DRIVE II PROJECT V2016 : PRIMAVERA

Priority Management for Vehicle Efficiency,
Environment and Road Safety on Arterials

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REPORT ON ANALYSIS OF FIELD TRIALS

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1 EXECUTIVE SUMMARY

This report is an appraisal of the data collected during the field trials. The analysis indicates that the aims of the project have been achieved. By using a combination of ATT queue management, public transport priority and traffic calming techniques, improvements have been achieved in efficiency, safety and environmental indicators on urban arterial roads.

The trials used networks operating under the following conditions:

(a) Baseline conditions, Leeds and Turin
(b) SPOT operating alone, Leeds
(c) SPOT operating with the strategies devised for PRIMAVERA, Leeds and Turin
(d) SCOOT operating alone, Leeds
(e) SCOOT operating with the strategies devised for PRIMAVERA, Leeds

The strategies for each city are as follows:

Leeds

SCOOT - Starting and stopping waves, bus priority and speed advice.
SPOT - Horizontal queue model, bus priority and speed advice.

Details of the analysis of the Leeds results are given in Section 2. The initial analysis of the data highlighted a problem. It became apparent that the sample sizes in the conflict studies were not large enough to give statistically significant results. Additional funding was requested to collect more data, but this was not forthcoming. Therefore no conclusions can be drawn from the field trials about any changes in safety due to the implementation of the strategies.

The main improvements deduced due to adoption of the PRIMAVERA strategies in Leeds are:

- a 10% reduction in travel times for buses, when compared to the current state-of-the-art UTC systems, without significant disruption to cars
- the virtual removal of speeding vehicles on entry to the arterial in the AM peak, with consequent improvements in safety.

Turin

SPOT - Cooperative auto-gating and speed advice.

Positive results on all the measured indicators have been obtained. Details of the analysis are given in Section 3. Section 3.1 presents an introduction to the field trials. A summary of the cases tested is given together with assumptions and references for the rest of the document. Sections 3.2 to 3.7 report the analysis of the data collected. Section 3.8 contains a comparison between the simulation and field trial results for the implemented strategy. Improvements produced from the adoption of the control strategy devised for PRIMAVERA in Turin can be summarised as follows:

- a reduction of travel time in the network of 10% in the AM peak and 12% in the PM peak
- a reduction of journey time on the arterial between 11% and 30% on selected routes in AM and PM peaks
- a reduction of bus journey times of about 6%
- a reduction in the number of stops on the arterial of the order of 30%
- no significant changes in the queue lengths in terms of vehicles per lane

2 ANALYSIS OF THE LEEDS FIELD TRIAL

2.1 INTRODUCTION

This section presents a summary of analysis of the data collected during the PRIMAVERA field trial in Leeds. A full description of the field trials and all the data collected can be found in Deliverable 13: "Field Trials Implementation and Data Collection". The specification for the field trials can be found in Deliverable 11: "Data Collection and Evaluation Methodology".

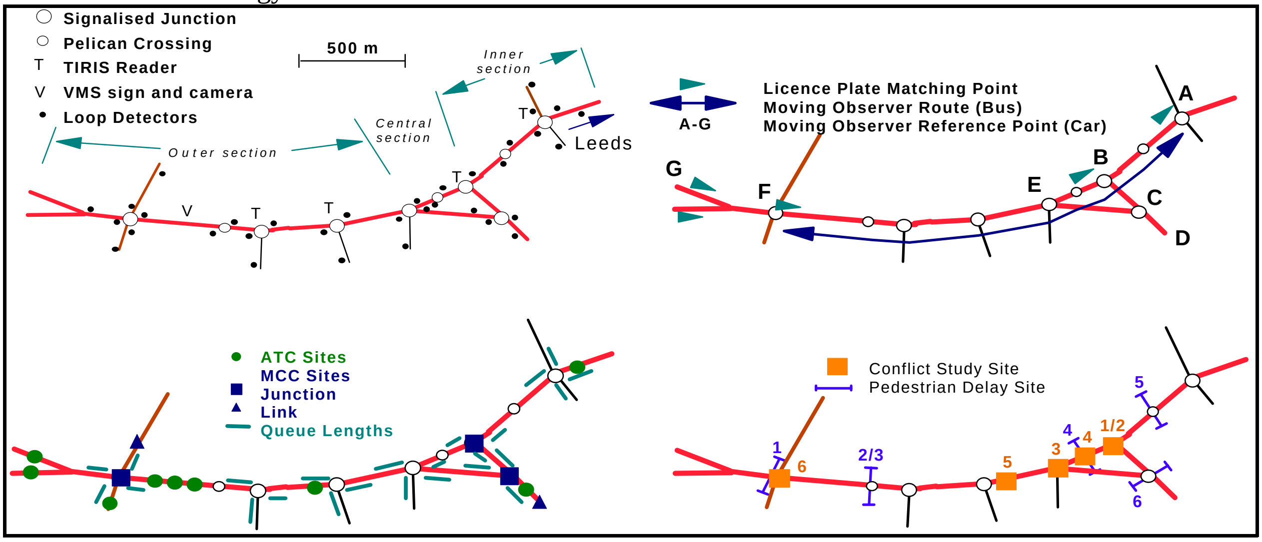

Figure 2.1: The Dewsbury Road Trial Site

The Leeds field trial site and the data collection points are shown in Figure 2.1. The urban arterial chosen for the field trial in Leeds was a 3km section of the A653; the Dewsbury Road. This is one of the main radial routes into Leeds, carrying approximately 23,000 vehicles per day. It is also a heavily used public transport corridor, peak flows being in excess of 36 buses per hour. It is typical of many urban arterials in that it attempts to combine the functions of general traffic movement, public transport corridor, shopping street and residential area. On the chosen section there are ten signalised intersections including three pelican crossings. In terms of physical characteristics Dewsbury Road can be divided into three distinct parts. The outer section comprises largely a four lane carriageway with closely spaced pedestrian refuges, so that it is almost a dual carriageway. Fronting the road is a mixture of light industrial and residential uses. The central section passes through a local shopping centre with shops on both sides of the road. This part of Dewsbury Road comprises two traffic lanes with localised widening to three lanes at the two signal controlled junctions. The inner section, closest to the city centre, is made up of three lanes with one lane for city bound traffic and two lanes outbound, one which is reserved as an evening peak bus lane.

Six types of survey were carried out as follows:

- journey times (cars and buses)
- automatic traffic counts
- classified vehicle counts
- queue lengths
- pedestrian delays
- conflict studies

The field trials have been designed to see whether improvements as predicted by simulations in Deliverable 12: "Evaluation of Simulated Strategies", occur in reality. Statistical tests have been carried out on the data collected during these field trials. These are used to produce confidence levels that the measured changes are real and not due simply to inherent variability in the data.

2.2 BUS TRAVEL TIMES AND DELAY

2.2.1 Data collected

Bus journey times were collected in two different ways. Number plate matching surveys were carried out, with data being collected during the morning peak in the inbound direction. During number plate matching surveys only partial registration plates are collected therefore it is not easy to distinguish buses with transponders from those without. Therefore this survey has only been used to indicate changes in travel times for the whole bus fleet.

Four of the major bus operators; Yorkshire Rider, Yorkshire Buses, Yorkshire Traction and West Riding Buses, equipped a total of 300 of their buses with transponders. The surveys during the field trials indicate that this resulted in approximately 65% of the buses using the Dewsbury Road being equipped.

Total bus journey times were measured by moving observers on buses. These times were measured for both inbound and outbound journeys over the Dewsbury Road trial site. Data was collected during both the morning and evening peaks.

2.2.2 Results

The results of the number plate matching surveys are shown in Table 2.1. This shows changes in journey times, along with the standard deviation of the observed journey times, the percentage change in the journey times and a statistical measure of confidence that the strategies have had an effect on the journey times.

Strategy	No of matches	Journey Time (seconds)	s.d.	% change in time	% confidence
Baseline	87	406	87		
SPOT +	52	382	84	-5.9	89
SPOT alone	48	455	118	12.1	99
SCOOT +	46	407	95	0.2	5
SCOOT alone	45	431	113	6.2	80

Table 2.1: Bus Travel Times - Number Plate Matching Surveys

The first point to note is that the use of both SCOOT and SPOT on their own without the bus priority or traffic calming components increases bus travel times. This is because on this arterial the UTC systems impose strong co-ordination (green waves) for cars between the signals. Buses travel at different speeds to cars and therefore can drop out of this co-ordination. The bus journey time variability, as indicated by the standard deviation, also increases when the UTC systems are used on their own.

The introduction of the integrated strategies appears to reduce bus travel times back to baseline values when used with SCOOT and improves on the baseline values when used with SPOT. When comparing the integrated strategies against the UTC systems on their own, the integrated SPOT based strategy reduces the travel time by 16% when compared with SPOT alone, with virtually 100% confidence of a statistically significant change. The integrated SCOOT based strategy reduces the travel time by 6% with 72% confidence.

The number plate matching surveys do not distinguish between transponder equipped and non-equipped buses, for this the moving observer surveys need to be examined. The results for the entire bus fleet are shown in Table 2.2.

	Inbound am	Outbound am	Inbound pm	Outbound pm
	Time	Time	Time	Time
Baseline				
Number of Trips	35	32	26	29
Mean Time	377	353	322	357
s.d.	86	79	98	74
SPOT				
Number of Trips	38	37	41	36
Mean Time	413	345	311	356
s.d.	114	56	73	86
% change in time	9.5	-2.3	-3.4	-0.3
% confidence	87	37	40	4
Integrated SPOT				
Number of Trips	27	27	41	40
Mean Time	371	326	282	334
s.d.	88	47	69	77
% change in time	-1.6	-7.6	-12.4	-6.4
% confidence	21	89	92	78
SCOOT				
Number of Trips	9	7	9	8
Mean Time	379	393	319	371
s.d.	58	69	47	43
% change in time	0.6	11.3	-0.9	3.9
% confidence	5	78	10	39
Integrated SCOOT				
Number of Trips	15	16	25	25
Mean Time	339	365	327	371
s.d.	80	100	67	76
% change in time	-9.9	3.4	1.4	3.9
% confidence	85	35	17	50

Table 2.2: Changes in bus travel time (Moving Observers)

The priority system only gives priority to transponder fitted buses travelling inbound. Table 2.3 shows the results for these equipped buses in this direction when the integrated strategies with bus priority are in operation.

	Inbound am	Inbound pm
	Time	Time
Integrated SPOT		
Number of Trips	21	25
Mean Time	348	290
s.d.	81	52
% change in time	-7.7	-9.9
% confidence	78	85
Integrated SCOOT		
Number of Trips	11	12
Mean Time	348	331
s.d.	87	63
% change in time	-7.7	2.8
% confidence	66	23

Table 2.3: Changes in bus travel time (Transponder fitted buses)

The moving observer results indicate that during the AM peak both the SPOT and SCOOT based integrated strategies manage to reduce bus journey times for inbound buses by about 8% for the transponder equipped buses, when compared with the baseline.

The moving observer surveys also indicate that the integrated strategies reduce travel times for outbound buses during the AM peak, when compared to the UTC systems on their own. In the PM peak SPOT alone reduces travel times by 3.4% inbound with little change to outbound travel times. The integrated SPOT based strategy reduces inbound travel times by 12.4% and the outbound travel times by 6.4%. SCOOT is not helpful to buses during the PM peak, making little difference to inbound travel times and increasing outbound travel times by 3.9%, whether operating alone or with the integrated components.

Approximate total travel time savings for introducing the integrated components into the UTC systems are shown in Table 2.4. These are based on bus patronage figures during the two hour peaks and the moving observer travel time surveys.

	AM Peak		PM Peak	
	Inbound	Outbound	Inbound	Outbound
Patronage	1700	800	1200	1500
Integrated SPOT				
Time saving (s)	42	19	29	22
Total saving (s)	71400	15200	34800	33000
Integrated SCOOT				
Time saving (s)	40	28	-8	0
Total saving (s)	68000	22400	-9600	0

Table 2.4: Total bus travel time savings

2.2.3 Conclusions

Both the number plate matching and moving observer results indicate that the adoption of the integrated strategies produces a significant reduction in bus travel times when compared with the UTC systems on their own. They also indicate that on this arterial the use of the UTC systems on their own results in an increase in bus travel times for inbound buses during the AM Peak, when compared with the baseline. The addition of the integrated components reverses this trend, resulting in a reduction in bus travel times when compared with both the UTC systems on their own and the baseline.

The integrated SPOT based strategy produced a reduction in both bus journey times and journey time variability according to both the number plate matching and the moving observer surveys.

2.3 CAR JOURNEY TIMES

2.3.1 Data collected

Moving car observers were used to collect journey times for two different routes around the network. The points defining these routes are shown in Figure 2.1. Route 1 was from A → B → E → F → G → F → E → C → D → C → B → A. Route 2 was from A → B → C → D → C → E → F → G → F → E → B → A. The surveys for both routes covered the hours 0730-0930 and 1630-1830. Six days of data were collected for each of the integrated strategies and three days of data for the UTC systems on their own.

In addition a registration plate survey was undertaken between 0730 and 0930 using five timing points on the Dewsbury Road, inbound towards the city centre, on one day for each condition. The timing points can be seen in Figure 2.1. Unfortunately, a communications link failed on the day of the survey for the integrated SPOT strategy, which invalidated the results.

2.3.2 Results

The two routes covered by the moving observers were broken down into 29 links, 17 of which are common to both routes, 5 only on route 1 and 7 only on route 2. These links are shown in figure 2.2. The data from both routes can be combined to give average travel times along each link. Flow data from the automatic traffic counts and manual classified counts can be used to determine typical flows along each link. If the link flows are multiplied by the average link travel times and summed across all the links then the total travel time for all vehicles can be determined. Further details of this analysis can be found in Appendix A.

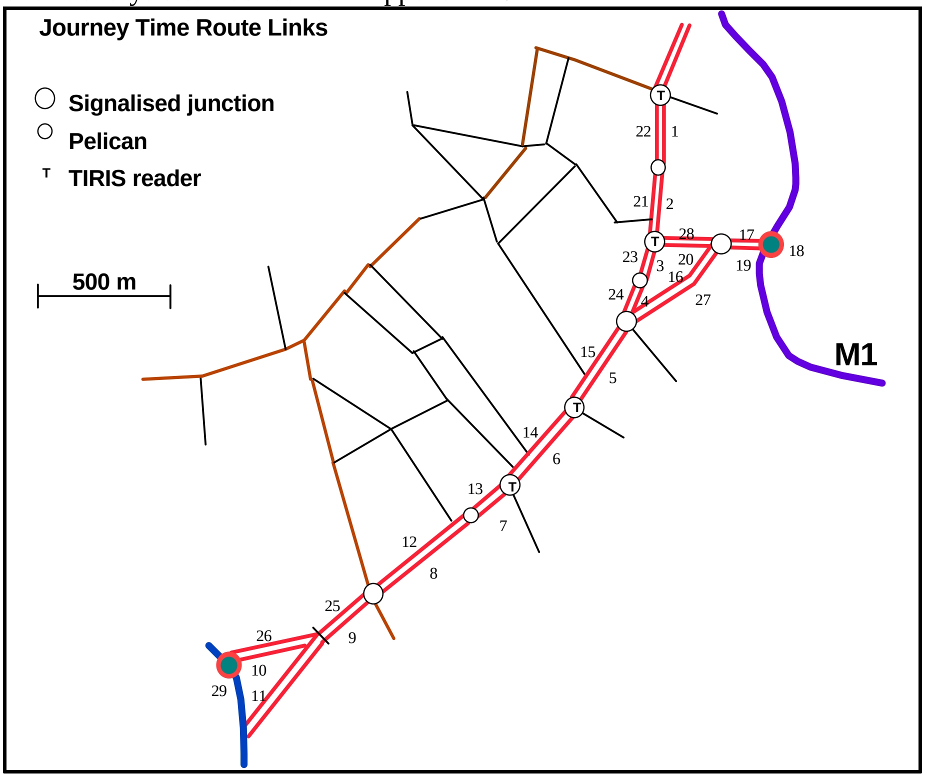

Figure 2.2: The journey time route links

Table 2.5 shows the changes in travel time on each link within these moving observer routes. The travel times for each of the integrated strategies is compared with the travel time for the UTC system operating without the integrated components. Therefore the integrated SCOOT strategy is compared against SCOOT without the starting and stopping wave, bus priority and traffic calming components. The integrated SPOT strategy is likewise compared against SPOT without the horizontal queue model, bus priority and traffic calming components.

The typical flows on each link during the two hour peak periods are also shown. These have been used to calculate the overall change in travel time for all the vehicles using the network covered by the moving observers. These changes in overall network time are given below the main table.

	AM Peak	AM Peak		PM Peak	PM Peak
	% change in	% change in		% change in	% change in

Link	Length (m)	AM Peak Flow	Travel Time SPOT +	Travel Time SCOOT +	PM Peak Flow	Travel Time SPOT +	Travel Time SCOOT +
1	288	1200	-0.82	3.92	1400	-6.70	9.06
2	235	1200	-16.84	-0.19	1400	-7.00	15.67
3	153	1200	-22.26	3.18	1300	-3.14	-12.29
4	204	1200	8.12	-9.97	1300	4.84	-7.62
5	401	1200	2.26	-5.75	2000	-0.98	3.47
6	395	1200	5.92	-7.35	2150	-4.23	1.06
7	193	1200	-9.06	-7.27	2150	-9.33	5.83
8	493	1200	-1.39	8.59	2100	13.81	54.28
9	246	1350	-11.43	7.12	1550	-8.58	5.31
10	451	800	8.44	5.70	800	1.17	7.84
11	552	1250	-22.79	22.48	800	-41.54	99.34
12	507	2200	11.86	-1.79	1900	3.90	12.29
13	180	2200	24.85	13.25	2100	-16.90	-4.50
14	390	2200	4.49	5.10	2100	1.45	10.97
15	405	2200	11.22	6.02	2500	1.79	-16.68
16	492	700	-0.18	-6.47	1050	9.24	-10.18
17	189	2000	-6.90	2.16	2500	3.30	23.94
18	231	2000	1.09	4.59	2500	2.99	-2.71
19	187	2000	-6.23	9.64	1400	6.35	81.44
20	256	900	29.86	34.60	700	6.42	-30.36
21	248	1700	18.12	-2.95	1200	12.91	-14.73
22	290	1700	-10.26	-9.54	1200	5.44	36.93
23	127	1600	-6.90	-3.78	1450	16.03	-24.30
24	226	1600	-13.37	18.34	1450	30.51	-6.71
25	208	1950	-8.48	4.79	1900	40.13	-22.60
26	469	700	7.76	13.53	1000	37.77	8.07
27	494	1100	23.65	-12.85	1000	7.19	2.07
28	246	900	-8.81	22.24	1300	6.78	10.62
29	67	800	2.82	-11.01	800	-3.59	2.25
		Network change(s)	3056	81343	Network change(s)	125755	136121

Table 2.5: The changes in travel times for each link

The total change in travel times for all vehicles travelling on these links, assuming a vehicle occupancy of 1.4 per vehicle is shown at the bottom of Table 2.5. For the AM Peak, these increases in car travel time are easily countered by the decrease in bus travel times in the same period. (See Table 2.4) For the PM Peak the increased car travel times exceed the bus travel time savings. The extra delay to cars during the PM Peak is probably a result of using the bus priority component. This component is only giving priority towards the city centre and during the PM Peak this is against the main traffic flow. The staging arrangements at some of the bus priority junctions means that extending green times for buses inbound can result in an increase in red time for vehicles travelling outbound. It is therefore recommended that the bus priority component is not used during the PM Peak.

2.3.3 Conclusions

The changes caused by introducing the integrated strategies is not simple. The travel time on some links is reduced while on others it increased. Overall there was very little change in car travel times during the morning peak, while during the evening peak there was a slight increase.

2.4 CONFLICT STUDIES

2.4.1 Data collected

Three conflict studies were carried out, namely:

(1) Integrated SPOT based strategy (week beginning 25th of July 1994)
(2) Baseline studies (week beginning 1st of August 1994)
(3) Integrated SCOOT based strategy (week beginning 25th of October 1994)

2.4.2 Results

(a) Integrated SPOT based strategy

Conflict Type	Vehicle-Vehicle	Vehicle-Pedestrian	Total
Serious conflicts	2	1	3
Border line cases	1	0	1
Slight conflicts	11	11	22
Total	14	12	26

Table 2.6: Conflicts - Integrated SPOT based strategy

(b) Baseline conditions

Conflict Type	Vehicle-Vehicle	Vehicle-Pedestrian	Total
Serious conflicts	1	1	2
Border line cases	1	2	3
Slight conflicts	2	5	7
Total	4	8	12

Table 2.7: Conflicts - Baseline

(c) Integrated SCOOT based strategy

Conflict Type	Vehicle-Vehicle	Vehicle-Pedestrian	Total
Serious conflicts	0	0	0
Border line cases	1	0	1
Slight conflicts	12	3	15
Total	13	3	16

Table 2.8: Conflicts - Integrated SCOOT based strategy

2.4.3 Conclusions

For the baseline studies, there were 12 conflicts observer, only 2 of which were categorized as serious conflicts, based on Time to Accident vs Speed trade off. When the integrated SPOT strategy was implemented, there were 26 conflicts observed during the period of study, only 3 of which were categorized as serious conflicts. For the integrated SCOOT based strategy there were 16 conflicts observed, no serious conflicts and only one borderline. In general, all observed conflicts in these two time scales were either conflicts between a motorised vehicle and another motorised vehicle (i.e. Vehicle-Vehicle) or between a motorised vehicle and a pedestrian (i.e. Vehicle-Pedestrian). Conflicts between a vehicle and a dog were also observed, two when the integrated SPOT based strategy was implemented and one during the baseline study, but these have been ignored in this study.

Using the statistical procedures of Nicholson (1987)[1] but substituting days of observed conflicts instead of years of observed accidents, we can say with 95% confidence that there has been a significant change from the baseline rate if the total number of all conflicts is outside the range 3 to 21. Similarly if the total number of serious conflicts is greater than 5 we can say with 95% confidence that there has been a significant increase. Thus none of the observed changes were significant, except for the total number of conflicts under the SPOT based strategy.

[1]Nicholson A.J. (1987) "The Estimation of Accident Rates and Countermeasure Effectiveness", Traffic Engineering and Control, October 1987, pp 518-523.

2.5 PEDESTRIAN DELAY

2.5.1 Data collected

The delay to pedestrians was measured at five sites (see Figure 2.1) during the morning from 07:00 to 10:00 and during the evening from 15:30 to 18:30. Sites 2 and 3 are the two halves of a staggered pelican crossing and are treated together in the following results. The total time that all pedestrians were delayed has been aggregated and an average delay per pedestrian calculated for each site. Statistical confidence levels in the observed changes have also been calculated.

2.5.2 Results

	Site Number				
Implementation	1	2/3	4	5	6
Baseline					
No. of pedestrians	379	206	719	241	451
Average Delay	17.44	13.88	17.10	19.10	16.45
SPOT					
No. of pedestrians	286	247	241	172	362
Average Delay (s)	28.08	11.22	28.11	27.72	28.67
Δ Average Delay	10.64	-2.66	11.01	8.62	12.22
% change	61.01	-19.17	64.37	45.11	74.25
% confidence	100	93	100	100	100
Integrated SPOT					
No. of pedestrians	418	247	344	228	365
Average Delay (s)	31.91	11.63	34.18	35.17	25.29
Δ Average Delay	14.47	-2.26	17.08	16.07	8.84
% change	82.97	-16.25	99.90	84.11	53.74
% confidence	100	86	100	100	100
SCOOT					
No. of pedestrians	437	249	404	237	314
Average Delay (s)	28.63	11.56	25.51	32.78	34.80
Δ Average Delay	11.19	-2.33	8.41	13.68	18.35
% change	64.17	-16.75	49.21	71.61	111.52
% confidence	100	88	100	100	100
Integrated SCOOT					
No. of pedestrians	369	105	404	235	279
Average Delay (s)	23.91	16.46	24.92	24.73	30.72
Δ Average Delay	6.47	2.57	7.82	5.62	14.27
% change	37.08	18.54	45.73	29.44	86.72
% confidence	100	40	100	100	100

Table 2.9: Pedestrian delay

2.5.3 Conclusions

It can be seen that the integrated SPOT based strategy caused an increase in pedestrian delay at four of the five sites, while the integrated SCOOT based strategy, SCOOT alone and SPOT alone all caused an increase at all of the sites.

If the average pedestrian flows are used at each site, it is possible to estimate the total change in delay across the five sites. This is shown in the following table.

	Site No.					
	1	2/3	4	5	6	Total
Average flow	378	211	422	223	354	1588
SPOT Delay change (s)	4020	-561	4650	1918	4327	14354
Integrated SPOT Delay change (s)	5467	-476	7216	3577	3131	18915
SCOOT Delay change (s)	4228	-490	3554	3045	6499	16836
Integrated SCOOT Delay change (s)	2443	543	3303	1252	5054	12595

Table 2.10: Change in Total Pedestrian Delay

All the systems result in increase in total pedestrian delay. This is not surprising as the UTC systems make full use of the available road space, resulting in fewer gaps for pedestrians to cross the road. However, if these increases in pedestrian delay are compared with the savings in travel time from implementing the strategies at this trial site, the bus travel time savings are an order of magnitude larger than the increases in pedestrian delay.

The comparison between the UTC systems on their own and the integrated strategies is seen in Table 2.11.

	Average change (s)	% change	% confidence
Integrated SPOT	+ 3.18	+ 12.7	100
Integrated SCOOT	- 1.91	-7.1	97

Table 2.11: Changes in Pedestrian Delay

There is an increase in pedestrian delay when the integrated SPOT based strategy is compared against SPOT alone. There is a slight decrease for the integrated SCOOT based strategy.

It is interesting to note that the only site which shows any improvement in pedestrian delay is the one just downstream of the VMS.

2.6 SPEED PROFILES

2.6.1 Data collected

A VMS to warn speeding vehicles was installed at the inbound entrance to the Dewsbury Road network at the end of March 1994. This VMS sign is a key part of the strategies, its aim being to reduce the number of speeding vehicles and to reduce the variability in vehicle speeds so that more compact platoons of vehicles are produced which can be more easily controlled by the new queue management strategies. To check that this aim is being achieved, speed profiles of vehicles were measured at three points close to the VMS sign; one just upstream (S12), one at the sign (S13) and one downstream of the sign (S14) beyond a pelican crossing. (Figure 2.3)

The data presented here covers five complete days (24 hours) of data for a period before the installation compared with a corresponding five day period after the installation.

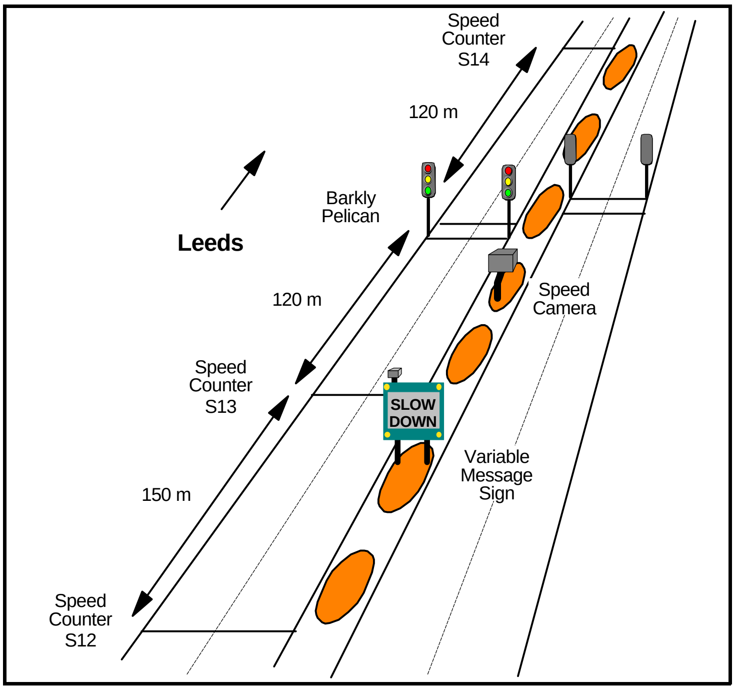

Figure 2.3: The location of the speed counters

2.6.2 Results

The change in speed distribution at these three points is shown in Figures 2.4 - 2.6. The speed limit at this site is 40 mph.

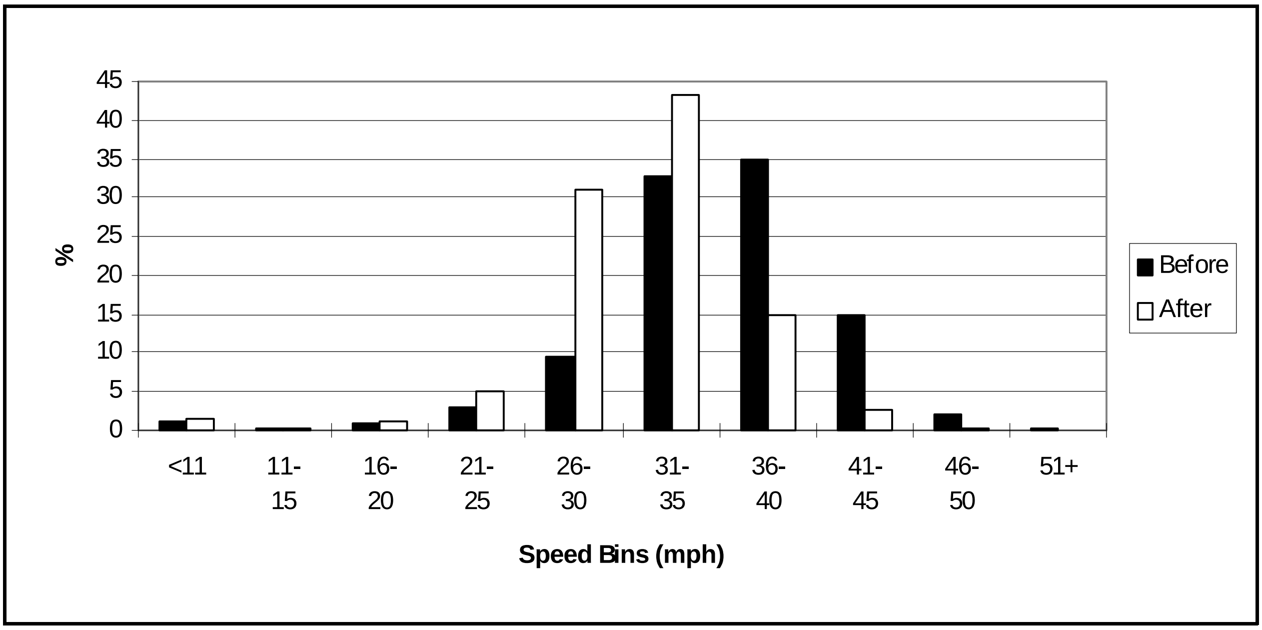

Figure 2.4: The Speed Profile at S12

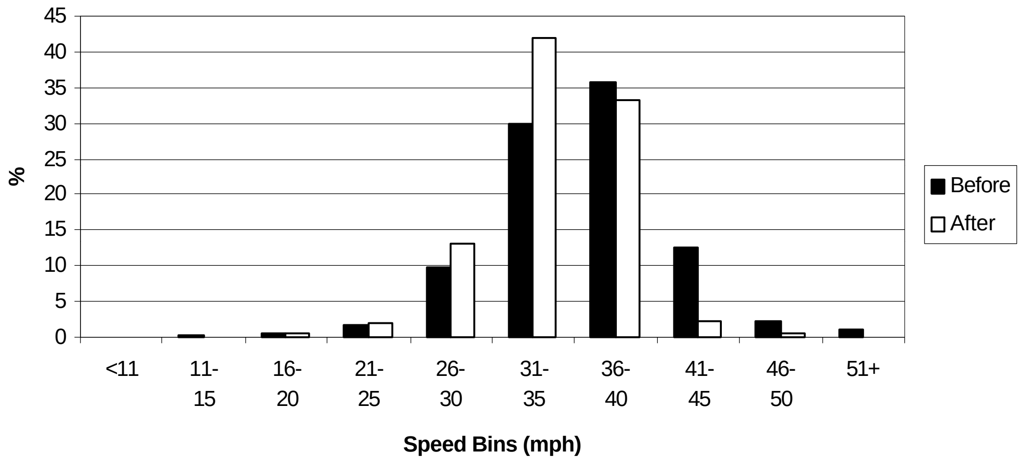

Figure 2.5: The Speed Profile at S13

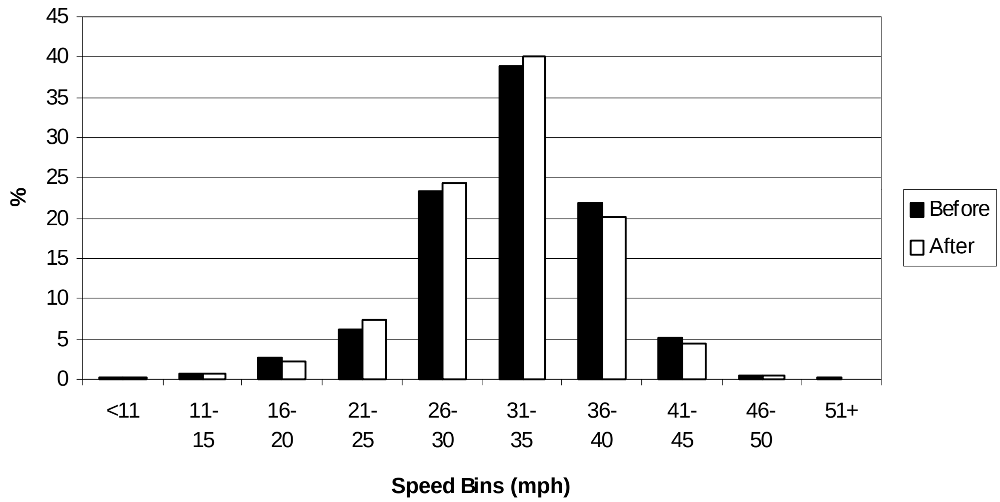

Figure 2.6: The Speed Profile at S14

The changes in the percentage of vehicles exceeding the speed limit, the mean speed and standard deviation of the speed are shown in Table 2.12.

	% speeding		Mean Speed		% confidence in change in Mean Speed	σ	
Site	Before	After	Before	After		Before	After
S12	18	3	35.3	31.3	100.0	6.6	5.8
S13	16	3	31.0	29.2	100.0	6.6	4.9
S14	6	5	29.4	29.2	99.9	6.6	6.5

Table 2.12: The effect of the VMS on vehicle speeds

2.6.3 Conclusions

The introduction of the VMS system has succeeded in reducing high speeding vehicles and producing lower variability of vehicle speeds. This should result in more compact platoons of vehicles.

Due to the very large sample size, there is a very high confidence that the mean speed of vehicles approaching the pelican crossing has decreased. A recent TRL report (Finch et. al. 1994) has indicated that a 1 mph reduction in vehicle speeds can result in a 5% reduction in accident rates, therefore significant safety benefits are predicted for this site. There is even strong evidence that the influence of the VMS extends downstream beyond a pelican crossing as a small but statistically significant reduction in speed has been recorded here.

2.7 QUEUE SURVEYS

2.7.1 Data collected

Queue length data has been collected at six junctions on the Dewsbury Road during both am and pm peaks.

2.7.2 Results

An analysis of all the results showed that overall there was not much difference between the implementations. A typical example is shown here, where queues on two approaches to the Dewsbury Road / Beeston Ring Road Junction during the afternoon are shown. While there are times during the period when one system has performed better than the others, overall no one system outperforms the others consistently at both arms considered.

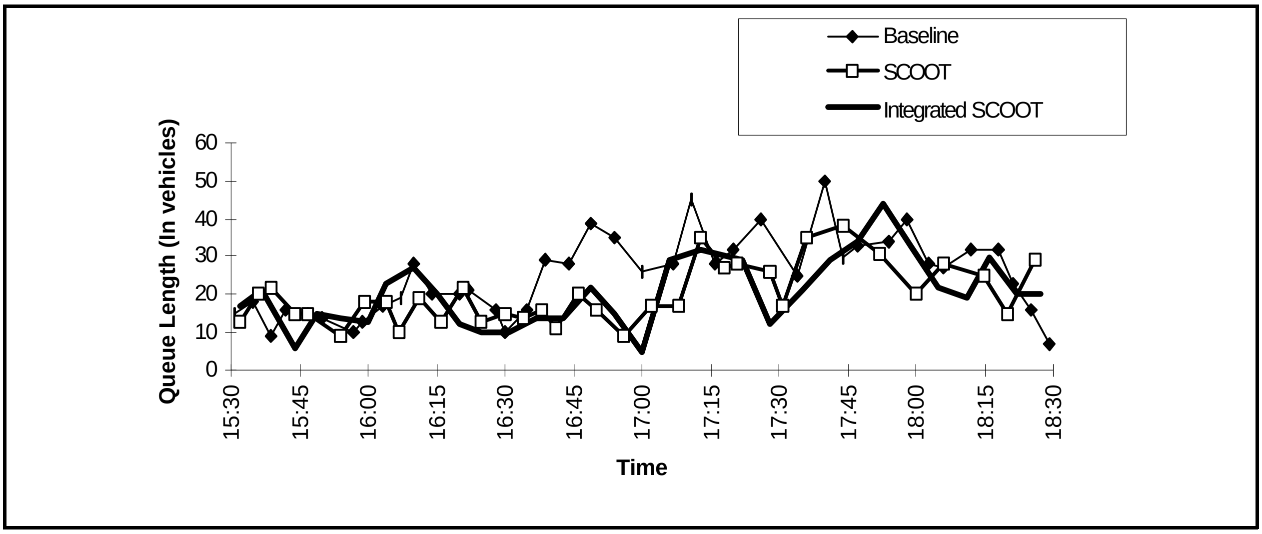

Figure 2.7: The queues at an approach to Beeston Ring Road junction

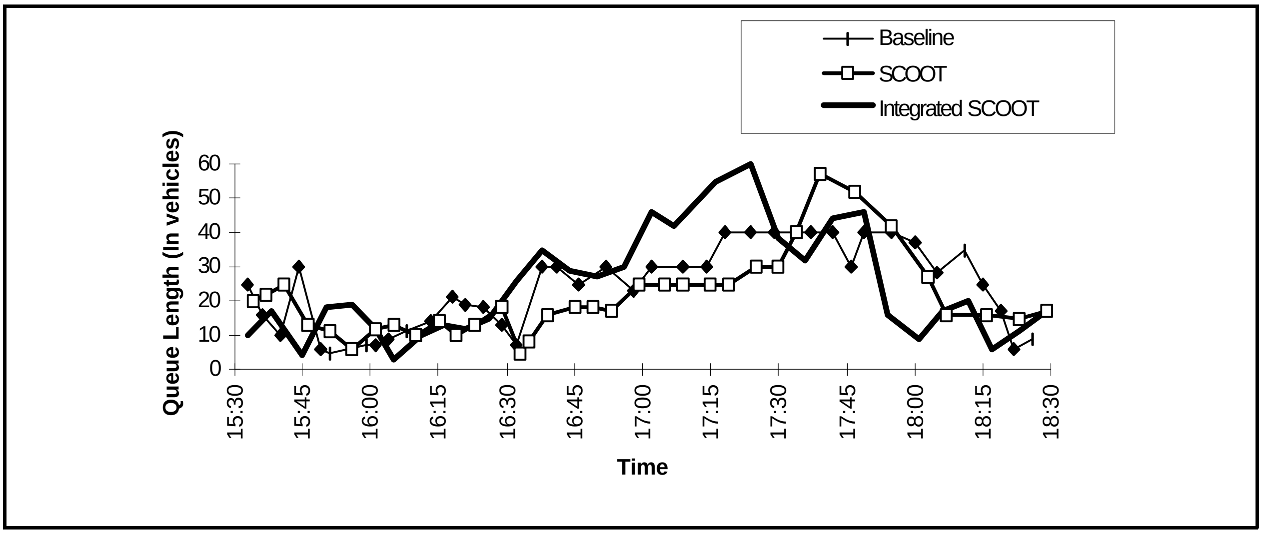

Figure 2.8: The queues at another approach to Beeston Ring Road junction

The average queues on each arm of the surveyed junctions during the survey periods have been calculated. These have been added together to give the total average queues on all arms of the junctions. The results are presented in Tables 2.13 and 2.14. During the AM Peak, the integrated SCOOT based strategy produces an increase of 8.4% in total queue length when compared with SCOOT alone. The integrated SPOT based strategy increases the total queue lengths by 11.7%. In terms of the extra visual intrusion produced by this increase in queue lengths, this is approximately equivalent to adding one extra car to the end of each queue during the peak period.

AM Peak	Baseline	SCOOT	SCOOT+	SPOT	SPOT+
Tommy Wass	66	62	69	83	95
Westland Road	21	17	21	19	18
Middleton Grove	12	17	22	15	25
Parkside / Garnet	32	37	36	35	31
Dewsbury / Tunstall	20	23	21	29	31
Hunslet Hall Road	20	16	24	26	29
Tunstall / Garnet	32	33	29	31	36
Total	204	205	222	238	266
% change			8.36		11.67

Table 2.13: The total average queues on all arms (AM Peak)

PM Peak	Baseline	SCOOT	SCOOT+	SPOT	SPOT+
Tommy Wass	86	77	88	91	82
Westland Road	16	17	25	19	16
Middleton Grove	13	20	20	17	28
Parkside / Garnet	37	35	38	29	36
Dewsbury / Tunstall	26	11	29	20	40
Hunslet Hall Road	23	14	19	14	16
Tunstall / Garnet	31	39	39	31	30
Total	232	214	257	220	249
% change			20.45		12.96

Table 2.14: The total average queues on all arms (PM Peak)

2.7.3 Conclusions

Queue lengths increase slightly when the integrated strategies are used, when compared with the UTC systems on their own.

2.8 COMPARISON WITH THE SIMULATION RESULTS

Table 2.15 shows the actual vs simulated travel times for the links on the routes covered by the moving observers during the field trials. These links are as shown in Figure 2.2. The time period being compared is the AM peak.

SPOT Link	Simulated % change	Actual % change	SCOOT Link	Simulated % change	Actual % change
1	2.7	-0.8	1	-0.8	3.9
2	2.9	-16.8	2	-9.9	-0.2
3	-1.0	-22.3	3	-8.3	3.2
4	-2.8	8.1	4	0.0	-10.0
5	-4.6	2.3	5	31.1	-5.8
6	-3.1	5.9	6	-1.8	-7.4
7	-7.7	-9.1	7	24.0	-7.3
8	-2.0	-1.4	8	11.3	8.6
9	-1.8	-11.4	9	10.3	7.1
10	0.1	8.4	10	0.0	5.7
11	-0.5	-22.8	11	11.2	22.5
12	7.1	11.9	12	-12.4	-1.8
13	3.4	24.9	13	-3.6	13.3
14	-7.5	4.5	14	-2.5	5.1
15	-10.6	11.2	15	0.0	6.0
16	-6.4	-0.2	16	7.3	-6.5
17	-0.2	-6.9	17	0.0	2.2
19	-25.9	-6.2	19	18.3	9.6
20	2.7	29.9	20	5.1	34.6
21	-0.3	18.1	21	0.0	-3.0
22	-1.0	-10.3	22	4.9	-9.5
23	-3.2	-6.9	23	6.3	-3.8
24	3.4	-13.4	24	0.2	18.3
25	8.3	-8.5	25	2.0	4.8
26	-0.3	7.8	26	9.2	13.5
27	-0.9	23.7	27	-1.0	-12.9
28	1.8	-8.8	28	43.2	22.2
Total change	-4.2	0.1	Total change	1.7	3.7

Table 2.15: Simulated vs actual changes in travel times

As can be seen there is rarely agreement between the simulated and observed results. There are a number of reasons for this. Firstly there is the usual problem with field trials of not knowing whether the changes being measured are due entirely to the strategy or to some external influence such as the weather or fluctuations in demand. Similarly, simplifications had to be made to the network and signal plan representations in the simulations which could result in discrepancies. Secondly, the simulations highlighted some areas where problems could occur. With these in mind the systems implemented on-street were changed to try and reduce these problems. For example, the simulations revealed that when using SCOOT, constraining the whole area to an 88s upper limit on cycle time did not allow cars to benefit as much as possible. Therefore during the field trials the area was split into two regions, one with the 88s constraint the other without. The simulations and the field trials are thus comparing different systems. Overall, for the whole network, the SCOOT results show reasonable agreement, both showing a small increase in travel time. The SPOT results are not so good, the simulations predicting a reduction in travel time, the field trials showing little change.

3 ANALYSIS OF THE TURIN FIELD TRIAL

3.1 INTRODUCTION

This section presents a summary of the analysis of the data collected during the PRIMAVERA field trials in Torino (Turin). A detailed description of the field trials can be found in Deliverable 13: "*Field Trials Implementation and Data Collection*". The specification for the field trials can be found in Deliverable 11: "*Data Collection and Evaluation Methodology*".

The field trials have been designed to see whether improvements as predicted by simulations in Deliverable 12: "*Evaluation of Simulated Strategies*", occur in reality. Statistical tests have been carried out on the data collected during the field trials. These are used to produce confidence levels that the measured changes are real and not due simply to inherent variability of the data.

The trials in Torino cover the network operating under the following conditions:

Baseline conditions, green wave coordinated fixed plan
SPOT operating with the strategies devised for PRIMAVERA

As there was not enough time to tune the forecast algorithm of the SIS-AVM system in Torino it has not been possible to test the strategy originally planned for the field trials. The bus priority component of the integrated strategy (bus stop protection) has therefore been dropped. The strategy applied in Torino is:

SPOT+ = SPOT + Cooperative Auto-gating + Speed Advice

The strategy adopted is totally decentralised and no interventions have been allowed by the Area Level Control of the UTOPIA system in Torino. The Traffic Control Centre has been used merely for its monitoring functionality.

Field trials have covered the Corso Grosseto area. The test site includes seven controlled intersections located along the Corso Grosseto arterial. See Deliverable 4: "*Description of the Test Sites*" for a more detailed description of the test site. For simplicity, in the rest of the document the intersections are identified by a numeric index. The following table shows the correspondence between the numeric code and the intersections, the diagram below a schema of the topology of the network:

Code	Intersection
11	Corso Grosseto - Via Casteldelfino
12	Corso Grosseto - Via Fea
13	Corso Grosseto - Via Bibiana
14	Corso Grosseto - Via Chiesa della Salute
15	Corso Grosseto - Via Ala di Stura
16	Corso Grosseto - Corso Vercelli - Via Botticelli
17	Corso Vercelli - Via Toscanini - Via Porpora

Table 3.1: Codes for the intersections

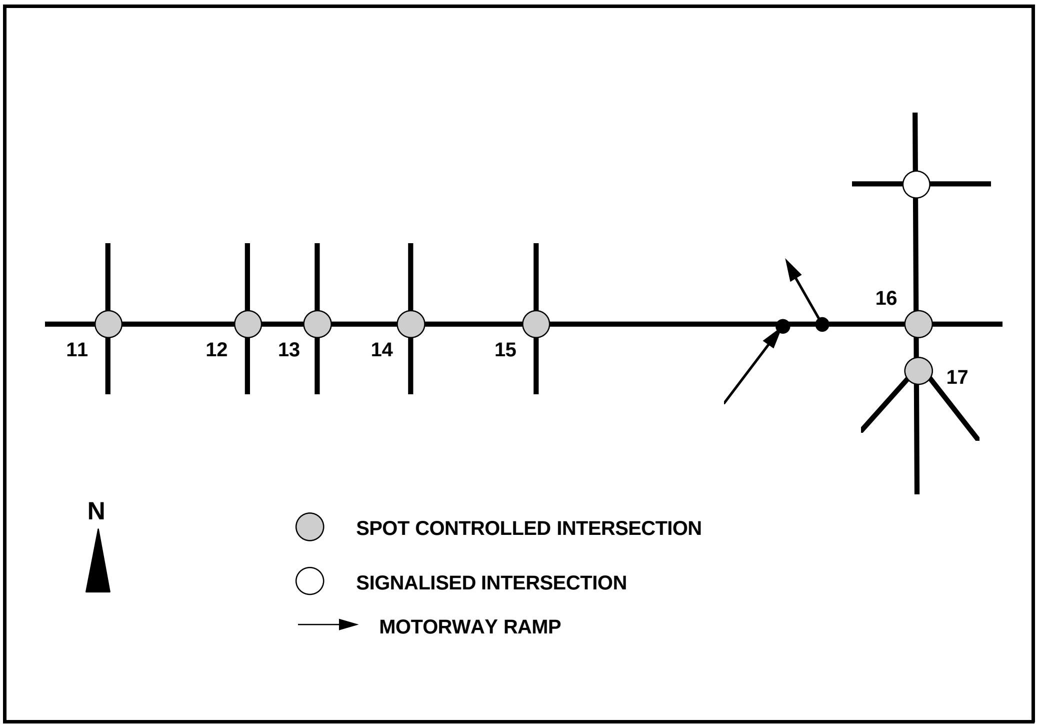

Figure 3.1: The topology of the Corso Grosseto test site

The baseline surveys were carried out from September to October 1994 while the SPOT+ surveys were carried out in June 1995. Between the Baseline and SPOT+ surveys significant modifications to one link, connecting intersections 15 and 16, have been implemented. These modifications have narrowed the carriageway from 4 to 3 lanes in order to facilitate the entrance and the exit from the motorway going to the airport. The changes have resulted in heavy congestion on the link. The link has therefore not been considered in the evaluation of the benefits/disbenefits introduced by the system.

Results are presented for the AM and PM peak periods. Timings for the peaks are 7:00-9:30 for AM and 17:00-19:30 for PM.

3.2 TRAFFIC SCENARIO

This section describes the traffic scenario where the field trials took place. First a description of the topology of the intersections together with information on the traffic movements is given for the more congested intersections in the network. Later the flow demand is presented. There is a gap of several months between the baseline surveys (October 1994) and the SPOT+ trials (June 1995), therefore an analysis of the flows in the area during the above mentioned periods has been made. The results show that small changes did occur in the demand, the biggest changes are reductions of less than 5%. As most of the intersections do not operate in oversaturated conditions it has been assumed that travel times do not change due to a different demand condition.

The following series of diagrams represent the topology, stage planning and turning movements for intersections 11, 15 and 16 where Manual Classified Counts took place. Intersections 12, 13, 14 have a topology very similar to intersection 11 and the same stage planning.

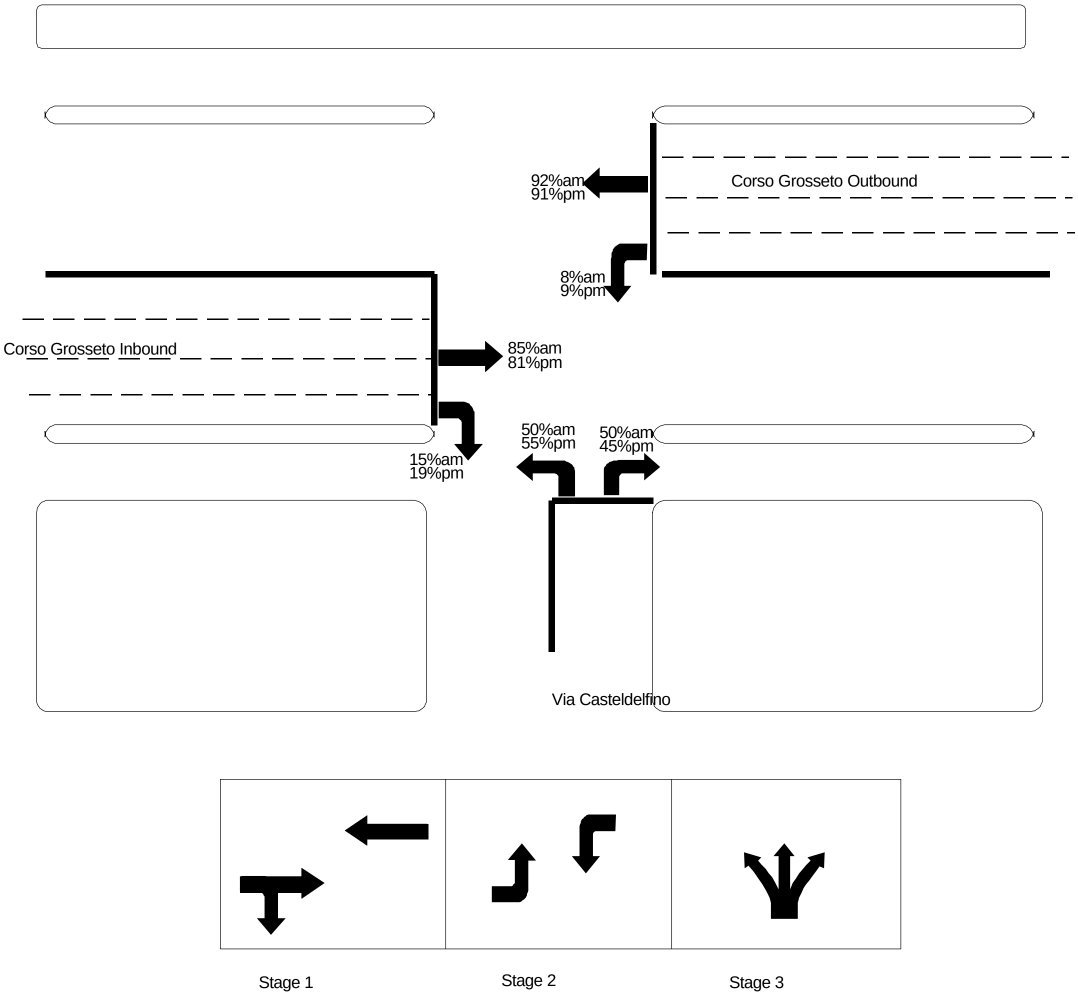

Figure 3.2: Topology and stage planning for intersection 11

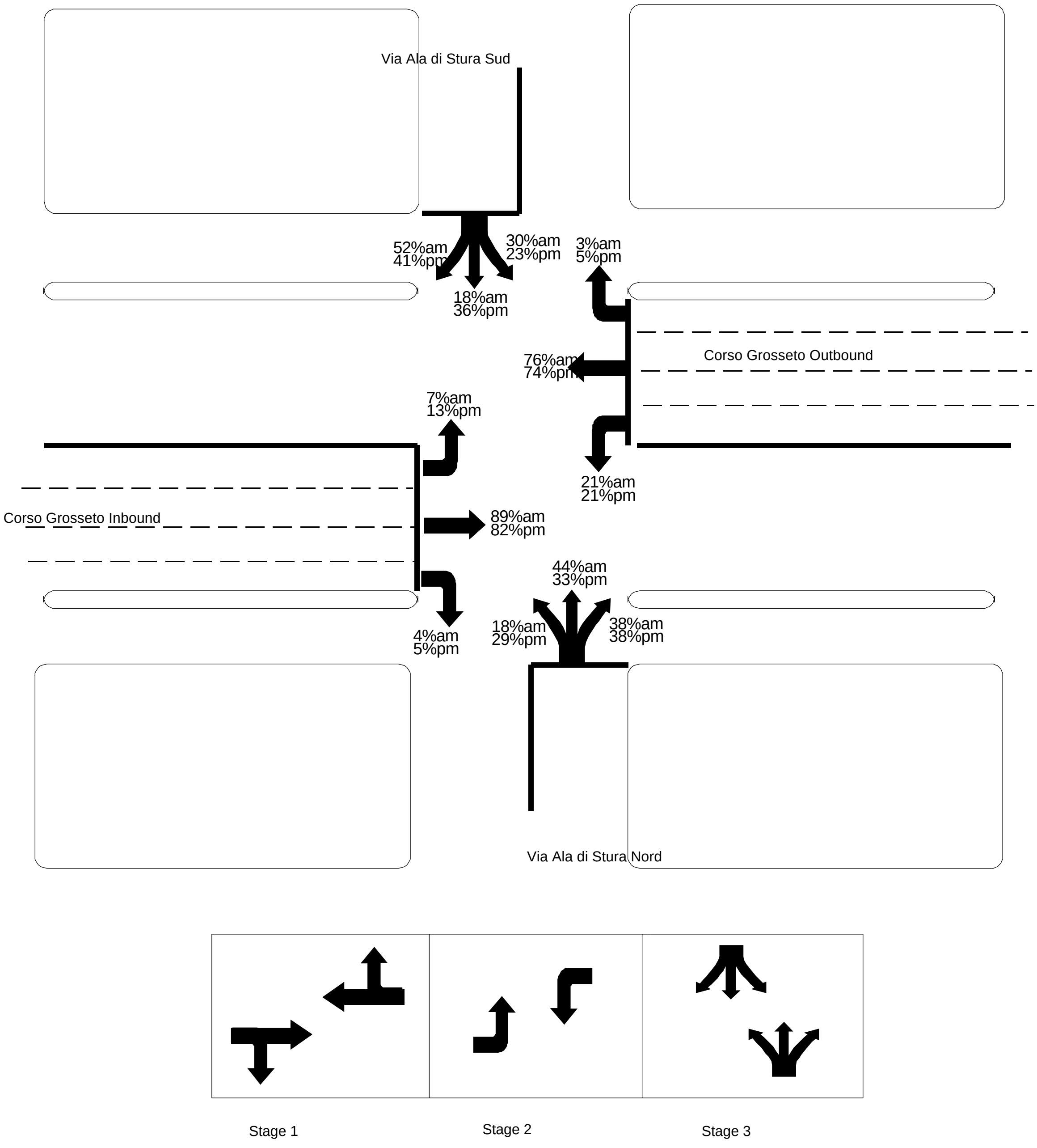

Figure 3.3: Topology and stage planning for intersection 15

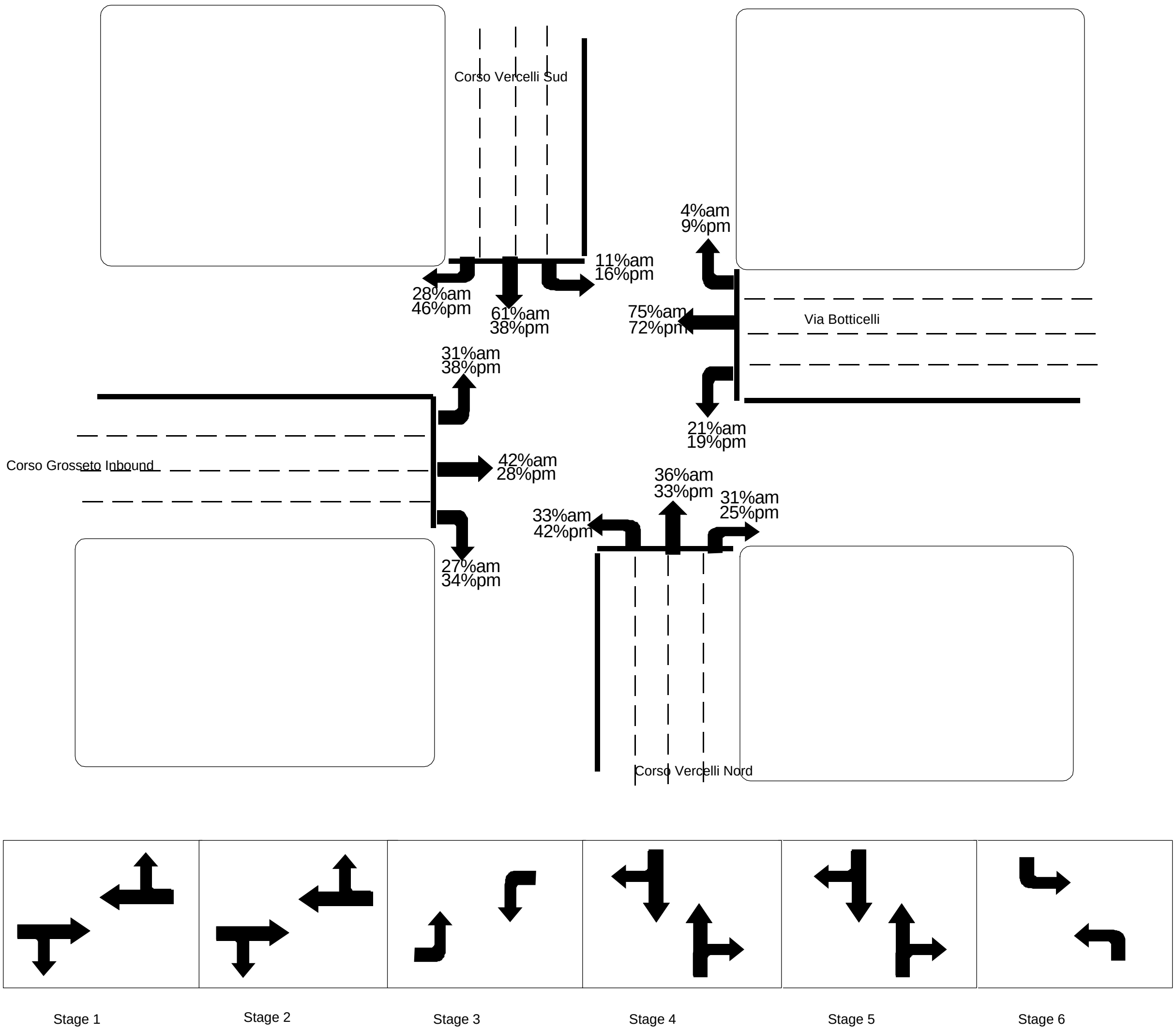

Figure 3.4: Topology and stage planning for intersection 16

The MCC surveys also gave an indication about the traffic composition on the arterial as summarised in the following table.

Category	Percentage
Cars	93.8 %
Lorries	5.6 %
Heavy Goods Vehicles	0.6 %

Table 3.2: Traffic composition on Corso Grosseto

More than 30 ATC counters were deployed in the Corso Grosseto area. For each day the flow profile, sampled at 5 min. intervals has been recorded. The following diagrams show the typical flow profile on one inbound and one outbound section. From the diagrams the two peaks can be easily identified. In absolute terms the dominant flow in the AM peak is in the inbound direction while during the PM peak inbound and outbound flows are comparable.

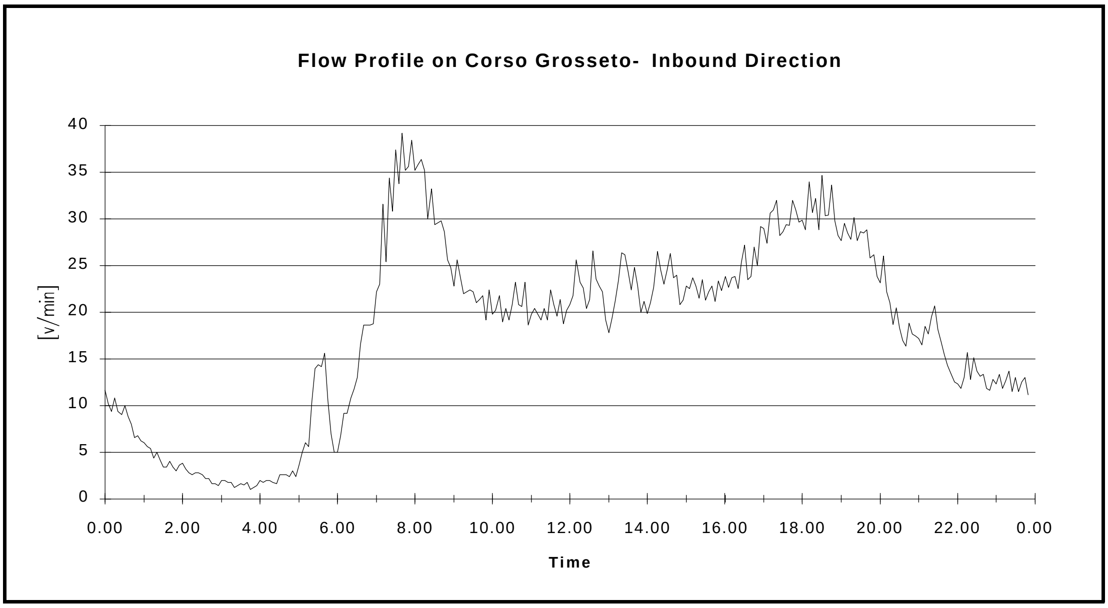

Figure 3.5: Flow profile on Corso Grosseto, inbound direction

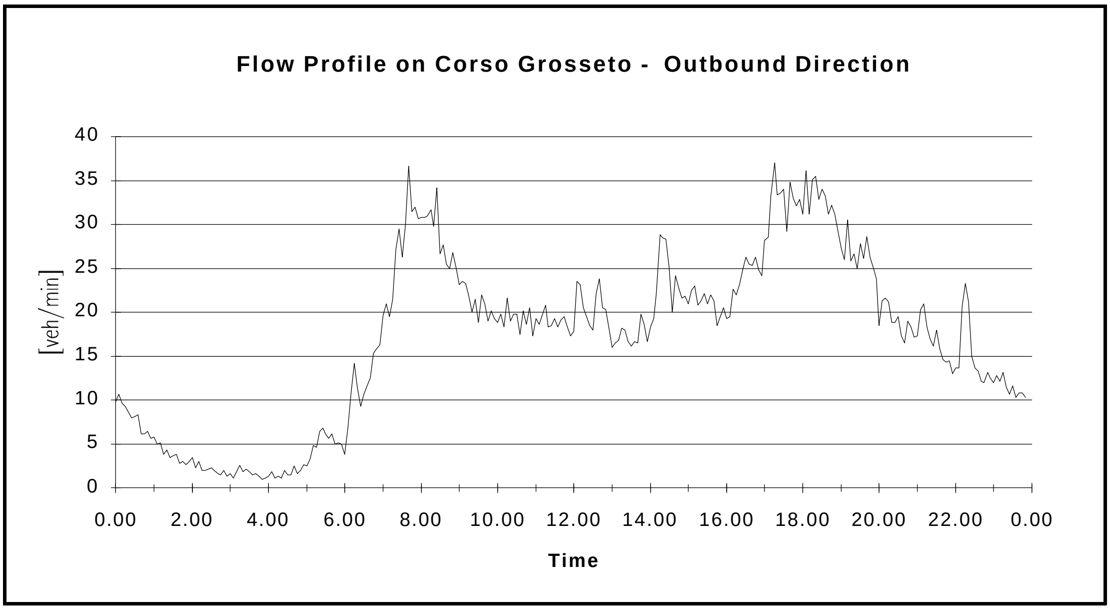

Figure 3.6: Flow profile on Corso Grosseto, outbound direction

For the assessment of the control strategies flows on all the links are needed. The following table and figures show the flows on each link aggregated for the peak periods. Two detectors were placed on links 15-16 and 16-15, one just at the exit of the upstream junction and the other after the confluence of the motorway coming and going to the airport.

Flows on the side roads represent only a small percentage of the flow on the arterial except for Via Botticelli and Corso Vercelli where they are comparable. These two roads are arms of intersection 16 which is the most saturated in the field trial area.

Link	AM: 7:00-9:30	PM: 17:00-19:30
entry 11	3882	4328
11 to 12	4289	4175
12 to 13	4717	4684
13 to 14	4340	4353
14 to 15	4021	4271
15 to 16, 1	3965	4188
15 to 16, 2	4769	4375
16 to 17	3341	2659
exit 17	2247	2337
entry 17	1866	2101
17 to 16	3434	3459
16 to 15, 1	5551	5290
15 to 15, 2	6576	7352
15 to 14	3911	4678
14 to 13	4222	4984
13 to 12	4913	5410
12 to 11	4683	5498
exit 11	4628	5014
Via Casteldelfino	1423	1407
Via Fea	448	821
Via Bibiana	1110	1270
Via Chiesa della Salute	590	994
Via Ala Nord	962	1523
Via Ala Sud	1248	1396
Corso Vercelli Sud	3572	3597
Via Botticelli	3909	3877
Via Toscanini	1509	1822
Via Porpora	826	1146

Table 3.3: Flows during the peaks on the links

Flows on the two routes, A and B, covered by the moving observers are now presented, along with the flows on the side roads.

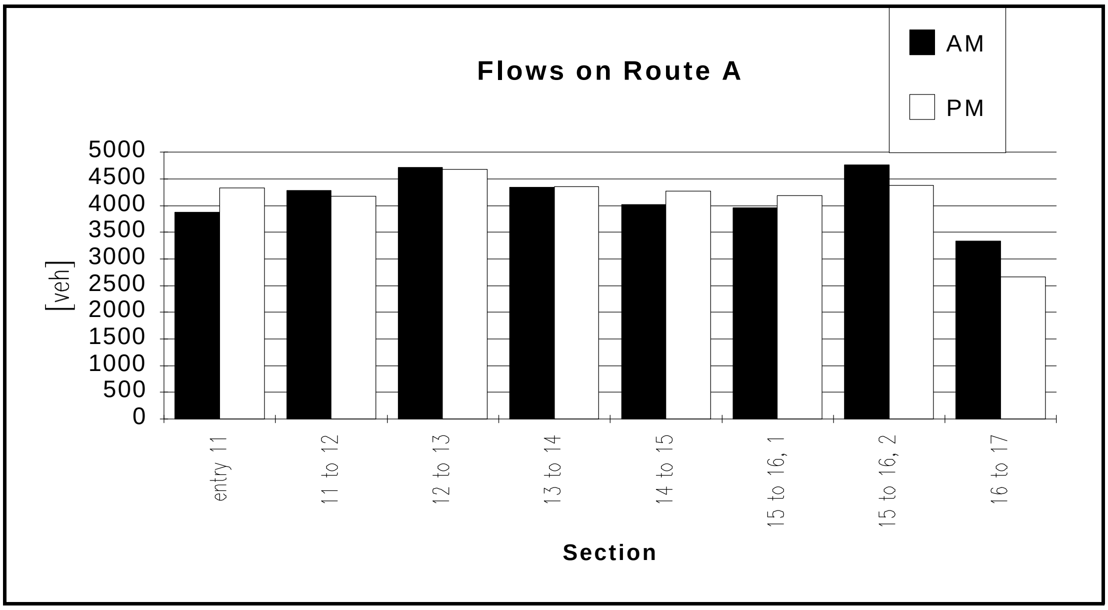

Figure 3.7: Flows on Route A, AM and PM peaks

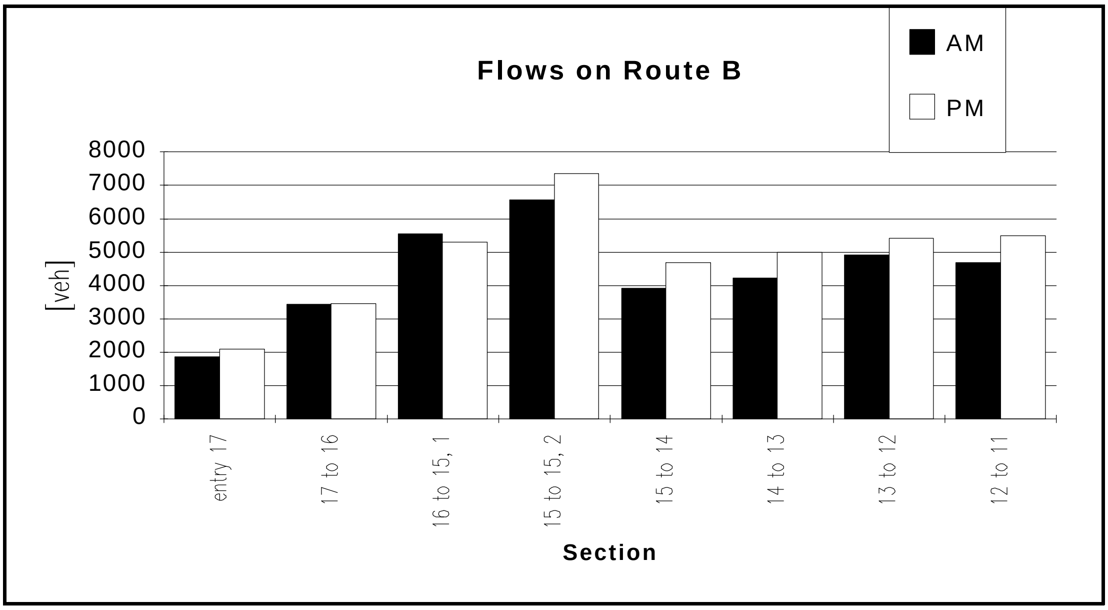

Figure 3.8: Flows on Route B, AM and PM peaks

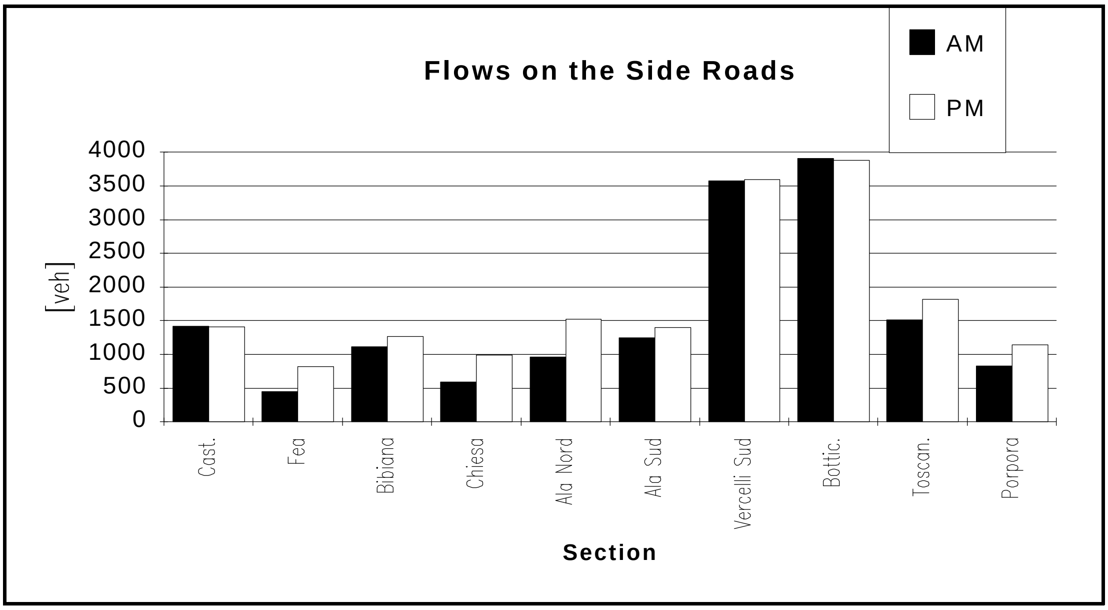

Figure 3.9: Flows on the side roads, AM and PM peaks

3.3 CYCLE TIMES

3.3.1 Data collected

For the baseline case cycle times were fixed for all the intersections. For SPOT+ cycle times have been collected through the monitoring facilities of the Traffic Control Centre in Torino.

3.3.2 Results

As SPOT implements an adaptive control stage timings vary from cycle to cycle. The following tables show the average length of the stages during the AM and PM peaks and their standard deviations as an indicator of the variability of the stage length. Values reported are in seconds.

JUNCTION	11			
Stage	1	2	3	CYCLE
Baseline	45	16	29	90
SPOT+ AM Av.	69	18	26	113
SPOT+ PM Av.	67	18	31	116
SPOT+ AM St.Dev.	14	0	9	14
SPOT+ PM St.Dev.	14	0	9	16

Table 3.4: Cycle timings for intersection 11

JUNCTION	12			
Stage	1	2	3	CYCLE
Baseline	47	14	29	90
SPOT+ AM Av.	75	22	15	112
SPOT+ PM Av.	72	21	18	111
SPOT+ AM St.Dev.	12	6	2	14
SPOT+ PM St.Dev.	15	6	4	15

Table 3.5: Cycle timings for intersection 12

JUNCTION	13			
Stage	1	2	3	CYCLE
Baseline	47	16	29	90
SPOT+ AM Av.	65	15	33	113
SPOT+ PM Av.	62	15	36	113
SPOT+ AM St.Dev.	15	0	10	13
SPOT+ PM St.Dev.	22	0	9	21

Table 3.6: Cycle timings for intersection 13

JUNCTION	14			
Stage	1	2	3	CYCLE
Baseline	40	16	34	90
SPOT+ AM Av.	83	15	17	115
SPOT+ PM Av.	74	15	30	119
SPOT+ AM St.Dev.	8	0	5	7
SPOT+ PM St.Dev.	17	0	11	16

Table 3.7: Cycle timings for intersection 14

JUNCTION	15			
Stage	1	2	3	CYCLE
Baseline	49	16	25	90
SPOT+ AM Av.	66	26	19	111
SPOT+ PM Av.	59	29	28	117
SPOT+ AM St.Dev.	13	4	5	15
SPOT+ PM St.Dev.	13	2	9	15

Table 3.8: Cycle timings for intersection 15

JUNCTION	16						
Stage	1	2	3	4	5	6	CYCLE
Baseline	25	17	18	13	23	14	110
SPOT+ AM Av.	40	21	33	27	14	27	162
SPOT+ PM Av.	40	22	33	29	23	32	179
SPOT+ AM St.Dev.	3	8	2	3	8	4	13
SPOT+ PM St.Dev.	3	8	2	2	10	2	11

Table 3.9: Cycle timings for intersection 16

JUNCTION	17			
Stage	1	2	3	CYCLE
Baseline	20	49	41	110
SPOT+ AM Av.	15	28	46	89
SPOT+ PM Av.	17	40	45	112
SPOT+ AM St.Dev.	1	7	17	16
SPOT+ PM St.Dev.	4	13	16	22

Table 3.10: Cycle timings for intersection 17

3.3.3 Conclusions

As in the baseline case the network can be split into two areas. The first, consisting of intersections 11 to 15, has a common cycle time; the second, dominated by intersection 16, is more saturated and is maintained at a higher cycle time. In general cycle times under SPOT+ are higher than the baseline case. Increases in stage lengths for the arterial stages is due to different coordination of the intersections.

3.4 CAR JOURNEY TIMES

3.4.1 Data collected

Journey times for private traffic has been collected by moving observers travelling on two routes on the arterial. Route A was covering the inbound direction, route B the outbound direction. Moving observers' data covered all the links on the arterial. For the side roads a delay indicator has been calculated using the flow information, the cycle and stages length and the estimated saturation flow using the formula:

$$D = \frac{s}{s-q} \cdot \frac{R^2}{2C}$$

where:

- s: is the saturation flow
- q: is the demand on the link
- R: is the red length in the cycle
- C: is the cycle length

The above formula is valid as long as (i) the distribution arrival pattern for the link is uniform and (ii) the degree of saturation is less than approximately 0.7. These conditions are valid for the side roads as (i) there are no other intersections close to the controlled ones and (ii) the degree of saturation on the side roads is low enough.

3.4.2 Results

Link Journey Times

First an analysis of link journey time is presented. As described in the introduction journey times on link 15 to 16 have been excluded by the evaluation.

Besides significant reductions in journey time on most of the links, it should be noted that there is also a general reduction in the variability, shown by the reduction in the standard deviation of the distribution.

ROUTE	A						
PERIOD	AM						
	entry 11	11 to 12	12 to 13	13 to 14	14 to 15	15 to 16	16 to 17
Baseline							
Trips	50	50	50	50	50	n.a.	50
Time (s)	27	52	39	25	42	n.a.	45
s.d. (s)	14	20	16	17	22	n.a.	14
speed (km/h)	27	21.5	12.8	24.5	21.6	n.a.	7.8
SPOT+							
Trips	45	45	45	45	45	n.a.	65
Time (s)	25	32	20	18	40	n.a.	32
% change	-5	-39	-48	-27	-6		-30
confidence	47	100	100	98	34		100
s.d. (s)	17	12	13	10	22	n.a.	21
speed (km/h)	28.6	35.5	24.7	33.7	23	n.a.	11.1

Table 3.11: Journey time on the links, Route A AM

ROUTE	A						
PERIOD	PM						
	entry 11	11 to 12	12 to 13	13 to 14	14 to 15	15 to 16	16 to 17
Baseline							
Trips	50	50	50	50	50	n.a.	50
Time (s)	25	57	42	31	40	n.a.	61
s.d. (s)	12	19	19	20	25	n.a.	38
speed (km/h)	29.4	19.7	12	19.9	122.7	n.a.	5.8
SPOT+							
Trips	32	32	32	32	32	n.a.	50
Time (s)	20	39	27	17	39	n.a.	36
% change	-20	-32	-34	-46	-5		-41
confidence	90	100	100	100	15		100
s.d. (s)	15	16	13	4	19	n.a.	18
speed (km/h)	36.5	29	18.3	37	23.8	n.a.	9.8

Table 3.12: Journey time on the links, Route A PM

ROUTE	B						
PERIOD	AM						
	entry 17	17 to 16	16 to 15	15 to 14	14 to 13	13 to 12	12 to 11
Baseline							
Trips	50	50	50	50	50	50	50
Time (s)	55	128	69	42	46	43	44
s.d. (s)	18	65	29	28	23	18	29
speed (km/h)	11	2.7	42.1	21.7	13.3	11.7	25.4
SPOT+							
Trips	65	45	82	45	45	45	45
Time (s)	62	138	75	34	21	13	35
% change	13	8	9	-21	-55	-69	-21
confidence	85	55	81	91	100	100	94
s.d. (s)	33	63	23	16	14	5	16
speed (km/h)	9.8	2.5	38.7	27.3	29.8	38	31.8

Table 3.13: Journey time on the links, Route B AM

ROUTE	B						
PERIOD	PM						
	entry 17	17 to 16	16 to 15	15 to 14	14 to 13	13 to 12	12 to 11
Baseline							
Trips	50	50	50	50	50	50	50
Time (s)	100	159	66	50	49	48	32
s.d. (s)	18	60	23	34	24	17	10
speed (km/h)	6.1	2.2	44.1	18.4	12.4	10.5	34.7
SPOT+							
Trips	50	50	65	32	32	32	32
Time (s)	59	156	79	33	25	21	34
% change	-41	-2	19	-34	-50	-56	6
confidence	100	19	100	100	100	100	51
s.d. (s)	27	62	20	16	18	10	14
speed (km/h)	10.3	2.2	37	27.8	24.8	23.6	32.7

Table 3.14: Journey time on the links, Route B PM

Route Journey Times

The following table shows the total route journey time for routes A and B in the AM and PM peaks. In all the periods a significant reduction in journey times has been found.

Case	Route A AM	Route B AM	Route A PM	Route B PM
Baseline (s)	231	428	255	504
SPOT+ (s)	167	379	177	407
% change	-28	-12	-31	-19

Table 3.15: Journey time on the routes

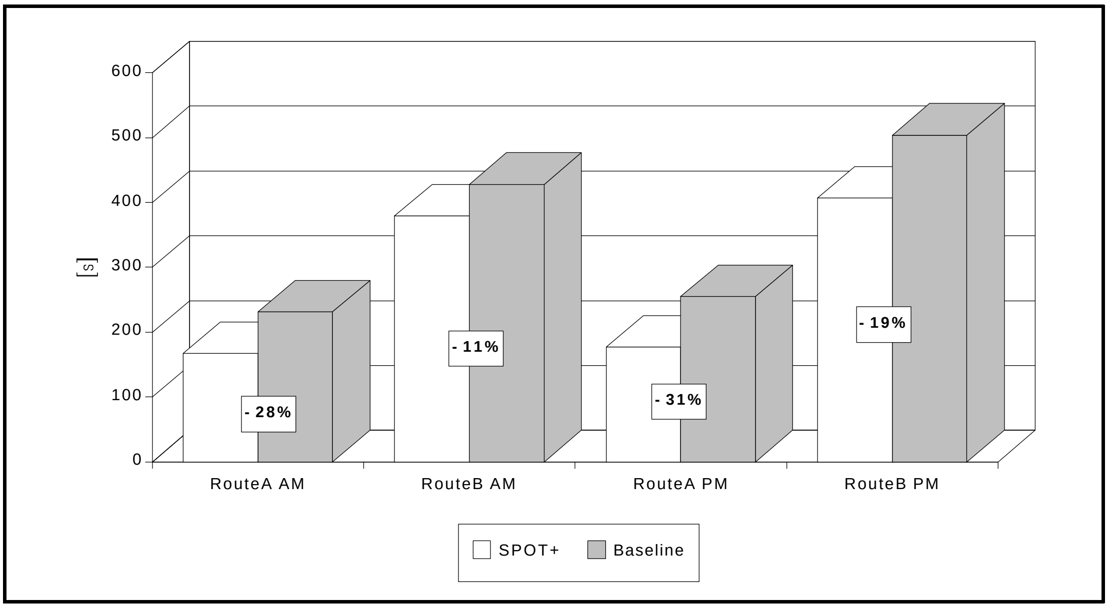

Figure 3.10: Journey time on the routes

The results show how the new system improves coordination between intersections. Significant benefits can be found during both peaks on the two routes. Such a result due to the coordination on the arterial should have introduced additional delays on the side roads. The aim of the following section is to evaluate a travel time indicator of the controlled network that also consider the side roads.

Network Travel Time

The aim of this section is to produce a travel time indicator for the network. Travel time is defined as the journey time on the link multiplied by the flow travelling on the link during the observation period. An indicator has been calculated for each intersection and then aggregated across the network.The following tables report the intersection and network indicators. Please refer to Appendix B for a table containing the link travel times. Values are in vehicle seconds.

Intersection	Baseline	SPOT+	% change
11	361155	335222	-7.2
12	448386	224493	-49.9
13	417582	231184	-44.6
14	291362	243011	-16.6
15	702489	770377	9.6
16[2]	638746	737090	15.4
17	341068	320183	-6.1
Network	3200789	2861559	-10.6

Table 3.16: Travel time in the network, AM peak

Intersection	Baseline	SPOT+	% change
11	333310	342279	2.7
12	523511	320563	-38.8
13	485479	305781	-37
14	396649	274885	-30.7
15	707643	831559	17.51
16[3]	748688	817841	9.2
17	488736	350454	-28.3
Network	3684016	3243361	-11.9

Table 3.17: Travel time in the network, PM peak

2Values for intersection 16 do not consider link 15 to 16
3Values for intersection 16 do not consider link 15 to 16

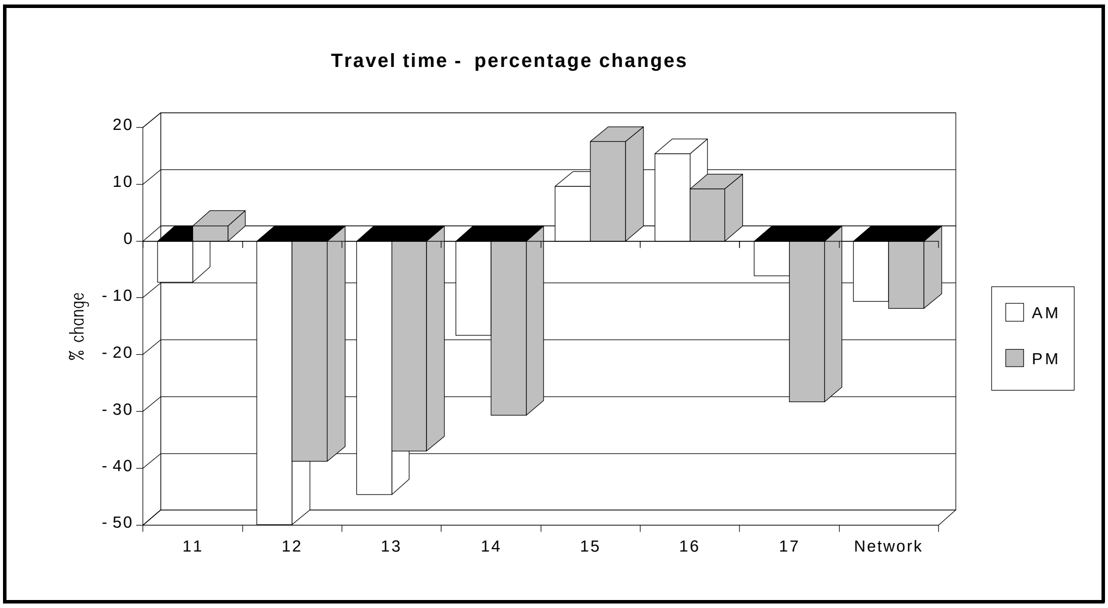

Figure 3.11: Travel time in the network, % changes

3.4.3 Conclusions

Journey time surveys have proved that there are considerable benefits, in the order of 12 to 30%, for the journey times on the travelled routes. These benefits have introduced delays to the side roads. Weighting the journey times with the demand on the link, significant benefits, of the order of about 10% for both AM and PM peaks, can be found. It should be noted that from intersection 16, which is the most congested in the area, one link is missing from the evaluation. Positive indicators on the excluded link could significantly change the network travel time indicators by a few percentage points.

3.5 BUS JOURNEY TIMES

3.5.1 Data collected

Bus journey times have been collected through the SIS-AVM system of ATM (Azienda Tramvie Municipali), the City Council's company that is in charge of public transport in Torino. The SIS gives for each section of the PT route the average journey time per hour. Only PT route number 2, a bus service, has been considered as it is the only route that travels entirely along the Corso Grosseto arterial.

3.5.2 Results

In this section only route journey time for the part of service 2 covering Corso Grosseto (from intersection 16 to 11 and vice-versa, are considered. Link journey times are reported in Appendix C. The following tables and diagrams show the bus journey times in the inbound and outbound directions from 7:00 up to 23:00. Values are in seconds.

Hour	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Base	336	361	340	360	310	318	332	330	330	350	355	323	324	322	341	329	330
SPOT+	336	336	330	325	328	322	320	323	323	327	333	351	342	329	324	316	314
% change	0.03	-6.84	-2.97	-9.70	6.04	1.38	-3.47	-2.15	-2.12	-6.49	-6.27	8.60	5.49	2.05	-5.01	-3.98	-4.84

Table 3.18: Bus Journey Time, Outbound direction

Hour	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Base	278	278	277	269	294	278	273	280	276	270	287	285	273	271	250	243	241
SPOT+	262	268	264	259	254	254	247	246	243	245	256	263	264	257	250	245	239
% change	-5.86	-3.60	-4.63	-3.79	-13.5	-8.36	-9.36	-12.4	-12.0	-9.31	-10.8	-7.7	-3.30	-5.38	-0.08	0.78	-0.46

Table 3.19: Bus Journey Time, Inbound direction

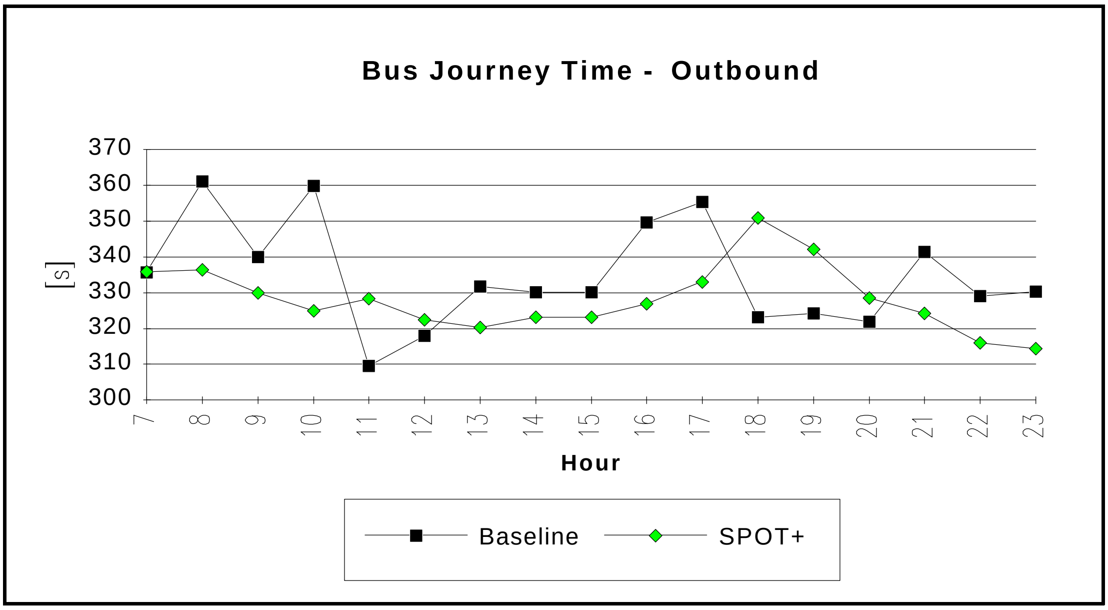

Figure 3.12: Bus Journey Time, Outbound direction

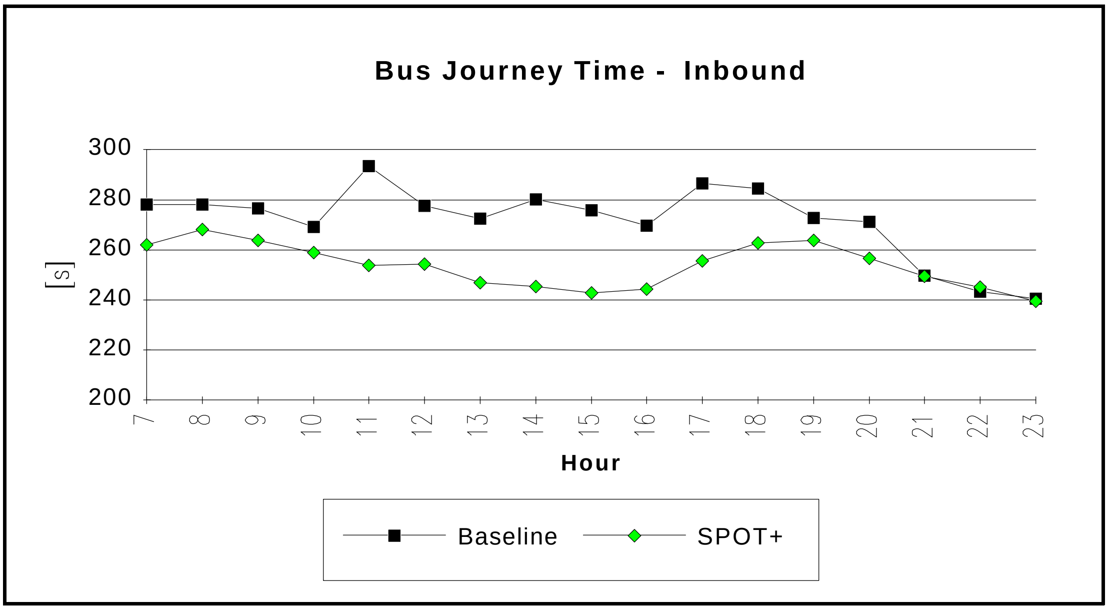

Figure 3.13: Bus Journey Time, Inbound direction

From the above diagrams it clear that for much of the day the inbound direction benefits from the new control strategy applied even if no bus priority measure were taken. This data confirms the private traffic data (journey time on route A) even if the effect is less marked. In the outbound direction benefits are shown in the AM peak and Off-peak periods while journey times are greater with the SPOT+ system during part of the PM peak.

The following table shows the average benefit/disbenefits introduced during the two peaks and during the whole day.

Period	7-23	7-9	17-19
Baseline	335	346	334
SPOT+	328	334	342
% change	-2	-3.3	2.3

Table 3.20: Bus Journey Time, Outbound direction

Period	7-23	7-9	17-19
Baseline	272	278	281
SPOT+	254	265	261
% change	-6.6	-4.7	-7.3

Table 3.21: Bus Journey Time, Inbound direction

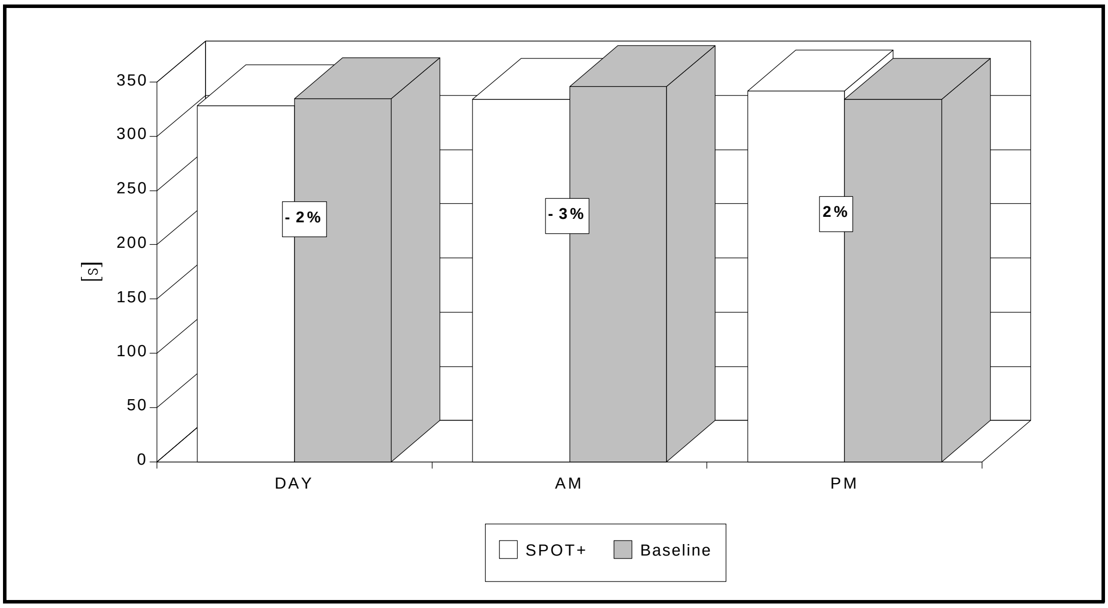

Figure 3.14: Bus Journey Time, Outbound direction

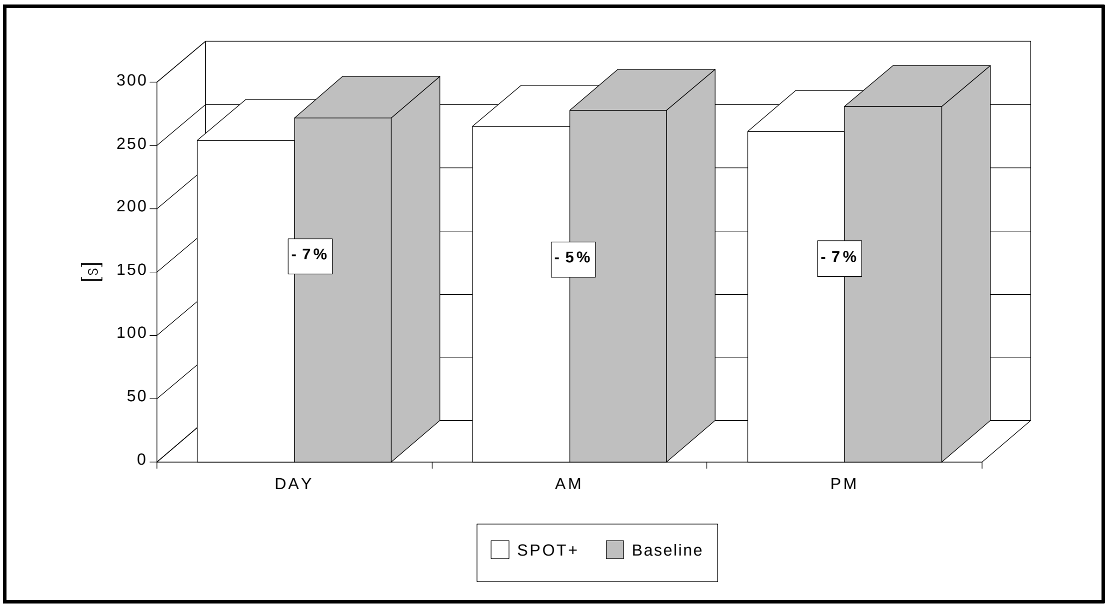

Figure 3.15: Bus Journey Time, Inbound direction

3.5.3 Conclusions

Even if no specific bus priority measures were provided by the applied strategy, bus journey times could have improved as a consequence of the better coordination on the arterial. Improvements are constant during the day for the inbound direction with an average 7% improvement; in the outbound direction there are some disbenefits during the day reducing the average improvement to only 2%.

3.6 STOPS

3.6.1 Data collected

Stops are an important indicator that give information about the coordination of the intersections and indirect information about driving comfort, driver's stress and pollution as the major emission rates occur during the acceleration and deceleration phases of the movements of the vehicles. Thus, as demonstrated by the simulation results, a reduction of the number of stops leads to a reduction in the emission of pollutants.

Stops have been recorded by moving observers on the route travelled. Thus data about stops cover only the links on the arterial.

By using the stopping rate for floating cars, the total number of vehicle stopped per peak period has been calculated by multiplying the measured rate by the flow on the link. By summing the stops on the links it is possible to work out an intersection and a network indicator.

3.6.2 Results

The following tables show the stopping rate measured by the moving observers.

ROUTE	A						
PERIOD	AM						
	entry 11	11 to 12	12 to 13	13 to 14	14 to 15	15 to 16	16 to 17
Baseline							
Trips	50	50	50	50	50	n.a.	50
Stops	23	31	41	7	25	n.a.	47
Stop rate (%)	46	62	82	14	50	n.a.	94
SPOT+							
Trips	45	45	45	45	45	n.a.	65
Stops	18	15	13	2	21	n.a.	46
Stop rate (%)	40	33	29	4	47	n.a.	71

Table 3.22: Stops on the links, Route A AM

ROUTE	A						
PERIOD	PM						
	entry 11	11 to 12	12 to 13	13 to 14	14 to 15	15 to 16	16 to 17
Baseline							
Trips	50	50	50	50	50	n.a.	50
Stops	33	39	42	11	20	n.a.	47
Stop rate (%)	66	78	84	22	40	n.a.	94
SPOT+							
Trips	32	32	32	32	32	n.a.	50
Stops	9	17	18	0	14	n.a.	35
Stop rate (%)	28	53	56	0	44	n.a.	70

Table 3.23: Stops on the links, Route A PM

ROUTE	B						
PERIOD	AM						
	entry 17	17 to 16	16 to 15	15 to 14	14 to 13	13 to 12	12 to 11
Baseline							
Trips	50	50	50	50	50	50	50
Stops	40	49	29	17	33	48	14
Stop rate (%)	80	98	58	34	66	96	28
SPOT+							
Trips	65	45	82	45	45	45	45
Stops	45	43	48	16	6	3	18
Stop rate (%)	70	98	59	36	13	7	40

Table 3.24: Stops on the links, Route B AM

ROUTE	B						
PERIOD	PM						
	entry 17	17 to 16	16 to 15	15 to 14	14 to 13	13 to 12	12 to 11
Baseline							
Trips	50	50	50	50	50	50	50
Stops	47	50	30	19	34	43	5
Stop rate (%)	94	100	60	38	68	86	10
SPOT+							
Trips	50	50	65	32	32	32	32
Stops	27	50	45	10	6	9	9
Stop rate (%)	54	100	69	31	19	28	28

Table 3.25: Stops on the links, Route B PM

Data on the links has been agregated at junction and arterial level using the flows on the links. Results are shown in the following table and diagram.

	AM			PM		
Inters.	Baseline	SPOT	% change	Baseline	SPOT	% change
11	3097	3426	11%	3406	2764	-19%
12	7376	1757	-76%	7909	3739	-53%
13	6655	1926	-71%	7324	3569	-51%
14	1937	1584	-18%	2735	1462	-47%
15	5824	5726	-2%	5564	6351	14%
16	3365	3350	0%	3459	3459	0%
17	4633	3678	-21%	4474	3000	-33%
Arterial	32887	21446	-35%	34871	24344	-30%

Table 3.26: Stops at the intersections and global indicators

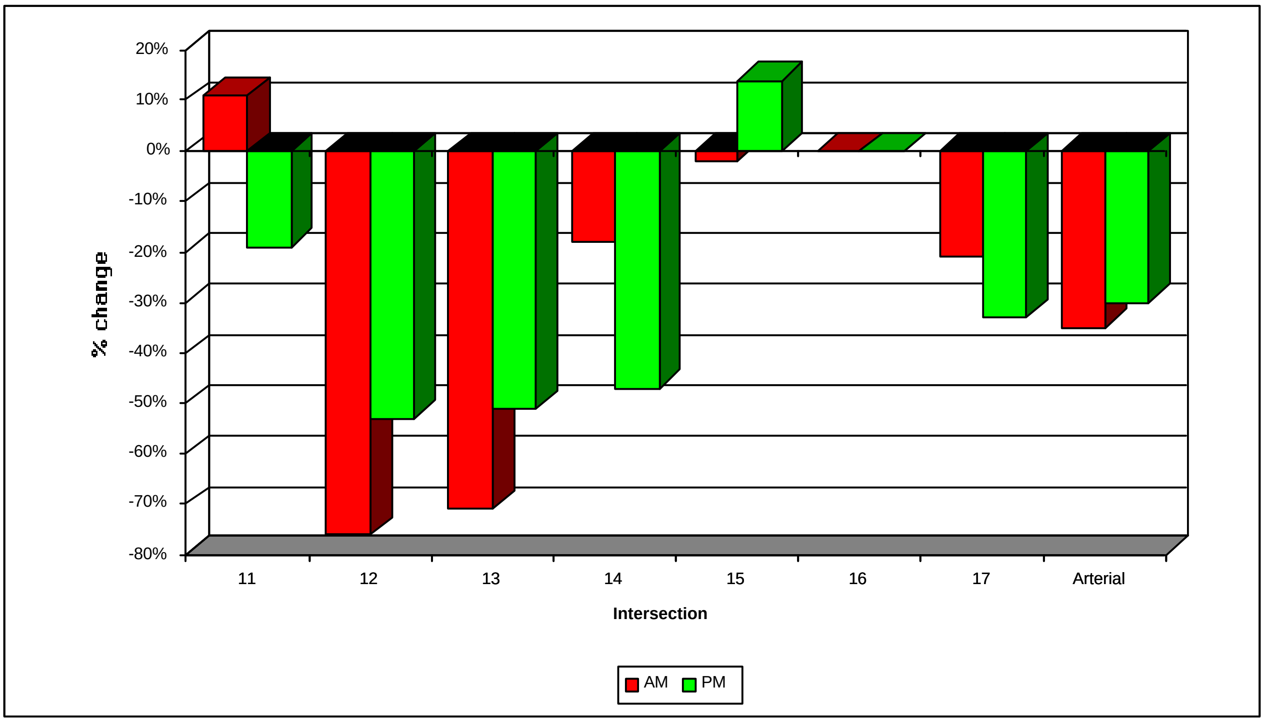

Figure 3.16: Stops at the intersections and global indicators, % changes

3.6.3 Conclusions

The introduction of the control strategy has significantly reduced the number of vehicles stopping at the traffic signals on the arterial.

The benefits may be quantified by a 35% reduction in the number of vehicle stopped during the AM peak and a 30% reduction during the PM peak.

These results only consider the arterial and not the side roads but, as no coordination can be provided on the side roads due to the distance of upstream signals, they are a significant indicator of the correct behaviour of the strategy applied.

3.7 QUEUES

3.7.1 Data collected

Queue lengths have been measured by observers at four junctions during both peaks. Data was collected at the start of the green stage for each link. The survey has given an indication about the evolution of the queues during the peak and about the average queue at the start of the green. As a comparison between profiles does not give any interesting information, the indicator used is the average queue.

3.7.2 Results

The Following tables show the comparison of the average queues for the two cases.

		Intersection	11	
		Grosseto Outb. 12 to 11	Grosseto Inb. entry 11	Casteldelfino
AM	SPOT+	23	18.3	12.3
	Baseline	32.3	18.0	10.9
	% change	-28.9	0	12.5
PM	SPOT+	24.3	17.65	12.2
	Baseline	14.9	16	11.5
	% change	63.2	7.4	6.6

Table 3.27: Queues on intersection 11

As a consequence of the higher cycle time the average queue on the side roads has increased slightly in the PM peak and had a more marked increase during AM peak. Because of the low flow on the link, the changes have a very low absolute value, of the order of 1-2 vehicles. No major changes can be found on the arterial in the inbound direction, entry link for the controlled area, while the outbound direction passes from a marked reduction during AM to a significant increase during PM. This is because there is a different coordination on the arterial as the same behaviour can be found in the link journey time analysis (link 12 to 11 passes from a 21% decrease in AM to a 6% increase during PM). The absolute value for queue length however stays at a low level considering that Corso Grosseto is a four lane carriageway.

		Intersection	15		
		Grosseto Outb. 16 to 15	Grosseto Inb. 14 to 15	Ala Sud	Ala Nord
AM	SPOT+	26.9	23.7	9.4	14.2
	Baseline	45.8	29.6	8.8	12.6
	% change	-41	-20	6.6	12.4
PM	SPOT+	34.3	28.7	19.8	15.3
	Baseline	44.9	16.4	19.9	11.7
	% change	-23.6	21.9	0	30.4

Table 3.28: Queues on intersection 15

Again because of the higher cycle times, queues on the side roads increase slightly, but not greater than 3 vehicles in absolute terms. A strong reduction in queues in the outbound direction of Corso Grosseto is noted, probably due to better management of the left turning traffic on Via Ala di Stura Sud. Changes in the coordination of the intersections, as for junction 11, result in the benefits of the AM becoming disbenefits in PM. Unlike junction 11 the changes in the average queues are not reflected in the journey times on the link.

Intersection	16

		Grosseto 15 to 16	Vercelli Sud	Vercelli Nord 17 to 16	Botticelli
AM	SPOT+	n.a.	34.8	38	46.4
	Baseline	n.a.	19.9	38.5	30.7
	% change		74.7	-1.4	51.2
PM	SPOT+	n.a.	40.3	60.25	60.6
	Baseline	n.a.	36.8	58.3	69.3
	% change		9.5	3.2	-12.5

Table 3.29: Queues on intersection 16

Intersection 16 is the place where major changes in queues have been detected. Major changes occurred on the two side roads where, with the new control strategy, significant increases in the average queue length can be seen in the morning peak. No relevant changes have been measured in the internal link between junction 17 and 16. For the absolute values of the changes it should be noted that all the links of this intersection have four lanes so even the biggest change gives only an increase of 4 vehicles per lane on Via Botticelli during the AM peak. It should be noted that link 15 to 16 has been excluded by this evaluation due to the problems described in the introduction.

Intersection	17

		Vercelli Nord entry 17	Toscanini	Vercelli Sud 16 to 17	Porpora
AM	SPOT+	8.5	12	12.9	5
	Baseline	13	12.4	13.1	5.9
	% change	-34.5	-3.3	-1	-15
PM	SPOT+	12.5	11.3	13.3	6.5
	Baseline	15.5	10.7	12.8	7.2
	% change	-19	4.7	3.9	-9

Table 3.30: Queues on intersection 17

Significant reduction of the queues occurred on Corso Vercelli Nord and Via Porpora during both peaks. No significant changes can be found on the other links. Absolute changes are not large, the biggest is of 5 vehicles on the four lanes of Corso Vercelli.

3.7.3 Conclusions

The new control strategy has slightly modified the queue distribution in the area. Changes can be summarised as a general increase on the side roads and a reduction on the arterial.

Even if significant in percentage terms, absolute changes, both for reductions and increases, have been limited to less than 4 vehicles per lane.

3.8 COMPARISON WITH THE SIMULATION RESULTS

One objective of the field trials was to validate the assessment made in the simulation stage when the selection of the strategies was made.

In this section some indicators, that can be compared directly with the simulation results, will be analysed. In particular it is possible to make an easy comparison between:

- travel times in the network
- journey times for buses
- stops in the network

Deliverable 12: "*Evaluation of Simulated Strategies*" should be referred to for the complete results of the simulations. As the simulationsonly covered the morning period the comparisons can be made only for the AM peak indicators.

The predicted change in network travel time agrees well with the field trials. The field trials indicate a 10% reduction against the 9% reduction predicted by the simulation results.

For bus journey time again the improvement predicted by simulation for service 2, 5%, is very close to the average gain of 4% for both directions obtained in the field trials.

A bigger difference can be found comparing the stops indicators. The 7% reduction predicted by the simulation becomes a 30% reduction in the field trials. This underestimate can derive from two factors:

- the field trials result considers only the arterial while the simulation considers the whole network.
- the calculation of stops in the NEMIS simulator is very sensitive to settings of thresholds to define a vehicle stop. The definition of a stop made by the human observer may have a certain degree of uncentainty.

As the efficiency indicators of the simualtion were very close or even underestimating the effects of the strategy it is possible to use the results predicted by the simulations for some other indicators that have not been measured in the field trials. If we consider the environment indicators that strongly depend on the stop rate and the travel time it is possible to assume that the benefits predicted by the simulations occurred during the field trials:

Indicator	% change
CO Emissions	5%
NOx Emissions	-2%
HC Emissions	-6%
Fuel Consumption	-3%

Table 3.31: Estimated effects on environmental indicators

4 CONCLUSIONS

The field trial data is showing that the adoption of integrated PRIMAVERA strategies on urban arterial roads is producing some significant improvements.

Journey times for private vehicles are being reduced, as is journey time variability.

Priority is being given to public transport resulting in reduced journey times, delay and journey time variability.

ATT traffic calming using a VMS and a speed enforcement camera is succeeding in reducing the number of vehicles travelling at excessive speed and is resulting in less variability in vehicle speeds. This produces compact platoons of vehicles which are more easily controlled by the new queue management strategies.

The following parameters have been studied:

- the influence of the new strategies on the performance in different traffic conditions
- link and individual intersection performance
- network performance
- effects of the new strategies on public transport
- the simulated changes compared to the field trial results

The main results are:

Leeds:

- a greater than 10% reduction in travel times for buses, when compared to the current state-of-the-art UTC systems, without significant disruption to cars
- the virtual removal of speeding vehicles on entry to the arterial in the AM peak, with consequent improvements in safety
- a slight increase in queue lengths at the controlled intersections and in pedestrian delay

Turin:

- The new control scheme reduces the travel time in the network for private traffic by about 10% compared with the fixed time system
- The new control scheme reduces the variabilty of link journey time
- The effects on the main public transport service are a reduction of between 2% and 7% in journey time
- The number of stops on the controlled arterial has been reduced more than 30%
- Minor changes occurred in the queue lengths, in general reductions on the main road and small increases on the side roads due to higher cycle times
- The field trials results fit very well with the predictions made by the simulations. According to this it is possible to estimate that pollutant emissions and fuel consumption will reduce by up to 5%

APPENDIX A: ANALYSIS OF LEEDS MOVING OBSERVER TRAVEL TIME DATA

This appendix describes how the car moving observer data was processed to arrive at the overall changes in travel time shown in Table 2.5 in Section 2.3. Moving car observers were used to collect journey times for two different routes around the network. As they passed various points along each route the time of day was recorded. The surveys for both routes covered the hours 0730-0930 and 1630-1830. The data was transferred from the hand written data collection sheets into a spreadsheet on a computer. To check the data for errors and to identify points of congestion, plots were produced of time against distance for each period's trips each day. (See eg. Figure A1). This allows obvious anomalies to be spotted and corrected if necessary, eg the run at 17:32 PM in figure A1.

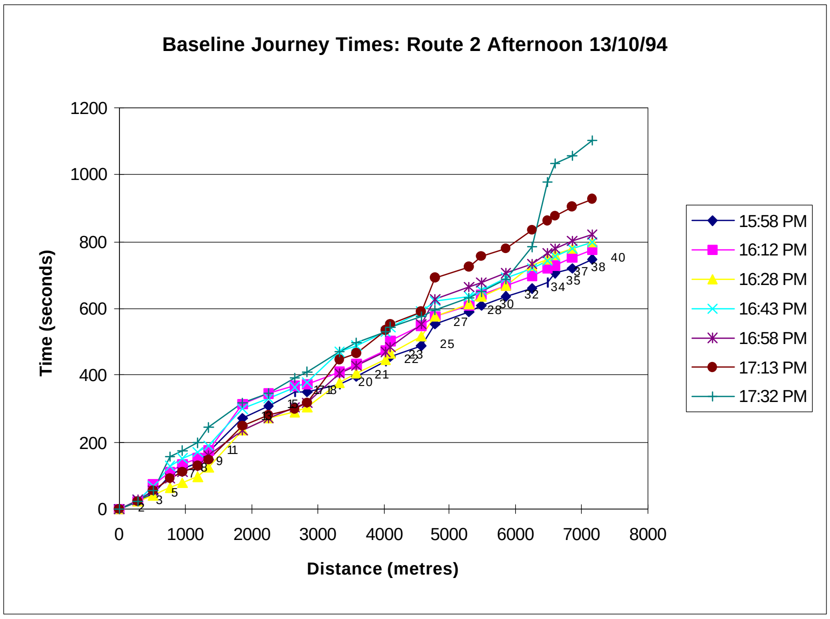

Figure A1: Time vs Distance for a set of moving car observations

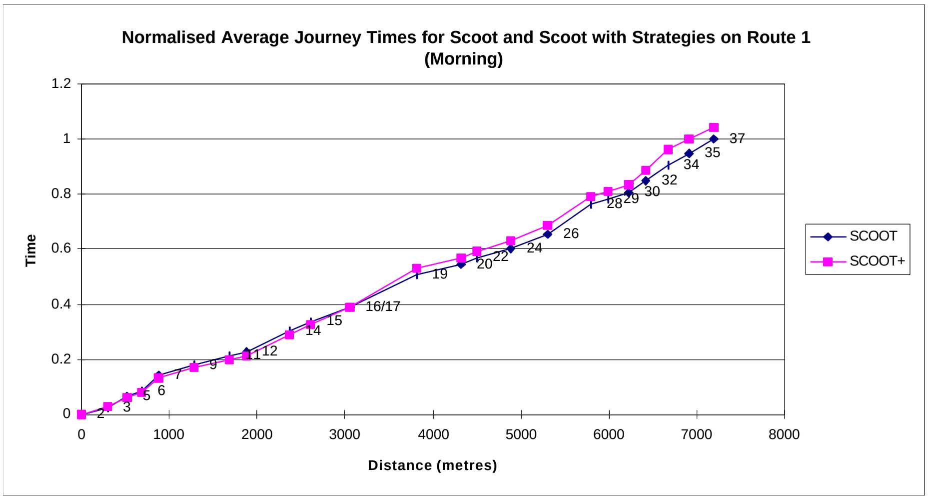

Figure A2: Average normalised time vs distance for a strategy

Once a complete set of data had been collected for any of the strategies, plots were made of the average time against distance for each route covered (eg. Figure A2). This allows an indication of the performance of the strategies to be determined. On its own this only shows how the strategies have affected travel times for vehicles travelling on the selected routes. We now need to try to determine how they have changed the total travel time for all vehicles using the various parts of the network covered by the routes. Data from both routes can be combined to give average travel times along each link. Flow data from the automatic traffic counts and manual classified counts can be used to determine typical flows along each link. If the link flows are multiplied by the average link travel times and summed across all the links then the total travel time for all vehicles can be determined. Obviously checks need to be made that the flows in the network have not changed significantly between runs. This can be done by examining the ATC data collected at various points around the network. Plots were made of the daily flow profiles on the days journey time data was being collected. (eg Figures A3 and A4)

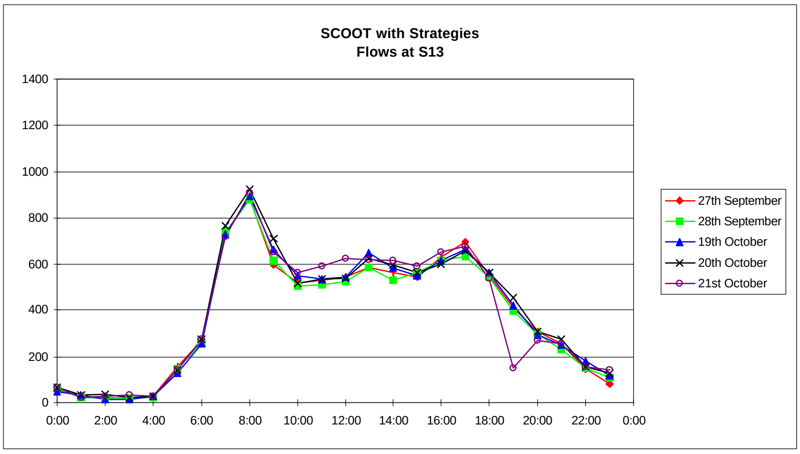

Figure A3: Flows at point S13 with SCOOT+ operating

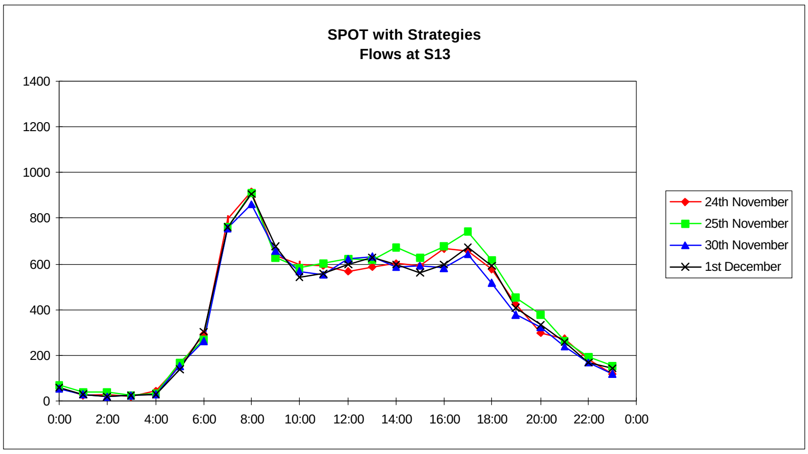

Figure A4: Flows at S13 with SPOT+ operating

Statistical tests were also carried out on the flows during the two hour peak periods. At most data collection points these showed no significant differences between the flows. In those cases where there was a difference it was in the flows during the baseline data collection. As the journey time analysis has concentrated on the differences between the integrated strategies and the systems without the integrated components, these differences were not important.

APPENDIX B: TABLE OF LINK TRAVEL TIMES

		AM						PM					
		Link			Micro			Link			Micro		
		Baseline	SPOT	**% change**	Baseline	SPOT	**% change**	Baseline	SPOT	**% change**	Baseline	SPOT	**% change**
Micro 11	**Gross in**	103185	97569	-5.44	361155	335222	-7.18	106041	85347	-19.52	333310	342279	2.69
	Gross out	207375	164539	-20.66				177353	188122	6.07			
	Castel.	50595	73114	44.51				49917	68811	37.85			
Micro 12	**Gross in**	223011	135141	-39.40	448386	224493	-49.93	237042	161249	-31.97	523511	320563	-38.77
	Gross out	211263	65180	-69.15				259450	115294	-55.56			
	Fea	14112	24171	71.28				27020	44019	62.91			
Micro13	**Gross in**	185483	96128	-48.17	417582	231184	-44.64	195231	128665	-34.10	485479	305781	-37.01
	Gross out	194213	87068	-55.17				246008	123664	-49.73			
	Bibiana	37885	47989	26.67				44240	53452	20.82			
Micro 14	**Gross in**	109199	79280	-27.40	291362	243011	-16.60	134517	72238	-46.30	396649	274885	-30.70
	Gross out	165370	131333	-20.58				232506	154234	-33.66			
	Chiesa	16794	32397	92.91				29625	48413	63.42			
Micro 15	**Gross in**	170389	160373	-5.88	702489	770377	9.66	116577	110985	-4.80	707643	831559	17.51
	Gross out	455593	495644	8.79				486530	579307	19.07			
	Ala Sud	33523	50150	49.60				56004	75865	35.46			
	Ala Nord	42984	64210	49.38				48532	65402	34.76			
Micro 16	**Grosseto**	n.a.	n.a.					n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Verc. in	106404	153699	44.45	638746	737090	15.40	107284	144651	34.83	748688	817841	9.24
	Botticelli	93399	108097	15.74				92504	135331	46.30			
	Verc. out	438944	475294	8.28				548899	537858	-2.01			
Micro 17	**Toscanini**	44798	51891	15.83	341068	320183	-6.12	55723	59501	6.78	488736	350454	-28.29
	Verc. in	150697	115422	-23.41				161650	106703	-33.99			
	Porpora	42405	36610	-13.67				61560	59530	-3.30			
	Verc. out	103168	116259	12.69				209803	124720	-40.55			
	Total	3200789	2861559	-10.60				3684016	3243361	-11.96			

APPENDIX C: TABLE OF PERCENTAGE CHANGES ON LINK JOURNEY TIME FOR BUSES OF SERV

Outbound direction

SIS Code		Junction	Hour 7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
812 LB	180 LB	**16**	0.83	-18.6	-13.5	-19.1	4.82	-0.12	-1.49	-4.80	-2.59	-17.7	-6.84	-5.38	5.75	2.82	-11.3	-15.7	-13.4
850 FM	190 FM	-	51.3	27.8	17.2	9.02	34.56	29.5	38.6	34.07	8.23	25.8	34.64	148	13.2	19.2	26.5	27.6	27.6
851 LB	200 LB	**15**	-2.53	12.7	7.24	-2.3	2.90	6	-6.22	10.95	7.05	9.54	3.75	20.9	28.2	7.58	6.03	14	22.9
870 FM	210 FM	**14**	-25.3	-34	-36.5	-22.1	2.10	-11.9	-33.7	-24.82	-23.38	-26.2	-16.55	0	-7.36	-11.6	-25	-26.6	-29.6
871 LB	220 LB	**13+12**	-12.2	-11.9	-3.35	-13.5	-9.36	-8.35	-5.55	-12.57	-11.88	-11.3	-14.01	-3.79	-11.5	-8.17	-9.25	-8.28	-1.64
890 FM	230 FM	-	-13.3	-5.37	-7.64	0	-19.6	0	-29.1	-20	-19.64	-15.8	-43.51	-35.1	-34	-38.5	-40	-39.3	-42.7
891 LB	240 LB	**11**	22.3	11.8	23.5	5.91	48.21	13.5	17.6	17.30	21.01	15.3	7.63	28.2	40	35.1	20.7	34.1	5.26

Inbound direction

SIS Code		Junction	Hour 7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1644 LB	1680 LB	**11**	6.35	3.56	-1.58	-0.64	-8.56	-2.2	5.73	-5.23	0.82	0.41	-1.57	-0.77	7.78	7.87	10.6	9.79	12.8
900 LB	1690 FM	-	-21.2	-7.04	-13.3	-20.6	-16.2	-30.6	-36.6	-33.33	-36.24	-32.2	-29.45	-22.5	-18.8	-25.5	-31	-34.2	-37.6
901 LB	1700 FM	**12+13**	-10.7	-5.4	-0.28	2.61	-18.1	-6.53	-9.48	-6.62	-2.928	6.98	-3.62	2.71	2.89	-4.56	11.6	24.1	23
880 FM	1710 FM	-	-44.3	-41.6	-38.8	-39.2	-37.3	-30.9	-45.1	-46.6	-47.85	-54.6	-44.5	-36.1	-41.1	-40.4	-42.6	-46.3	-52.2
881 LB	1720 LB	**14+15**	1.12	2.84	2.86	2.18	-3.92	-3.62	-4.35	-7.49	-12.69	-9.38	-9.93	-7.46	2.36	1.47	7.46	5.06	2.07
860 FM	1730 FM	-	-23.6	-19.4	-33.8	-26.7	-32.9	-26.5	-31.5	-38.02	-38.62	-37.8	-30.41	-38.3	-40.5	-38.8	-45.3	-45.9	-44.9
862 LB	1740 LB	**16**	-15.3	-1.98	24.3	14.2	43.33	29.5	16.5	10.62	8.28	11	2.05	23.7	29.1	44.9	48.2	34.3	36.4