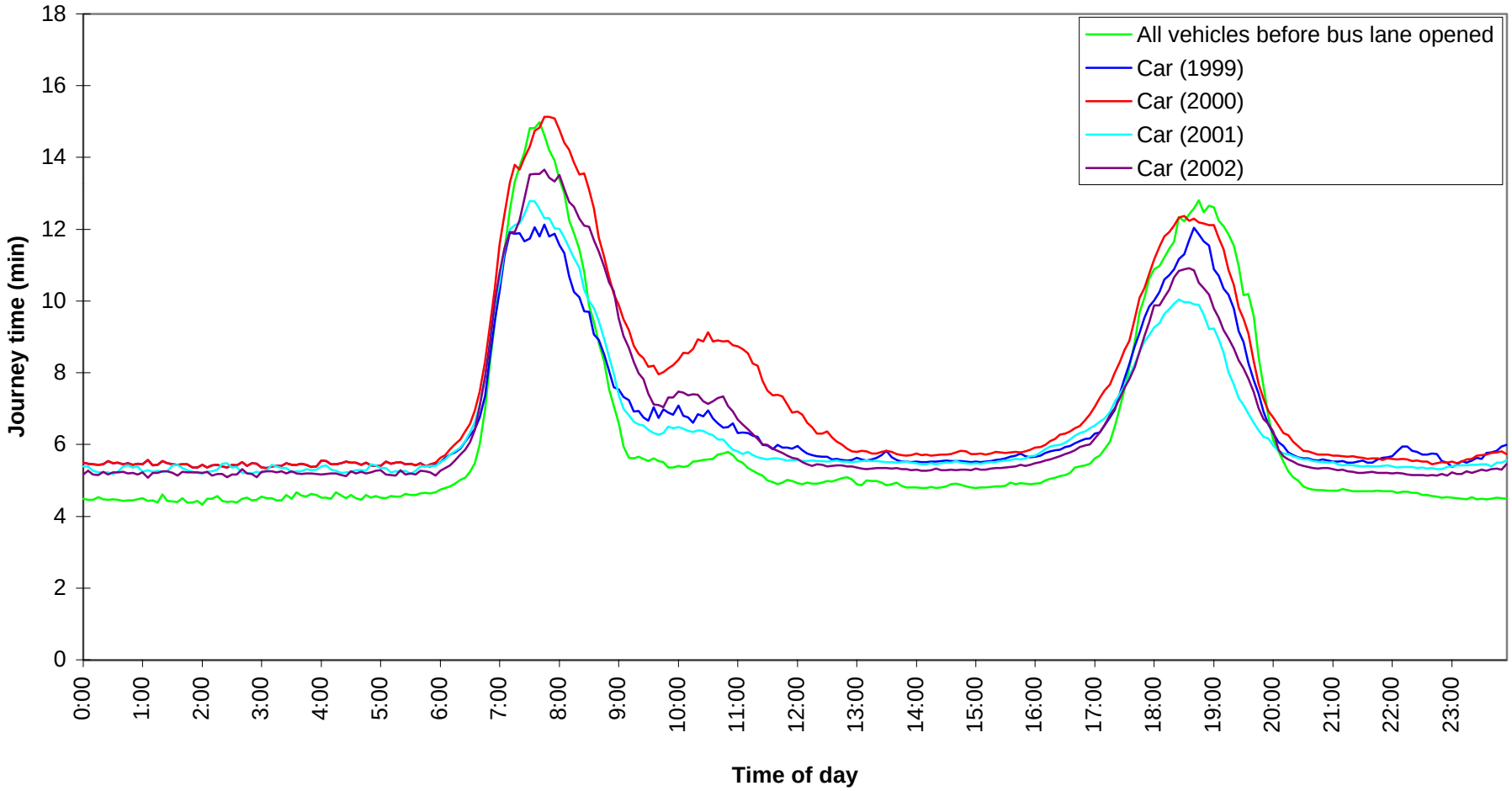

Figure 8
Journey time (M4 J4 - start of elevated section)
(8.4 km)
All weekdays (including incidents)

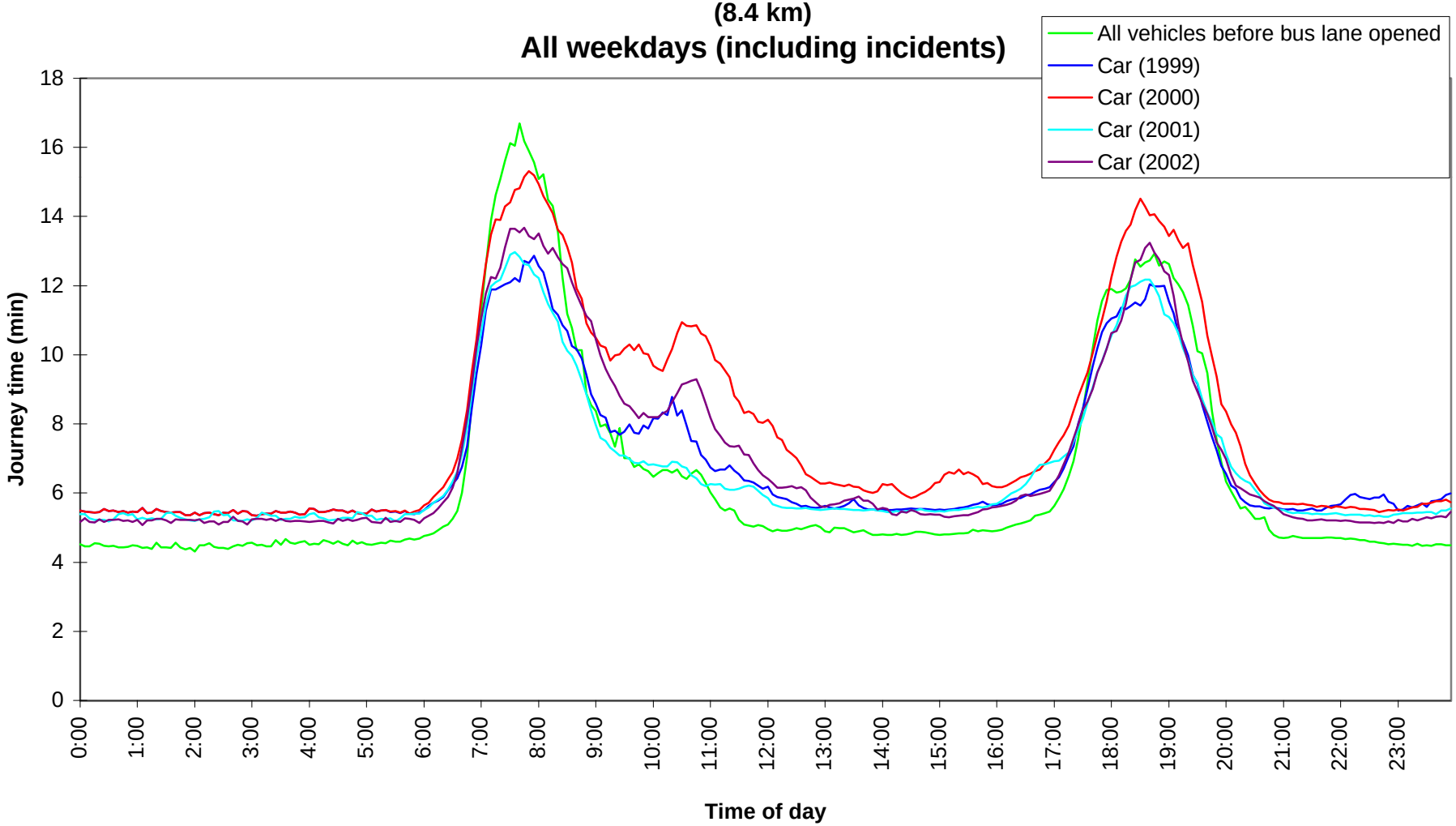

Figure 9
Journey time (M4 J4 - start of elevated section)
(8.4 km)
Weekdays excluding incidents

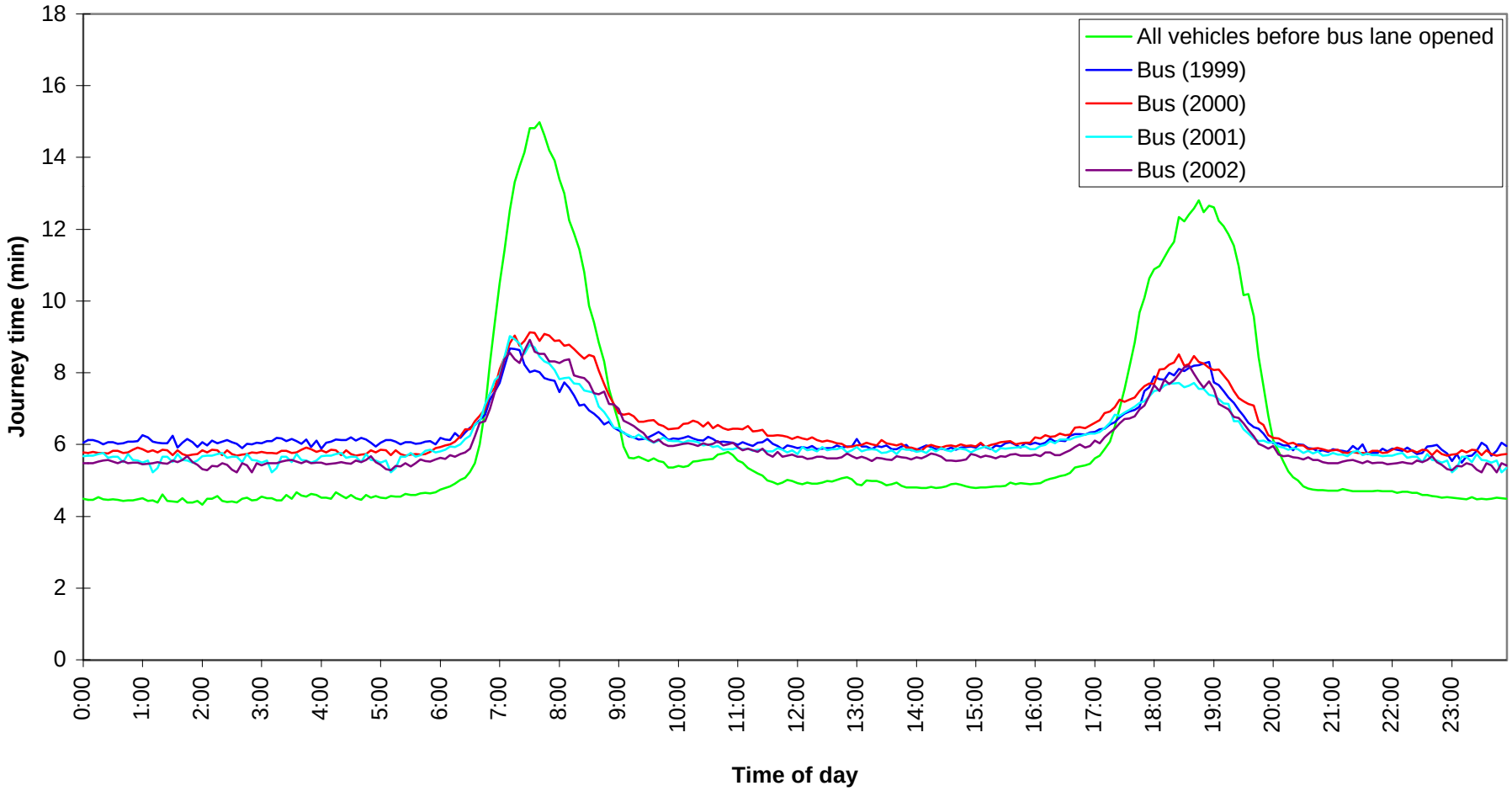

Figure 10
Journey time (M4 J4 - start of elevated section)
(8.4 km)
All weekdays (including incidents)

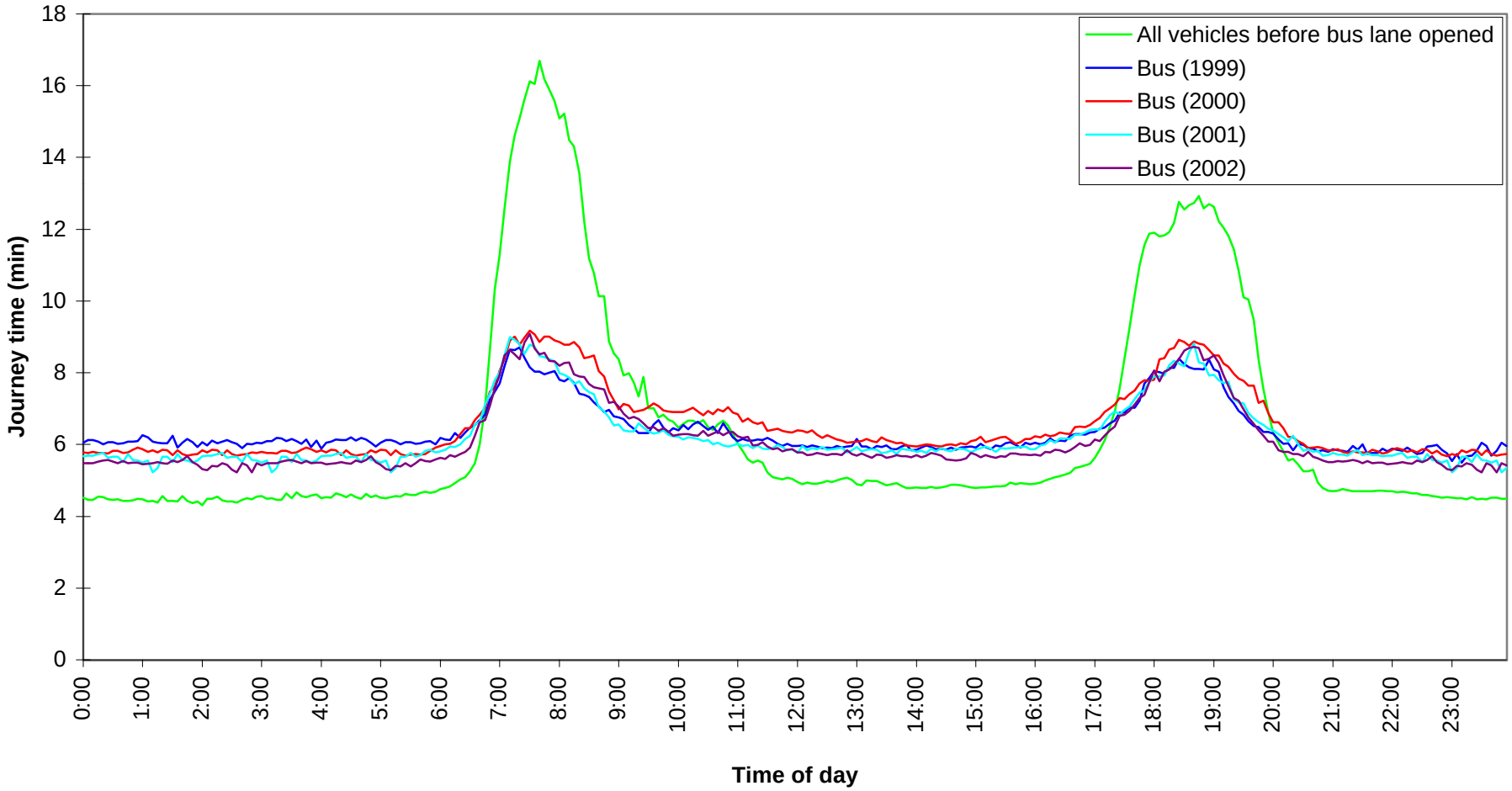

Figure 11
Journey time variability (M4 J4 - start of elevated section)
Weekdays excluding incidents

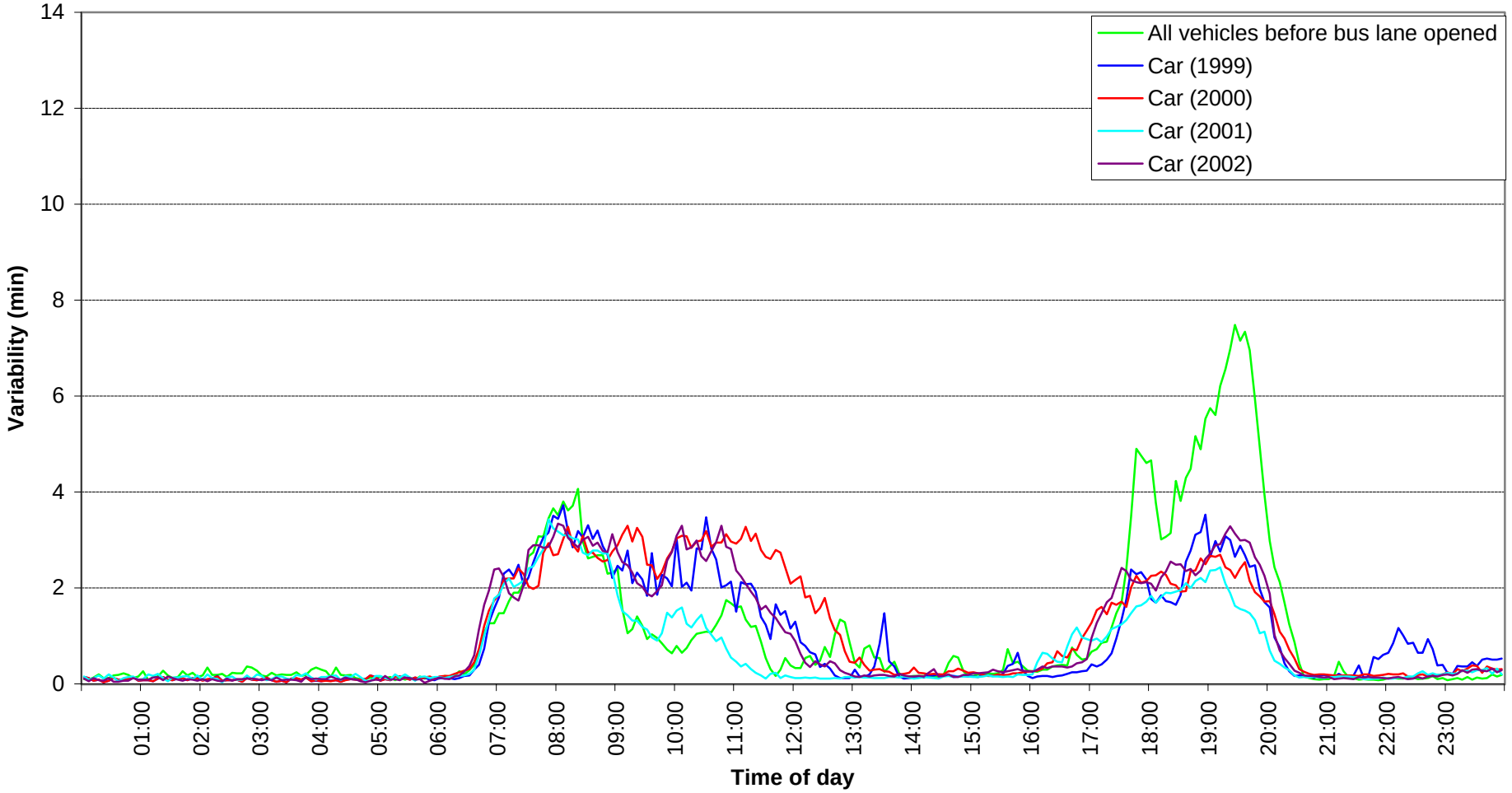

Figure 12
Journey time variability (M4 J4 - start of elevated section)
All weekdays (including incidents)

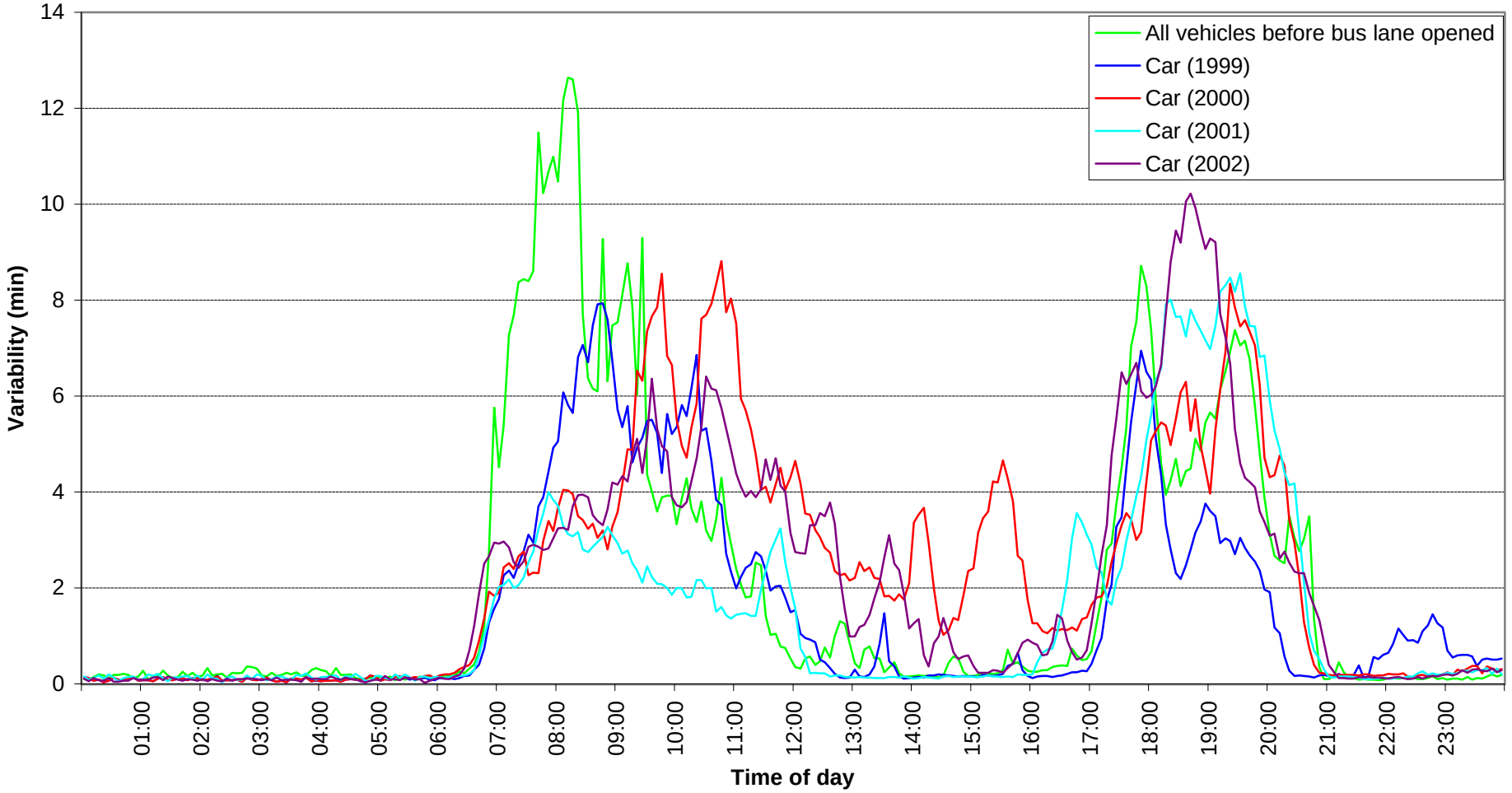

Figure 13
Journey time variability (M4 J4 - start of elevated section)
Weekdays excluding incidents

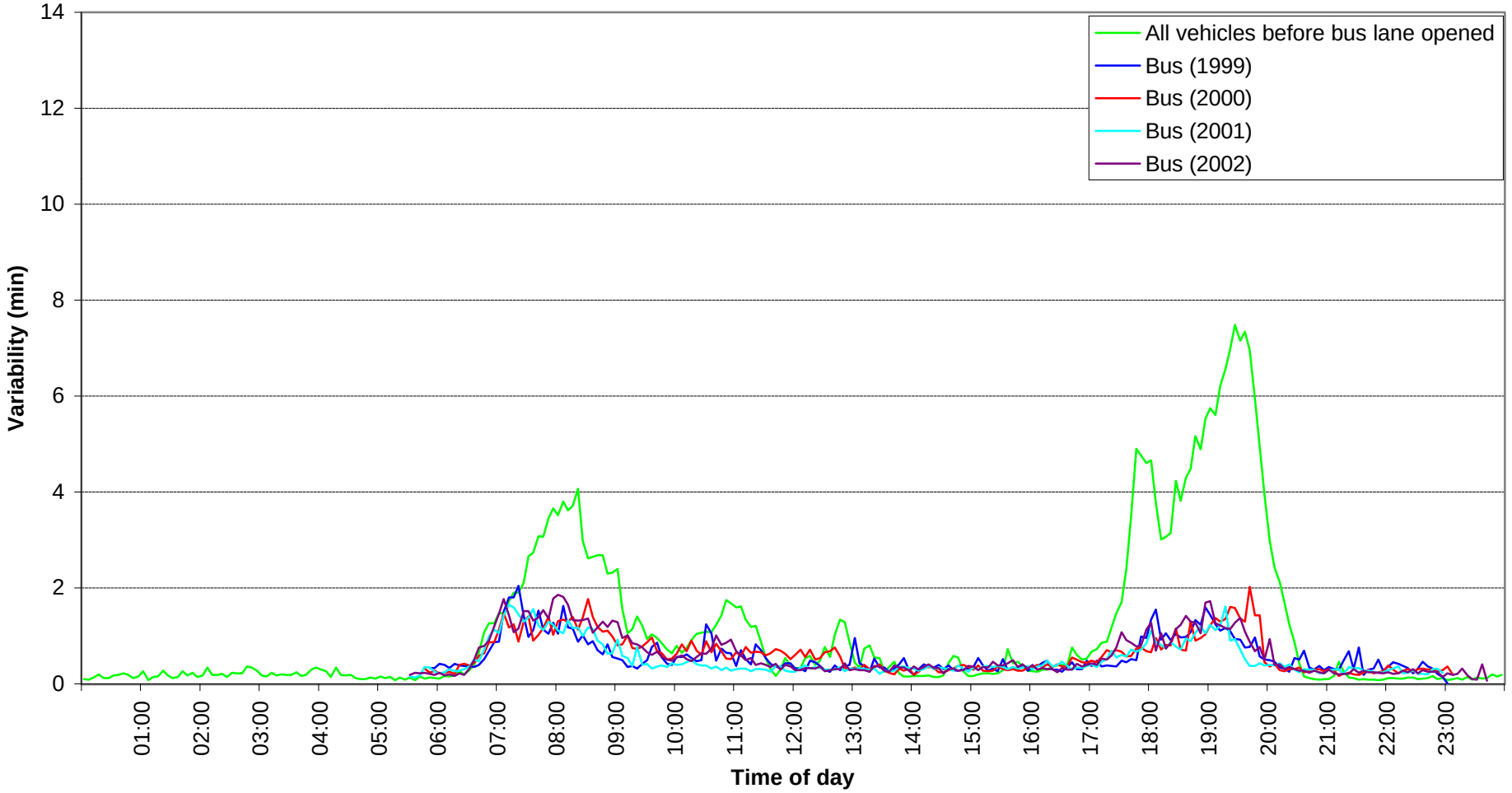

Figure 14
Journey time variability (M4 J4 - start of elevated section)
All weekdays (including incidents)

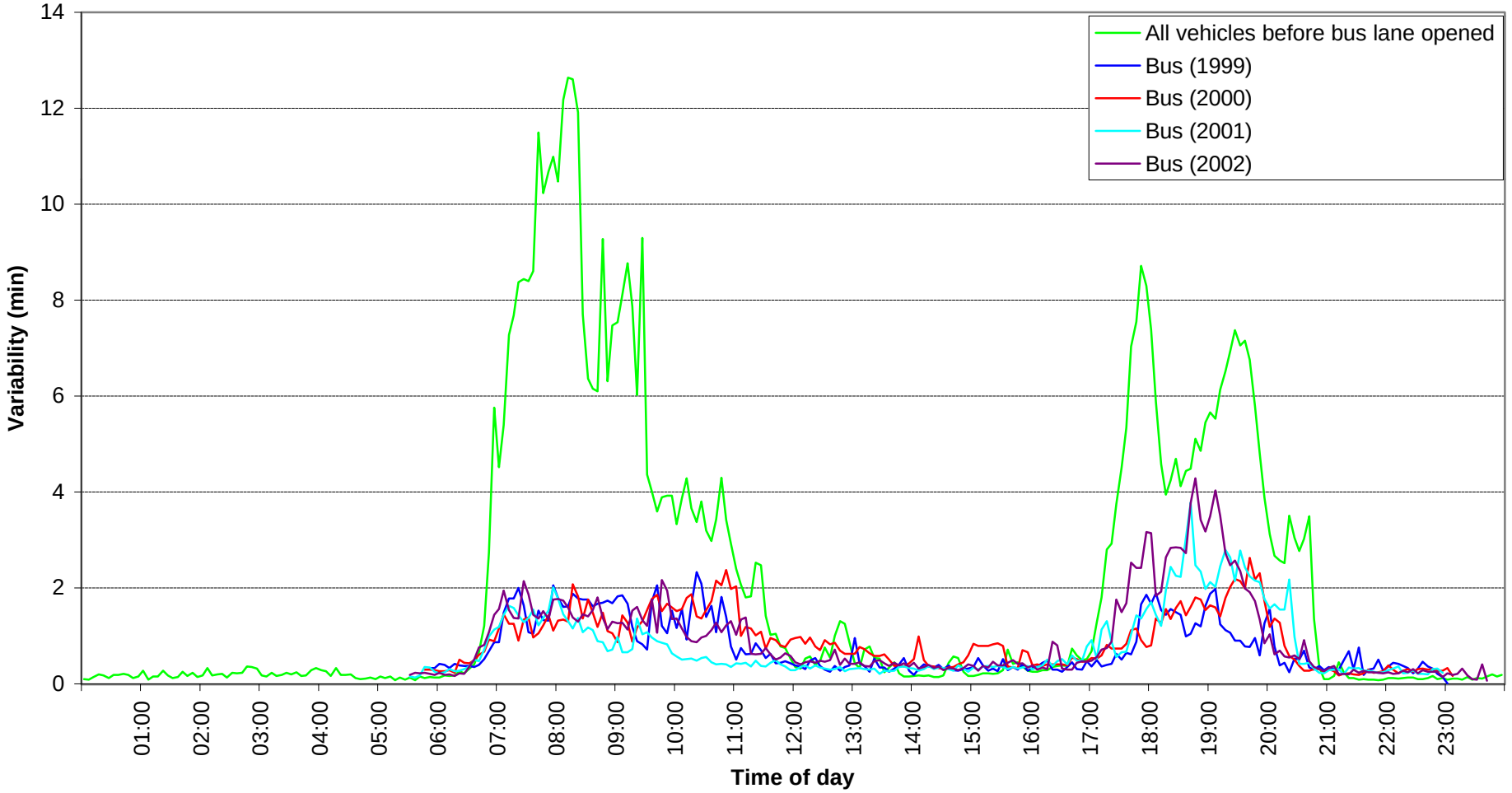

Figure 15
Vehicle Speed composition in July 2002, M4 J3 (loop 2216B)

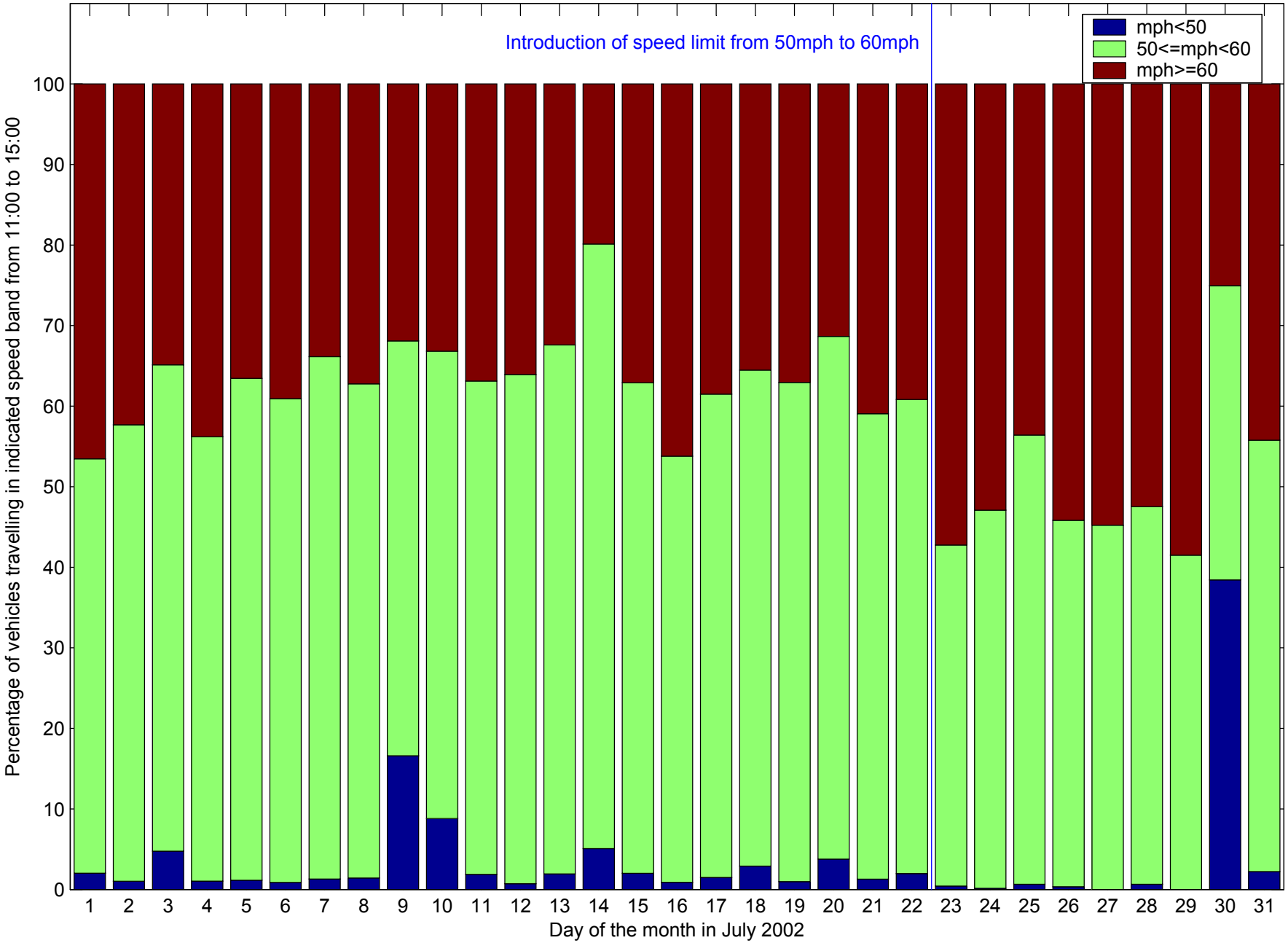

Figure 16

Composition of traffic in M4 Bus lane: Thursday 7th November 2002