DRIVE II PROJECT V2016 : PRIMAVERA

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

ITS University of Leeds
MIZAR Automazione SpA
Città di Torino
HETS
Peek Traffic Ltd

DELIVERABLE No. 9
WORKPACKAGE No. WP480
Deliverable Type : P
Contract Date : January 1993
Submission Date : September 1995

Initial Simulation Results

Stephen Clark, Ken Fox, Bob Pretty and Simon Shepherd (ITS)
Fabrizio Biora and Salvatore Conte (MIZAR)

Commission of the European Communities - R&D programme Telematics Systems in the Area of Transport (DRIVE II)

PRIMAVERA DOCUMENT CONTROL SHEET

Title	**Reference Number**
Initial Simulation Results	V2016/017

Issue Status	**Origin**			**QA**		
	Submitted by	Signed	Date	Approved by	Signed	Date
Draft	Ken Fox		21/9/93			
Draft	Ken Fox		25/11/93			
01	Ken Fox		4/9/95	Fabrizio Biora		

TABLE OF CONTENTS : INITIAL SIMULATION RESULTS

1. EXECUTIVE SUMMARY

This document describes the initial simulation results of individual strategies from the DRIVE II PRIMAVERA project.

This project started by reviewing state-of-the-art ATT traffic control and management techniques for:

- managing queues on urban arterial corridors to reduce the disruption caused to crossing and opposing traffic, particularly in saturated and oversaturated conditions;
- providing priority to public transport;
- calming the traffic movement, ie. reducing speeds to more constant and appropriate lower levels, minimising braking and acceleration and thus reducing noise and pollution and improving safety. Queues in particularly sensitive sections of the route are also discouraged;

This resulted in a list of strategies as candidates for testing by simulation on models of the proposed field trial sites in Leeds and Turin. Given the time and cost constraints on the project it would be impossible to rigorously test all the strategies discovered, therefore the list was reduced to those strategies most likely to succeed.

The initial list of strategies was first checked for feasibility of implementation at each trial site and the remaining strategies were then ranked by a panel of experts using a Delphi approach, as recommended by DRIVE I project SECFO.

The top ranking strategies for each site were then simulated using the NEMIS micro-simulation package. From the simulation results the potential conflicts between each strategy in achieving the scheme objectives have been identified, allowing integrated ATT strategies to be developed for testing.

The results of these individual simulation tests are presented here. Conditions likely to be found during the morning peak period were simulated.

Each simulated strategy was evaluated using an evaluation framework developed for the project and described in Deliverable No. 11 : Evaluation Methodology.

The main conclusion from the simulations is that there is scope for developing integrated ATT strategies using the individual elements tested here that will act together to produce measurable benefits in safety, efficiency and environmental impacts during the field trials. The results from the simulations of the integrated strategies are reported in Deliverable 12 : Evaluation of Simulated Strategies and Implications for Field Trials.

2. STRATEGY COMPONENTS

2.1 Introduction

A first attempt at ranking the strategies was made by performing a Delphi study with a panel of experts. Details of this process are given in Appendix B. This enabled the initial list of strategies to be reduced to a more manageable number. The remaining strategy components were then tested by simulation.

2.2 Leeds Environment

For the SCOOT runs the base environment is the existing road network with signals controlled by the standard SCOOT 2.3 system which is currently installed in Leeds, although it does not control the Dewsbury Road. Similarly for the SPOT runs the base environment uses the standard SPOT system. This allows the new strategies to be tested against the best system currently available at each site.

The existing network contains a number of minor roads which have been modelled in NEMIS by incorporating sets of them into single roads. A road map of the Dewsbury Road network is shown in figure 2.1. The roads in the NEMIS simulation model are indicated on the map.

2.3 Leeds Strategies

The strategies in Leeds will be implemented via signal control using either SCOOT or SPOT. Some of the strategies can only be implemented with SPOT, some only with SCOOT and some with either. Details of the implementation plans can be found in Deliverable No. 8.

In the following descriptions of the strategies that have been simulated, each junction is referred to by the number given in the following table. The location of each junction on the Dewsbury Road along with the distances between them (m) can be seen in Figure 2.2.

Junction Number	Junction Name
1	Tommy Wass
2	Barkly Parade Pelican (Inbound)
3	Barkly Parade Pelican (Outbound)
4	Westland Road
5	Middleton Road
6	Parkside Lane / Garnet Road
7	Stratford Street Pelican
8	Tunstall Road
9	Burton Avenue Pelican
10	Hunslet Hall Road
11	Tunstall Road / Garnet Road

Table 2.1 : The signal controlled junctions at the Dewsbury Road test site

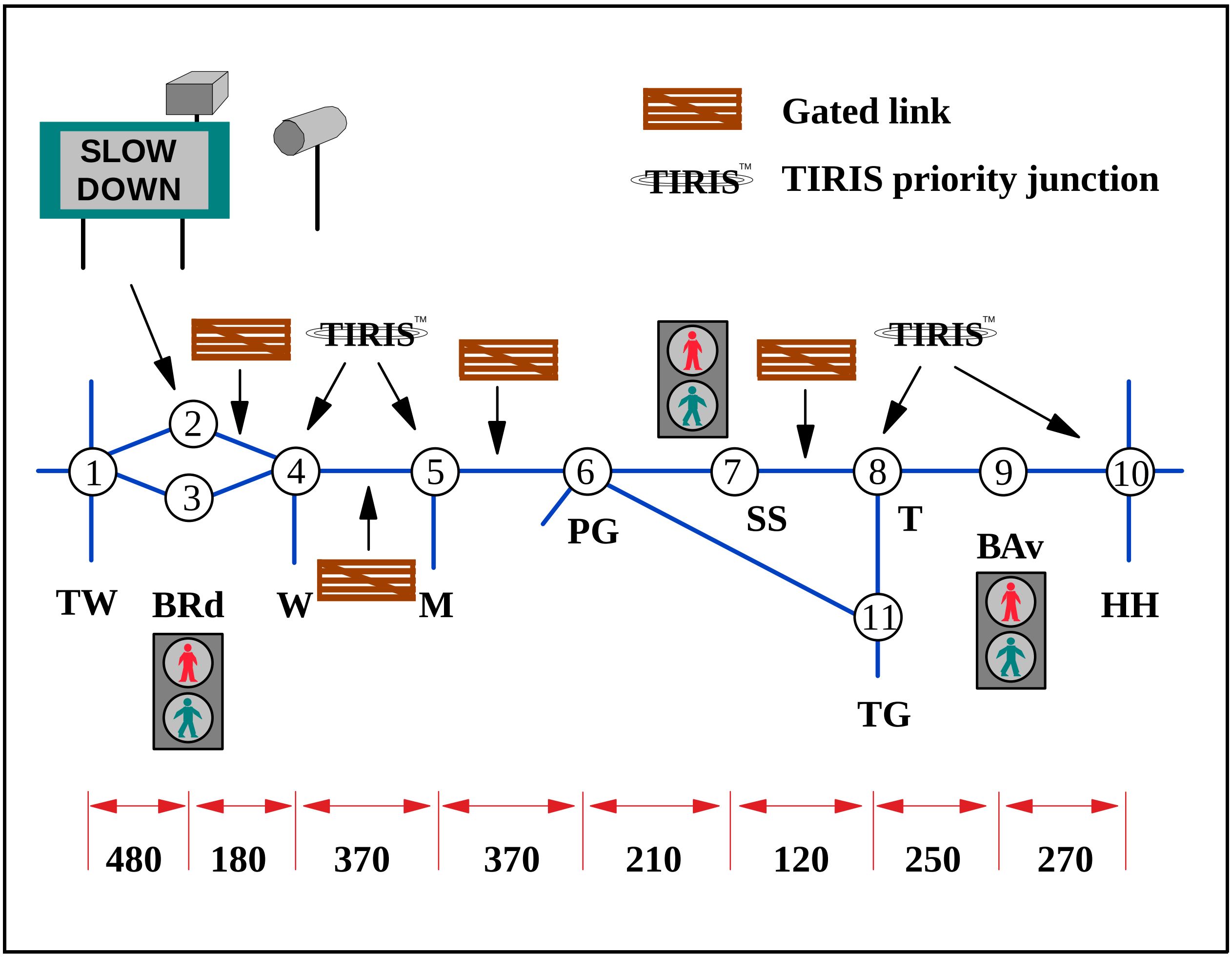

Figure 2.2 : The signalised intersections on the Dewsbury Road

The strategies that have been tested by simulation are described below. They are listed in the following table together with a short abbreviation that will be used in the rest of the document to refer to the strategy.

Strategy code	**Strategy name**
Q	Horizontal Queue Model
A1	Auto-gating 1 - The MX strategy
A2	Auto-gating 2 - Local Feedback Control
A3	Auto-gating 3 - Linear Quadratic Co-ordinated Feedback Control
A4	Auto-gating 4 - Linear Quadratic Integral (LQI) Control
U	Unconstrained SCOOT
P	Bus progression
B	Bus priority with TIRIS
S	Speed Advice
W	Starting and Stopping Wave

Table 2.2 : The strategy components tested at the Dewsbury Road site

- Horizontal Queue Model (Q)

This strategy improves the model within the SPOT system so that queue lengths of traffic are estimated accurately. As well as improving the overall performance of the UTC system this also allows strategies such as the auto-gating strategies, to be implemented as they need an accurate estimate of the amount of space available on each link to store queues.

- Auto-gating 1 - The MX Strategy (A1)
- Auto-gating 2 - Local Feedback Control (A2)
- Auto-gating 3 - Linear Quadratic Co-ordinated Feedback Control (A3)
- Auto-gating 4 - Linear Quadratic Integral LQI Control (A4)

Gating stores vehicles upstream of a critical bottleneck, in a pre-determined section of road with plenty of storage capacity. Auto-gating or metering is a new form of gating whereby each link stores vehicles without blocking-back. This is achieved by funnelling the green times according to the downstream queues or space left.

The four methods used involve the calculation of an upper limit to the total length of green time to be allotted to a link. This value is then used to overwrite temporarily the maximum green time for the stage which is green to the link; in cases where the link receives green time in more than one (consecutive) stage, the upper limit of green time is distributed between the relevant stages.

- Unconstrained SCOOT (U)

SCOOT operates with one common cycle time over the whole network. The traffic engineers at the UTC centre in Leeds placed an upper limit on this cycle time of 88s as they were concerned about pedestrian delay at each junction. SCOOT can operate at higher cycle times and in the absence of constraints it will tend to do so to relieve congestion. Therefore a simulation was performed to see what benefits would ensue if the SCOOT cycle time was not constrained, but allowed to increase to the 120s system limit. All the other simulations using SCOOT retained the 88s cycle time constraint.

- Bus progression (P)

In common with most UTC systems, SCOOT tries to optimise the traffic signal settings to benefit the traffic stream as a whole. Traffic does not, however, behave in a homogeneous manner. In particular a set of signal offsets geared to providing a green-wave to traffic as a whole, tends to provide a red-wave to buses. Work has shown that in a fixed time context, significant benefits can be achieved if the bus traffic stream is separated out and given extra weight (Robertson and Vincent, 1975).

Within the context of PRIMAVERA, a similar benefit can be achieved by placing an additional constraint on the offset optimiser. A set of bus progression offsets can be developed off-line, using the BUS TRANSYT program. These offsets then become the default offsets and have a maximum offset weight associated with them. Thus SCOOT is encouraged (but not forced) to use these offsets rather than those from the offset optimiser.

- Bus Priority using TIRIS (B)

If information on the approach of a bus at a set of signals is available then this information can be used by the SCOOT optimiser in order to benefit buses. This benefit may take a number of different forms:

(i) Prevent an early termination of the stage which benefits the bus;
(ii) Extend the stage which benefits the bus;
(iii) Recall early the stage which benefits the bus.

Separate weights are available in SCOOT to facilitate each of these actions. These weights are applied at each split optimisation decision (which takes place 5 seconds before a stage change is due) to the merit values associated with three courses of action. These actions are ADVANCE (bring the stage change forward by 4 seconds), STAY (leave the stage change where it is) or RETARD (put back the stage change by 4 seconds). When a bus crosses the detector, a prediction is made of when the bus will reach the stop line and appropriate action is taken.

It should be noted that there is no absolute guarantee of priority to buses at a junction. At each split decision SCOOT will take into account the merit values associated with decisions on conflicting links in order to reach a decision. Four junctions in the inbound direction (4, 5, 8 and 10) will be equipped with TIRIS readers. Priority is given to bus services 2, 24 and 46.

- Speed Advice (S)

Recent research has shown that lower impact speeds can drastically reduce the severity of vehicle-pedestrian accidents. In practice the situation of excessive speeds is only likely to occur during the inter-peak period, since congestion tends to keep speeds low during the peak.

The installation of a speed camera on the southern section of Dewsbury road at node 2, provides a mechanism for enforcing slower progression speeds. This will be combined with a VMS sign warning drivers if they are travelling too fast to slow down. In the NEMIS model it has been assumed that this mechanism will be completely successful in limiting the maximum speeds of the vehicles.

- Starting & Stopping Wave (W)

Situations in which a queue grows so as to block the entrance to the link at an upstream junction can cause various problems, including loss of junction capacity, increased driver stress and hazards to pedestrians crossing at the junction. Such situations, termed spill-back, are likely to happen in congested networks or on short links. This strategy attempts to control when this spill-back clears from an upstream junction. From work conducted as part of a SERC project (Montgomery et al, 1993), it was shown that the least disruptive strategy was to arrange for the starting wave to reach the upstream junction towards the end of either main or minor stage green. For the purposes of PRIMAVERA, the end of minor stage green was chosen as the position in the cycle. If this is effective then there should be a reduction in the number of stops experienced by vehicles thereby reducing the levels of various pollutants and driver stress.

In order to implement this strategy in SCOOT, use is made of the offset-bias function in combination with an off-line calculation of the required offset. Empirical measurements in Leeds (Argüello and Torres, 1990), showed that the starting wave travels back at a speed of 6m/s. Once link lengths and the point in the upstream cycle at which the starting wave is to arrive at are known, offsets can be calculated. Within SCOOT, as the weight on a link's default offset is increased, up to its maximum of 127, the SCOOT offset optimiser is much more likely to use the default offset. Facilities are incorporated in SCOOT in order to increase this bias weight in real-time, as congestion (ie queue length) grows within the affected link.

The following table shows which strategy components have been implemented with SCOOT and which with SPOT.

Strategy Component	SCOOT	SPOT
Horizontal Queue Model		✓
Autogating 1 - The MX Strategy	✓	✓
Autogating 2 - Local Feedback Control	✓	✓
Autogating 3 - Linear Quadratic Co-ordinated Feedback Control	✓	
Autogating 4 - Linear Quadratic Integral LQI Control	✓	
Unconstrained SCOOT	✓	
Bus progression	✓	
Bus Priority using TIRIS	✓	✓
Speed Advice	✓	✓
Starting & Stopping Wave	✓	

Table 2.3 : The strategy components implemented by each system in Leeds

2.2 Using SPOT in Turin

The strategies in Turin will be implemented via signal control using SPOT. Full details of the implementation plans can be found in Deliverable No. 8 : Implementation Aspects Report.

In the following sections the different intersections will be referred to using the SPOT number they have been given. The following table shows their relationship with the real intersection names.

SPOT number	Intersection
11	Grosseto / Casteldelfino
12	Grosseto / Roccavione
13	Grosseto / Bibiana
14	Grosseto / Chiesa della Salute
15	Grosseto / Ala di Stura
16	Grosseto / Rebaudengo / Vercelli
17	Rebaudengo / Vercelli / Toscanini

Table 2.4: The SPOT controlled junctions at the Corso Grosseto test site

In Turin seven intersections are to be controlled by SPOT units on the Corso Grosseto test site; for a detailed description of the test site refer to PRIMAVERA Deliverable 4. Figure 2.3 shows the schematic topology of the test site.
For the Corso Grosseto test site a set of individual strategies have been selected for the off-line evaluation through simulation.

The tested individual strategies are listed in the following table together with a short abbreviation that will be used to refer to the strategy in the rest of the document.

Strategy code	**Strategy name**
G	Green Wave fixed time plan
E	SPOT enhanced by PRIMAVERA
Q	Co-operative Auto-gating / Horizontal Queue Model
B	Bus Priority + Bus Stop Protection
C	Calming by de-synchronisation
S	Speed Advice

Table 2.5 : The strategy components used at the Corso Grosseto test site

Integrated strategies are identified by the combination of the individual strategies' abbreviations.

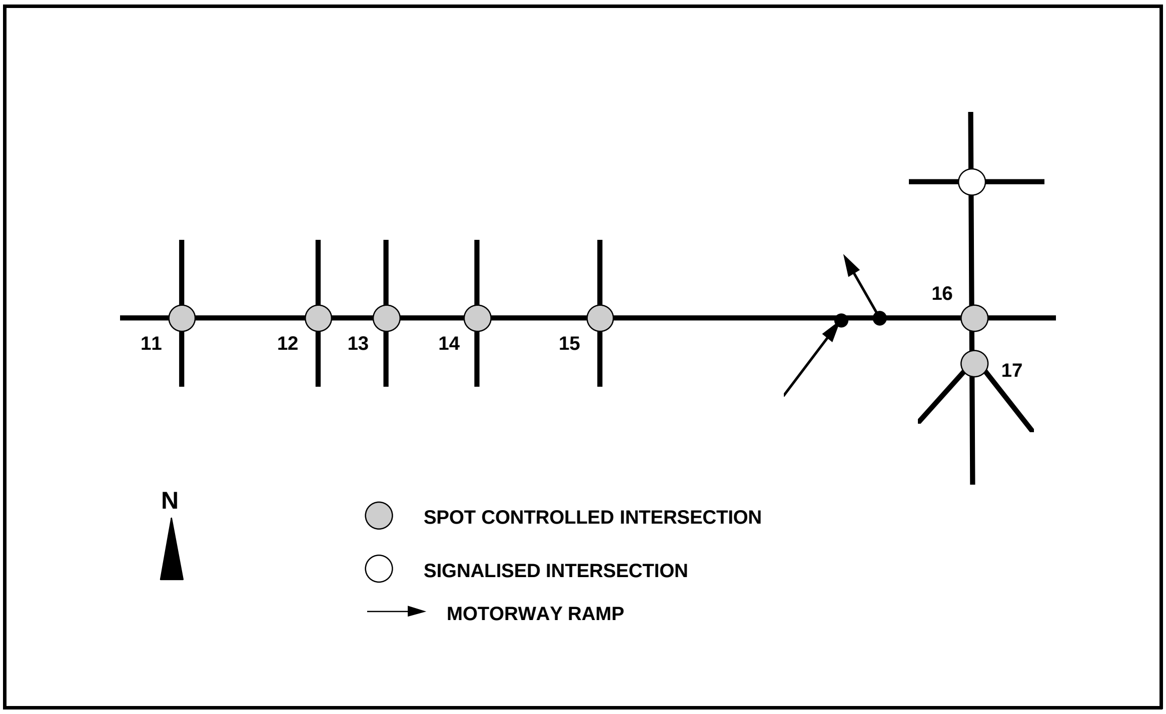

Figure 2.3 : The topology of the Corso Grosseto test site

The strategies have been implemented by introducing new commands and modifying the cost function of the SPOT controller. The implementation stage has produced an enhanced version of the SPOT software that can itself be considered as one of the PRIMAVERA achievements.

The new software includes:

1. the introduction of the "Look Ahead" cost (see PRIMAVERA Deliverable No. 8) into the cost function. This is an added cost that operates only at the end of the optimisation horizon and could also be thought of as a terminal cost.

2. the introduction of

   a) "synchronisation"
   b) "de-synchronisation"

   commands for each incoming link. These commands alter the nominal queue profile used in the terminal cost according to the level of synchronisation required.

3. modification of the "spatial horizon" of each unit. This feature modifies the cost function of the controller as each local unit is also able to minimise

   a) delays
   b) storage capacity excesses

   on the outgoing links.

In the following sections each of the strategies is described in more detail together with a description of how these strategies have been applied in the test network.

- Green Wave fixed time plan (G)

The base case used for a comparison of the strategies is the "green wave" fixed time plan currently in use on the test site. This uses a 90s cycle length for intersections 11, 12, 13, 14, 15 and a 110s cycle for intersections 16 and 17.

- Enhanced SPOT (E)

The version of the SPOT software used as a base includes some of the PRIMAVERA results that improve the performances of the controller in saturated and over-saturated conditions. It can be considered itself as one of the PRIMAVERA achievements. In particular, features 1 and 2(a) above are used.

Results obtained with this version can also be used as a reference case for the performance evaluation of the other strategies.

The terminal cost is used on all the intersections. Intersection 14 is forced to be synchronised with the arrivals coming from intersection 13. This implies a platooning action in the middle of the arterial in the West-East direction that has been found to be beneficial for the whole network.

- Cooperative Auto-gating / Horizontal Queue Model (Q)

This strategy can be implemented in different ways each of them requiring a different level of cooperation between adjacent intersections.

At a first level only a saturation protection of the link connecting two SPOT units is performed. This is achieved by the downstream controller sending information, every three seconds, about the link occupancy (horizontal queue) to the upstream one. The excess of link storage capacity is then taken into account in the cost function of the upstream unit by the calculation of how the downstream horizontal queue will evolve according to its planned policy. (Point 3(b) of the above list). The strategy implemented in this way does not provide any synchronisation between the intersections.

At a second level the downstream unit cooperates with the upstream, with the aim of keeping the link of interest cleared of queues. (Point 2(a)). This, as well as making the task of the upstream controller easier, also produces synchronisation considering the upstream unit as the master intersection.

At a third level the upstream controller modifies its cost function in order not only to protect the link but also to minimise delays on the link (Point 3(a)). This produces synchronisation considering the downstream unit as the master intersection.

Autogating at the first level is applied at all the intersections. However blocking back phenomena are mainly present at intersection 16 because of large volumes of traffic coming off the motorway exit ramp.

- Bus Priority + Bus Stop Protection (B)

This strategy gives priority to buses using the arrival forecast supplied by an AVM system. The innovative part of the strategy is the "protection" of links where a public vehicle is expected and there is a bus stop which is often obstructed by private traffic queues. To obtain this protection the "storage capacity" parameter of the link is temporarily reduced by a pre-defined percentage and a clearing command for the approach is issued when a public vehicle is expected on the link. "Nominal" parameters are restored as soon as the public vehicle leaves the link. The strategy could also be applied on links where there is not a bus stop but where public vehicles share the approach with private traffic that obstructs their movements.

This kind of strategy can be really disruptive to private traffic movements as the traffic signal policy can become totally unbalanced towards the protected links.

Bus priority for bus service number 2 is given all along Corso Grosseto (intersections 11,12,13,14,15,16) in the West-East direction because the bus occupancy is great here during the AM Peak.

Bus stop protection is performed at intersection 16 where a bus stop near the motorway exit is often obstructed.

- Calming by de-synchronisation (C)

The aim of this strategy is to reduce excessive speeding on a link through the de-synchronisation of a particular direction of traffic. As a control centre is not designed to do this, de-synchronisation of the intersections can only be obtained through local level commands without using a "reference de-synchronised area level plan" that could not be evaluated by the local controllers.

To implement this strategy a suitable set of weighting factors and "nominal queues profiles", as defined in Deliverable 8, are used in order to make a chosen traffic direction preferable to another.

This strategy can be effective only where intersections are near enough to allow the downstream traffic lights to influence the behaviour of drivers exiting from the upstream one.

From the initial simulation results it was noted that most of the time spent at high speed was on the links connecting intersections 11 - 12 and 15 - 16 in the West-East direction. Of these two links the strategy is only applicable on the first one as the second one is 800m long.

- Speed Advice (S)

This strategy involves speed advice being given at the exit of the intersection that is the optimal speed to follow in order to find a green light at the downstream intersection. For safety considerations the speed advice is limited in a range from 30 to 55 km/h and is given through a VMS indication directly driven by the SPOT unit.

Expected benefits of this strategy are not only in terms of safety but also efficiency. In fact well defined platoons travelling at limited speed can be managed better by any traffic responsive system as the expected travel time on the approaches cannot be estimated by on-line measurement but has to be provided as an initialisation parameter.

The presence of the VMS relaxes the constraint of the "downstream traffic light visibility" as described for the previous strategy.

In the simulations driver compliance to the advice is assumed to be absolute. This means that this strategy could also be viewed as being speed enforcement rather than speed advice.

Speed advice is given at the entry of the links where the proportion of high speed driving is great (see above).

3. EVALUATION FRAMEWORK

3.1 Purpose

The Evaluation Framework for the simulations is described fully in Deliverable 11 : Evaluation Methodology. Both a Cost-Benefit approach and a Multi-Criteria method have been used to assess the simulations. The Cost-Benefit approach has been used for impacts which are easily quantifiable in monetary terms, while the Multi-Criteria approach uses impacts which are not easily costable. The Cost-Benefit approach tends to favour strategies that reduce travel times, while the Multi-Criteria approach is able to incorporate environmental and safety issues more easily. The computer program MASCOT has been used to assess the Multi-Criteria results. This program is able to carry out a sensitivity analysis of the weights and scores to see what changes have to be made to change the strategy rankings.

3.2 Impacts

The simulation evaluation process closely follows that of the field trial evaluation, by trying to use a similar set of impacts. This is not always possible as some impacts, such as pedestrian accidents, cannot be directly assessed by the simulation. Equally, some parameters, such as vehicle exhaust emissions, are much easier to estimate from the simulations rather than to measure on the street.

The impacts used are described fully in Deliverable 11.

3.3 Costs and Weights

3.3.1 The Cost Benefit Analysis Parameter Values

In the Cost Benefit Analysis (CBA) monetary values have to be given to each impact evaluated. The rates used are those given in the DRIVE I EVA manual, they are as follows:

Impact	Cost
Travel Time (UK)	14.26 ECU/person hour
Travel Time (Italy)	18.28 ECU/person hour
Fuel Consumption	0.36 ECU/l
CO Emissions	3 ECU/ton
NOx Emissions	443 ECU/ton
Hydrocarbon Emissions	348 ECU/ton
Fatal Casualty	744,177 ECU
Serious Casualty	105,593 ECU
Slight Casualty	7,080 ECU

Table 3.1 : The cost of each impact used in the CBA

The travel time values are per person hour. These values have to be multiplied by the average occupancy of the private and public vehicles. From the before surveys carried out in Leeds an average value of car occupancy for buses was 35 persons / bus. For cars the Leeds value is 1.4 persons / vehicle.

The company that runs public services in Turin, ATM, has provided PRIMAVERA with an estimate of the average occupancy (in passengers) for each service travelling in the area in the AM Peak. Values are reported in the following table:

	Average Occupancy (Persons)	Cost (ECU/hour)
Private Traffic	1.4	25.6
Bus Service 2	36	658
Bus Service 10	23	420
Bus Service 52	16	292.5
Bus Service 46	25	457
Bus Service 51	22	402
Bus Service 62	36	658

Table 3.2 : The bus occupancy for the Corso Grosseto bus routes

As all the different simulations use the same O/D matrix with vehicles following the same routes and run for the same period of time the part of Vehicle Operating Cost based on the distance travelled is not taken into account as it will be the same for each run.

It has not been possible to find any reliable relation between the impacts measurable through the simulation and the accident rates for Turin. So this cost term is not considered in the analysis of the Turin results.

For the Multi-Criteria Analysis the computer program MASCOT is being used. This has a set of built-in weights for most impacts of interest but is lacking in a few of these such as variability in journey time. We have therefore produced our own set of weights for the missing values.

3.3.2 The parameters for the Multi-Criteria Analysis

Impact	Units	Target % change	Official	Environmental
Efficiency				
Car travel time saving	K veh s	-15	5.5455	3.0248
Bus travel time saving	K veh s	-5	138.6388	106.645
Travel time sd reduction	K veh s	-15	2.7728	1.5124
Bus time sd reduction	K veh s	-10	69.3194	53.3225
Stops	K	-10	0	100
Speed sd	m/s	-1	0	-0.3
Environment				
Fuel consumption saving	K litres	-5	360	3600
NOx emissions	kg	-10	-0.443	-4.43
HC emissions	kg	-10	-0.348	-3.48
CO emissions	kg	-10	-0.003	-0.03
Visual intrusion by queues	veh	-10	10	15
Safety				
Mean speed	m/s	0	0	-10
Excessive speed time	K s	-5	0	50
Fatal casualty reduction	-	-5	744177	1284910
Serious casualty reduction	-	-5	105593	211186
Slight casualty reduction	-	-5	7080	12390

Table 3.3 : Weights and targets used for the Leeds MCA

The value function used to evaluate each link/network impact is:

$$F(i) = i/O$$

where i : is the percentage benefit obtained by the strategy on a particular impact
O : is the Criterion Utility of the impact, ie. the percentage benefit deemed desirable

This value function allows both improvements and worsening to be evaluated.

4. RESULTS

4.1 General Comments

For the SCOOT runs the base environment is the existing road network with signals controlled by the standard SCOOT 2.3 system which is due to be installed in Leeds prior to the field trials. Similarly for the SPOT runs the base environment uses the standard SPOT system. This allows the new strategies to be tested against the appropriate current state-of-the-art system at each site. Simulations have also been carried out using the fixed time plan that was operating when the data was collected during the initial PRIMAVERA surveys. The simulations with this plan were only used to calibrate the NEMIS model.

It should be emphasised that it is not an aim of PRIMAVERA to compare the performance of SPOT based systems against SCOOT based systems. Each system has different constraints applied to its operation that would make it unfair to make a direct comparison. The main difference is that the SCOOT system has been restricted to work with a maximum cycle time of 88 seconds compared to a 120 second maximum cycle time for SPOT. This decision was taken because SCOOT operates all junctions at a common cycle whereas SPOT can function with unequal cycle times. It was felt by the local autority engineers in Leeds UTC that a common cycle time of 120 seconds would cause problems for pedestrians at certain junctions. SPOT can use higher cycle times at those junctions where there is no pedestrian problem.

4.2 Introduction

The following overall network parameters are collected from the NEMIS output files for use in the evaluation process.

- Mean speed (m/s)

This is the total distance travelled divided by the total time taken.

- Time spent by vehicles travelling at high speed

This is the amount of travel time that vehicles are travelling in excess of 15 m/s (54 km/h).

- Number of vehicles being impeded by blocking back throughout the simulated network

- Stops

This is the number of vehicle which stopped at least once while travelling down each link. Only one stop per link is counted, so in over saturated conditions the actual number of stops will be underestimated.

- Standard deviation of speed (m/s)

At every time step the speed of each vehicle to the nearest m/s is recorded and a table of frequencies built up. The standard deviation of this frequency distribution can be calculated.

- Total travel time (s)

- Maximum Queues

The sum of the maximum queues on each link of the modelled network

- Delay

This is defined as the sum of the time that vehicles spend in a queue. A vehicle is defined as being in a queue if the distance between the vehicle and the vehicle in front of it is less than or equal to 12 m and the speed of the vehicle is less than 5 m/s.

- Flows

The sum of the flows out of each link in the network

- Public Transport Travel Time

- Total fuel consumption (l)
  Total NOx emissions
  Total HC emissions
  Total CO emissions

NEMIS has the capability of modelling some pollution emissions and fuel consumption of all the vehicles in the simulation. The following three pollutant emissions are estimated: Carbon Monoxide, Nitrogen Oxides and unburnt Hydrocarbons. These quantities are obtained from look-up tables which give the amount of pollution emitted by each class of vehicle according to the speed and acceleration of the vehicle.

- Public Transport Flows

The sum of the flows of public transport vehicles out of each link in the network

- Standard deviation of Travel Time (s)

The sum of the standard deviations of vehicle travel time for each link in the network

- Standard deviation of Public Transport Travel Time (s)

The sum of the standard deviations of each public transport trip down all links in the network

- Accidents

An estimate of the sum of the number of accidents that will occur on each link on the network. Calculations are based on vehicle flows, mean vehicle speeds and road types. An analysis of the accident prediction methods is given in Appendix D.

For the Cost Benefit Analysis the following parameters are used

Total Travel Time
Fuel Consumption
NOx Emissions
HC Emissions
CO Emissions
Public Transport Travel Time
Accidents

The costs given in Section 3.3 are used to calculate the overall cost of each strategy and the benefits over the base case.

The remaining parameters are used for the Multi-Criteria Analysis.

Information is also available for each link in the network. The value of every impact parameter on every link can be obtained.

4.3 Leeds Trial Site

4.3.1 Changes in impacts

Results from the simulations indicate that significant benefits can be obtained by the individual strategies. As expected, on their own, the individual strategy components tend to produce benefits in one or two of the efficiency, environment and safety goals of the DRIVE programme, but not in all three. It is hoped that it will be possible to integrate the individual measures in such a way as to produce benefits in all three goals.

Impact	Q	A1	A2	B	S
Mean Speed (m/s)	0.54	-2.51	-3.91	5.62	-1.92
Speeding Time (s)	0.80	-0.24	-0.08	1.83	-8.65
Blocking Back (s)	-0.32	-5.76	-18.57	-20.43	-6.41
Stops (veh)	-0.18	2.26	4.50	-4.67	3.43
Delays (s)	0.37	6.44	8.63	-8.08	5.19
Travel Time (s)	-0.54	2.60	4.20	-5.41	2.14
Fuel Consumption (l)	0.12	1.03	1.37	-1.24	0.04
CO Emissions (g)	-0.68	2.30	2.18	-4.31	1.30
NOx Emissions (g)	-0.54	1.30	0.81	-2.51	0.53
HC Emissions (g)	-0.58	2.01	2.55	-4.16	1.48
Bus Travel Time (s)	-0.57	0.46	1.62	-2.85	0.77
Bus TT 2 (s)	0.59	0.31	4.62	-6.07	1.55
Bus TT 24 (s)	3.96	1.26	8.85	-4.51	4.87
Bus TT 46 (s)	-1.06	1.28	4.35	-3.47	2.87

Table 4.1: % changes in Network Impacts over standard SPOT : SPOT based simulations - AM Peak

Impact	S	U	W	A1	A2	A3	A4	P	B
Mean Speed (m/s)	-0.31	20.99	-0.56	-6.48	-9.92	-10.69	-13.83	-2.55	-2.12
Speeding Time (s)	-10.32	9.59	-0.80	4.21	5.28	8.87	9.61	2.13	2.79
Blocking Back (s)	-14.35	-59.80	-17.93	-3.48	67.40	54.72	98.15	4.61	-7.74
Stops (veh)	1.05	-9.19	0.15	1.96	4.52	5.45	6.04	1.02	-0.19
Delays (s)	-2.04	-21.00	-5.10	12.92	16.10	24.31	30.12	0.97	4.55
Travel Time (s)	0.37	-16.16	0.54	6.81	11.20	12.40	16.32	2.90	1.94
Fuel Consumption (l)	-0.99	-4.52	0.55	2.43	5.11	4.62	6.31	1.36	0.84
CO Emissions (g)	-0.45	-9.50	-0.15	5.45	10.27	9.30	11.11	1.86	2.09
NOx Emissions (g)	-0.85	-5.10	-0.32	3.85	7.44	6.06	6.71	1.17	1.70
HC Emissions (g)	0.10	-11.58	0.15	5.68	9.99	9.84	12.07	2.06	1.99
Bus Travel Time (s)	-0.45	-12.61	0.43	5.24	9.14	7.89	5.98	-0.09	2.47
Bus TT 2 (s)	0.47	-24.9	-2.51	2.68	4.40	10.96	13.14	-1.75	1.44
Bus TT 24 (s)	0.40	-23.7	-1.42	5.20	5.51	10.73	11.48	-0.76	2.42
Bus TT 46 (s)	1.20	-22.0	-3.53	5.89	9.33	18.01	23.18	-0.28	0.87

Table 4.2: % changes over SCOOT: SCOOT based simulations - AM Peak

4.3.2 Cost Benefit Analysis

The following tables indicate the results of the Cost Benefit Analysis. All values refer to the two hour data collection period. All the monetary values are in ECU.

Strategy	Cost (ECU)	Benefit over standard SPOT	% Benefit over standard SPOT
TIRIS	26606.83	901.13	3.28
Horizontal Queue	27395.91	112.04	0.41
Speed Advice	27829.06	-321.11	-1.17
Autogating 1	27878.04	-370.09	-1.35
Autogating 2	28188.33	-680.38	-2.47

Table 4.3 : SPOT based strategies for the AM Peak : Existing Environment

For the SPOT based strategies both the TIRIS bus priority scheme and the new horizontal queue model produce slight improvements when compared to the latest state-of-the-art SPOT system.

Strategy	Cost (ECU)	Benefit over standard SCOOT	% Gain over standard SCOOT
U	33290.99	4872.78	12.77
S	38138.36	25.41	0.07
W	38352.77	-189.00	-0.50
P	38726.29	-562.52	-1.47
B	38902.48	-738.71	-1.94
A1	40233.25	-2069.48	-5.42
A2	41548.87	-3385.10	-8.87
A3	41672.33	-3508.56	-9.19
A4	42173.50	-4009.73	-10.51

Table 4.4 : SCOOT based strategies for the AM Peak : Existing Environment

For the SCOOT based strategy components, the unconstrained system shows a benefit while the speed advice and Starting & Stopping wave components show little change. All the other strategies show a disbenefit.

For the CBA, travel time figures dominate the savings associated with each strategy. Typically they are about ten times larger than the accident savings, twenty times larger than the fuel savings and a thousand times larger than the pollution emission savings. The CBA will therefore favour strategies which reduce travel time, with little regard for environmental or safety factors. As safety is a concern on the Dewsbury Road, an MCA which readily identifies changes in safety is preferred.

4.3.3 Multi-Criteria Analysis

A multi-criteria analysis has been carried out using the MASCOT program. This program comes with three sets of weights built-in that reflect the opinions of the values of "Official", "Environmental" and "Commercial" groups. This set of weights has been supplemented by some additional values for impacts not originally considered. As the results of the "Commercial" weights are very similar to those using the "Official" weights, only the "Official" weights are considered here. The weights and targets used can be found in Table 3.3 in Section 3. In the following tables the Performance Indicator is the score obtained by multiplying the weights by the values of each impact obtained from the simulations. These have been broken down further into their Safety, Efficiency and Environment components; the DRIVE programme goals. The number in brackets at the top of each column is the score that would have been achieved by a strategy that achieved all the targets. The number in each column is the proportion of the target score achieved by the strategy.

Strategy	Performance Indicator (4056)	Safety (315)	Efficiency (3015)	Environment (726)
B	1781	-0.30	0.45	0.70
Q	474	-0.05	0.05	0.46
S	-395	0.10	-0.16	0.09
A1	-574	0.05	-0.17	-0.11
A2	-718	0.11	-0.30	0.21

Table 4.5 : an MCA of the SPOT based strategies using "Official" weights

Strategy	Performance Indicator (4859)	Safety (1446)	Efficiency (2035)	Environment (1378)
B	938	-0.42	0.40	0.53
S	779	1.12	-0.25	-0.24
Q	71	-0.18	-0.01	0.26
A2	-802	0.00	-0.38	-0.02
A1	-815	0.00	-0.23	-0.24

Table 4.6: an MCA of the SPOT based strategies using "Environmental" weights

Strategy	Performance Indicator (5796)	Safety (161)	Efficiency (4726)	Environment (909)
S	33	0.17	0.02	-0.11
W	-280	-0.10	-0.03	-0.13
P	-1100	0.16	-0.19	-0.27
B	-1214	0.00	-0.19	-0.33
A1	-3211	0.28	-0.56	-0.65

Table 4.7: an MCA of the SCOOT based strategies using "Official" weights

Strategy	Performance Indicator (5950)	Safety (1165)	Efficiency (3109)	Environment (1676)
S	1563	1.62	-0.02	-0.14
W	-586	0.06	-0.08	-0.25
P	-1725	-0.33	-0.21	-0.41
B	-1836	-0.47	-0.23	-0.36
A1	-3909	-0.62	-0.60	-0.78

Table 4.8: an MCA of the SCOOT based strategies using "Environmental" weights

4.4 Turin Trial Sites

4.4.1 Changes in impacts

The following tables report a summary of the results of the simulations on the Corso Grosseto test site respect to the network based impacts. For bus travel time network data is reported together with data related to each service that crosses the area.

Impact	FIX	SPOT	Q	B	C	S
Mean Speed (m/s)	7.21	8.03	8.03	7.57	7.91	7.9
Speeding Time (s)	79669	94178	93844	93941	90054	64349
Blocking Back (s)	2330	215	295	3462	222	248
Stops (veh)	17421	16556	16230	16877	17200	16233
Delays (s)	527598	417750	417070	485127	427892	417822
Travel Time (s)	1508137	1343484	1340569	1420544	1358333	1361466
Fuel Consumption (l)	2675.75	2764.04	2748.87	2857.57	2806.46	2553.66
CO Emissions (g)	202896.3	194372.4	192254.1	197041	195191	191659.3
NOx Emissions (g)	5024.16	4938.11	4899.19	4962.01	4939.43	4919.97
HC Emissions (g)	15820.75	14881.32	14747.17	15256.18	14879.39	14867.35
Bus Travel Time (s)	14103	14313	14176	14329	13405	13667
Bus Delay (s)	4947	5034	4731	5079	4128	4312
Bus Del. Ser. 2 (s)	2005	1504	1459	851	1176	1246
Bus TT 2 (s)	6305	5879	5821	5030	5545	5612
Bus TT 10 (s)	1741	1759	1810	2056	1710	1768
Bus TT 52 (s)	1190	1408	1435	1451	1157	1272
Bus TT 46 (s)	1347	1472	1386	1783	1477	1474
Bus TT 51 (s)	2045	2234	2268	2486	2040	2068
Bus TT 62 (s)	1475	1561	1456	1523	1476	1473

Table 4.9 : Results of the simulations on Corso Grosseto, network impacts

% Change	SPOT	Q	B	T	S
Mean Speed	11.37	11.37	4.99	9.71	9.57
Speeding Time	18.21	17.79	17.91	13.04	-19.23
Blocking Back	-90.77	-87.34	48.58	-90.47	-89.36
Stops	-4.97	-6.84	-3.12	-1.27	-6.82
Delays	-20.82	-20.95	-8.05	-18.90	-20.81
Travel Time	-10.92	-11.11	-5.81	-9.93	-9.73
Fuel Consumption	3.30	2.73	6.80	4.88	-4.56
CO Emissions	-4.20	-5.25	-2.89	-3.80	-5.54
NOx Emissions	-1.71	-2.49	-1.24	-1.69	-2.07
HC Emissions	-5.94	-6.79	-3.57	-5.95	-6.03
Bus Travel Time	1.49	0.52	1.60	-4.95	-3.09
Bus Delay	1.76	-4.37	2.67	-16.56	-12.84
Bus Del. Ser. 2	-24.99	-27.23	-57.56	-41.35	-37.86
Bus TT 2	-6.76	-7.68	-20.22	-12.05	-10.99
Bus TT 10	1.03	3.96	18.09	-1.78	1.55
Bus TT 52	18.32	20.59	21.93	-2.77	6.89
Bus TT 46	9.28	2.90	32.37	9.65	9.43
Bus TT 51	9.24	10.90	21.56	-0.24	1.12
Bus TT 62	5.83	-1.29	3.25	0.07	-0.14

Table 4.10 : Percentage changes over the fixed time plan reference case

4.4.2 CBA

As a first step strategies have been evaluated through a CBA analysis. The lack of a safety cost has biased this evaluation towards gains in efficiency. The obtained ranking of the strategies is shown in the following table. Costs and benefits are related to 1 hour of simulated time during the AM peak.

Strategy	Cost (ECU)	Benefit (ECU)	% Gain
Q	12614.94	1199.48	8.68
S	12628.85	1185.57	8.58
T	12667.05	1147.38	8.31
SPOT	12669.96	1144.46	8.28
B	13195.26	619.17	4.48

Table 4.11: CBA of the Turin Simulations

Appendix C gives further details of benefits obtained by each strategy for the different impacts.

According to this analysis strategies can be divided into two classes. In the first class the benefit is about 8% of the total cost. This benefit mainly derives from improvements in travel time for the private traffic. There is little difference between the benefits of these strategies.

The Bus Priority strategy belongs to the second class whose percentage benefit is about 5%. It appears that if this strategy reaches its target objective in improving travel time and delays of the controlled service, disruptions caused to private traffic and other bus routes are excessive in monetary terms.

4.4.3 MCA

As stated above, two different MCAs have been performed. The two scenarios have been obtained by changing the objective score associated with the three DRIVE goal categories impacts. This score is assigned to the strategy proportionally to the satisfaction of the Criterion Utilities of the different impacts. The overall performance indicator is the sum of the scores obtained by the goal category impacts.

The following table shows the strategy ranking according to the efficiency scenarios described earlier in section 3.5. The number in brackets in the header of the tables represents the objective score of each goal category.

Efficiency Oriented Scenario

Strategy	**Performance Indicator**	**Safety (24)**	**Efficiency (52)**	**Environment (24)**
S	69,14	19,79	39,61	9,74
Q	38,85	1,51	32,91	4,42
SPOT	37,69	1,58	33,03	3,08
T	37,66	3,57	32,16	1,94
B	1,58	-8,62	10,89	-0,69

Safety Oriented Scenario

Strategy	**Performance Indicator**	**Safety (48)**	**Efficiency (54)**	**Environment (48)**
S	98,67	39,58	39,61	19,49
Q	44,78	3,02	32,91	8,84
T	43,16	7,13	32,16	3,87
SPOT	42,34	3,15	33,03	6,16
B	-7,72	-17,24	10,89	-1,37

Comparing the MCA rankings with the CBA rankings the most obvious difference is the effect on the evaluation of safety indicators.

Here the Speed Advice strategy appears in the top position under both scenarios. This is because this strategy is most effective at reducing the time spent at excessive speed in the network and thus has by far the greatest impact on the safety criteria.

Once again the Bus Priority strategy is at the bottom of the list. It even gets even a negative score as performance indicator in the Safety scenario.

5. CONCLUSIONS

5.1 General

This deliverable has reported on the results of simulations of a number of individual strategies for queue management, public transport priority and traffic calming. In this report each strategy has been tested separately. Tests of strategies in combination (integrated strategies) are reported in Deliverable 12.

The strategies require a UTC system for their implementation, and in this project two systems have been employed, ie SPOT and SCOOT. The simulation runs are carried out by implementing the strategies on the actual UTC systems, but instead of being connected to actual detectors and traffic signals, the systems are connected via an interface to the NEMIS microsimulation program. This NEMIS simulation model allows the strategies to be evaluated against a large number of impacts as described in Deliverable 11.

Two networks are modelled, which are the networks scheduled for the field trials of the finally selected optimum strategies. On the Turin network (Corso Grossetto) the UTC system employed is SPOT, whereas on the Leeds network (Dewsbury Rd), both SPOT and SCOOT will be employed.

5.2 Leeds - SPOT - AM peak

The TIRIS bus priority and horizontal queue stratgy components show positive benefits in money terms over standard SPOT. Although quite small in percentage terms, in absolute terms the overall benefit of the best strategy is still substantial at approx 900 ECU per two hour period, or approx 225 kECU per year. The benefits of the TIRIS strategy may seem small, but the overall figure conceals a larger benefit to the equipped buses, offset by lesser benefits to other traffic. An MCA also indicates that the TIRIS system is best, although it predicts disbenefits for safety. The key aim for producing integrated strategies will be to try and maintain the efficiency and environmental benefits while reducing the safety disbenefit..

5.3 Leeds - SCOOT - AM peak

The largest benefit is obtained by allowing SCOOT to run to a longer cycle time than the 88 seconds to which it is currently constrained on this site. However this constraint has been imposed on the grounds of pedestrian delay and safety. Of the constrained strategy components, the speed advice and starting and stopping wave components come top in both the CBA and MCA. Only the starting and stopping wave component manages to reduce bus travel times.

5.4 Turin - SPOT - AM peak

The base SPOT strategy gives substantial benefits over the existing situation in terms of all three indicators used in the multicriteria analysis (safety, efficiency and environment). The 'B' strategy (selective bus priority and bus stop protection) is consistently the worst under all indicators. This is mainly due to the disruptive effects of this strategy on non priority buses and other traffic. These effects are partly site specific and require further investigation, but on the basis of present results there would appear to be no place for this strategy. The best strategy from the simple CBA analysis appears to be cooperative autogating. However under the multicriteria analysis this strategy drops to second place overall, being bettered by the speed advice strategy. Interestingly the speed advice strategy is the best even in terms of the efficiency indicator. This is because a greater number of impacts are incorporated into the MCA efficiency indicator than the simple CBA analysis.

According to the MCA results, the speed advice strategy is by far the best individual strategy, under both the efficiency oriented and safety oriented scenarios. It appears that the speed advice, when followed, produces more compact platoons, leading to smoother traffic flow, less stopping and starting, and hence lower fuel consumption and emissions.

REFERENCES

Argüello, R. and Torres, M. (1990). "*Queue Management Project, Measurement of traffic parameters on Wellington Street*". ITS Technical Note 296, Supplemental Report.

Biora, F. (1993) *Implementation Specification Report*, Deliverable No. 7, DRIVE II Project V2016 - PRIMAVERA

Burton, J. and Lanteri, F. (1993) *Description of Field Trial Sites*, Deliverable No. 4, DRIVE II Project V2016 - PRIMAVERA

Harvey, T. (1992) *A Review of Traffic Calming Techniques*, Deliverable No. 3, DRIVE II Project V2016 - PRIMAVERA

Lanteri, F. (1992) *Features of Public Transport Priority Systems*, Deliverable No. 2, DRIVE II Project V2016 - PRIMAVERA

Lanteri, F., Biora F. and Shepherd, S.P. (1993) *Implementation Aspects Report* Deliverable No. 8, DRIVE II Project V2016 - PRIMAVERA.

Montgomery, F. O., Clark, S.D. and May, A.D. (1993). "*Use of coordinated signal settings to reduce junction spill-back*". IEE Colloquium on Electronics in Managing the Demand for Road Capacity, Digest No:1993/205, pp 10/1-10/10.

Quinn, D. (1992) *A Review of Queue Management Strategies*, Deliverable No. 1, DRIVE II Project V2016 - PRIMAVERA

Road Accidents Great Britain 1991 - The Casualty Report, Department of Transport, HMSO.

Robertson, D.I. and Vincent, R.A. (1975). "*Bus priority in a network of fixed-time signals*". TRRL Laboratory Report 666.

Watson, S., Shepherd, S.P., Fox, K.A., Clark, S.D., Hodgson, F., May, A.D., Marler, N., Biora, F. and Conte, S. (1993) *Evaluation Methodology*, Deliverable No. 11, DRIVE II Project V2016 - PRIMAVERA.

APPENDIX A : DESCRIPTIONS OF STRATEGIES AND ENVIRONMENT COMPONENTS

POLICY : QUEUE MANAGEMENT

STRATEGY 1 : AUTO-GATING / METERING 1 - The MX Strategy

Description

Gating stores vehicles upstream of a critical bottleneck, in a pre-determined section of road with plenty of storage capacity. Auto-Gating or metering is a new form of gating whereby each link stores vehicles without blocking-back. This is achieved by funnelling the green times according to the downstream queues or space left.

The four methods described involve the calculation of an upper limit to the total length of green time to be allotted to a link. This value is then used to overwrite temporarily the maximum green time for the stage which is green to the link; in cases where the link receives green time in more than one (consecutive) stage, the upper limit of green time is distributed between the relevant stages.

The objectives are :-

i) to reduce total travel time and delay in the system;
ii) to reduce the amount of blocking-back in the system caused by an over-saturated intersection;
iii) to improve safety along the length of the arterial via queue relocation;
iv) to reduce vehicle emissions especially towards the centre of the city.

This first method is basically the MX strategy which was developed in DRIVE 1 (Shepherd 1991), but adapted to use the Cremer and Schoof model. Instead of using the percentage space left downstream, it now uses the average percentage space left downstream given by the Cremer and Schoof model to determine the green time as follows :-

$$g(k)=\frac{[g_{des}(k)+2g(k-1)+2g(k-2)+g(k-3)]}{6}$$

where

$$g_{des}(k)=\frac{g_{\max}\ X}{X_c}$$

g(k) is the green time for the main direction at cycle k
g_{des}(k) is the desired green time for cycle k
g_{max} is the maximum permissible green time
X is the percentage average space left downstream per cycle
X_c is the critical percentage average space left downstream
The resulting green time is then further bounded by maximum and minimum permissible values.

TACTIC : AUTOMATIC GATING

The only variables which influence this control method are the maximum and minimum green times and the value of X_c. For this study, the maximum and minimum green times were considered fixed for all junctions; only the critical space downstream was varied. The values for X were taken from the Cremer and Schoof model during the simulation runs.

A command is provided to allow the engineer to alter the critical percentage X_c for any link.

A link-based message is made available to report, at the start of the green in cycle k, the upper limit of length of green time $g(k)$ for the current cycle, the "desired" green time $g_{des}(k)$ for the current cycle, the calculated spare capacity X as a percentage of the maximum queue, the current value of critical percentage X_c, and the actual green time implemented for the previous three cycles ($g(k-1)$, $g(k-2)$ and $g(k-3)$).

SCENARIO

This tactic could be added to either SPOT or SCOOT with the addition of an extra stage and so could be tested on both field trial networks using the relevant interfaces.

REFERENCES:

Shepherd S.P. (1991)
Shepherd S.P. (1993)

NOTES

Possible accident problem if the stage order is changed. Early starts are not liked in W. Yorks. There is a fixed congestion offset in SCOOT 2.4. Need extra bolt-on to SCOOT 2.3.

POLICY : QUEUE MANAGEMENT

STRATEGY 2 : AUTO-GATING / METERING 2 - Local Feedback Control

Description

The remaining three methods have been adapted from ramp metering strategies described by Papageorgiou et al (1989).

This first method uses the link densities from the next link downstream only to determine the green time in the main direction. The strategy aims to regulate the average link density over a period to a pre-specified desired density, which can be varied according to conditions. The control is as follows :-

$$g_i(k+1)=\frac{q^{i}_{desout}(k+1)\ g_i(k)}{q^{i}_{out}(k)}$$

where

$$q^{i}_{desout}(k+1)=q^{i}_{out}(k)-K\ [\overline{\rho_j}(k)-\overline{\rho^{d}_{j}}]$$

$g_i(k)$ is the green time for link i at cycle k
$q^i_{out}(k)$ is the modelled number of vehicles leaving link i in cycle k
$q^i_{desout}(k)$ is the desired number of vehicles to leave link i during cycle k

$\overline{\rho_j}(k)$, $\overline{\rho^{d}_{j}}$ are the average density on link j over cycle k and the desired average density for link j.

K is a gain feedback which determines the response of the control.

Link i feeds traffic into link j.

The control is again bounded by the same maximum and minimum green times. The values for the average density over the cycle and the number of vehicles leaving a link per cycle are taken directly from the Cremer and Schoof model. The variables which influence the control system are the gain feedback and the desired average density. The latter determines the steady state solution and, given a constant demand high enough to sustain the desired density, the system would settle to this value. The value of K determines the response to the deviations from the desired density.

Although the above equations are written in terms of densities in vehicles per metre, it was easier to program the control in terms of numbers of vehicles present on a link. This is possible because to convert from densities to number of vehicles present requires only a multiplication by a constant. This constant can be divided into the gain term K.

For this study the desired density and the gain feedback term were varied and the responses noted.

TACTIC : AUTOMATIC GATING - EARLY CUT-OFF + VARIABLE OFFSETS

The commands and message are as for Method 4, but with the restriction that only the gain matrix K_2 may be accessed. For the purposes of changing elements of K_2, only those elements k_{ij} for which $j=i+1$ may be altered.

SCENARIO

This tactic could be added to either SPOT or SCOOT with the addition of an extra stage and so could be tested on both field trial networks using the relevant interfaces.

REFERENCES:

Shepherd S.P. (1991)
Shepherd S.P. (1993)

POLICY : QUEUE MANAGEMENT

STRATEGY 3 : AUTO-GATING / METERING 3 - Linear Quadratic Co-ordinated Feedback Control

Description

This method basically extends the local feedback control method, by using information from all links both upstream and downstream. The feedback term becomes a feedback matrix and the control law is written as follows :-

$$\underline{q_{desout}}(k+1) = \underline{q_{out}}(k) - \underline{K}\ [\underline{\overline{\rho}}(k) - \underline{\overline{\rho^{d}}}\ ]$$

where the notation is as before only in vector terms.

TACTIC : AUTOMATIC GATING THROUGH REGULATING DENSITIES

The commands and message are as for Method 4, but with the restriction that only the gain matrix K_2 may be accessed.

SCENARIO

Firstly the tactics will be simulated using NEMIS in an SERC sponsored project. Then the best tactics will be adapted for use in either SPOT or SCOOT and so could be tested on both field trial networks using the relevant interfaces.

REFERENCES:

Shepherd S.P. (1991)
Shepherd S.P. (1993)
Papageorgiou, M. et. al. (1989)

POLICY : QUEUE MANAGEMENT

STRATEGY 4 : AUTO-GATING / METERING 4 - Linear Quadratic Integral LQI Control

Description

This method is yet another extension of the control law, and brings in an integral term, which basically means that any changes in link densities from one cycle to the next are penalised. The control is written as follows :-

$$\underline{q}_{desout}(k+1) = \underline{q}_{out}(k) - \underline{K}_1[\overline{\underline{\rho}}(k) - \overline{\underline{\rho}}(k-1)] - \underline{K}_2[\overline{\underline{\rho}}(k) - \overline{\underline{\rho}^d}]$$

This time there are two gain matrices to define and the desired link densities. In the associated ramp metering strategy tested by Papageorgiou et al (1989), the desired densities were given for selected bottleneck sections only. In the signalised arterial case all densities are given as there is a control point leading into each link; however it was recognised that as the last junction inbound was critical and therefore a fixed bottleneck, the gain terms associated with this junction could be increased.

Various values have been tested for both the gain matrices and the desired densities. As usual the resulting green times were bounded by maximum and minimum values.

TACTIC:

A command has been provided to allow the engineer to alter the "average desired density" for any link. A further command has been provided to allow the engineer to print out either of the two gain matrices or to alter any element of either gain matrices.

A link-based message is made available to report, at the start of the green, the upper limit of green time for the current cycle (cycle *k*), the equivalent value for the previous cycle, the "desired discharge", the actual discharge for the previous cycle, the average density over the current cycle, the equivalent value for the previous cycle and the current figure for desired average density.

SCENARIO

Firstly the tactics will be simulated using NEMIS in an SERC sponsored project. Then the best tactics will be adapted for use in either SPOT or SCOOT and so could be tested on both field trial networks using the relevant interfaces.

REFERENCES:

Shepherd S.P. (1991)
Shepherd S.P. (1993)
Papageorgiou, M. et. al. (1989)

POLICY : QUEUE MANAGEMENT

STRATEGY 5 : DOUBLE CYCLE TIMES AT CRITICAL JUNCTIONS

Description

At critical junctions, there is an advantage in having cycle times as long as possible because of high levels of saturation and, usually, many stages (phases). At upstream junctions, however, there may be benefits in having shorter cycle times because they lead to shorter queues and reduce pedestrian delay. In such cases, using double the cycle time at the critical junction compared with other nearby junctions should give good progression. Put another way, the cycle time at upstream junctions is halved.

Objectives

i) reduce total travel time.
ii) reduce pollution due to idling vehicles.

TACTIC: DOUBLE CYCLE TIMES

Firstly, it has to be established whether a double cycle time is feasible at the critical junction. The double cycle time must not lead, for example, to a great increase in pedestrian disobedience. Then the timing plans for SCOOT or SPOT must be recalculated. If there are extensive queues, the upstream junction on a congested approach may also need to operate on double cycle time.

SCENARIO

Can be implemented at both sites. Will be simulated as before and after situations. Minimum and maximum stage lengths will still apply.

REFERENCES

May, A.D. et. al. (1988)
May, A.D. (1991)

NOTES

Can be achieved with SCOOT 2.3 and 2.4. Could lead to accidents as impatient drivers try to make right turns into gaps which are too small.

POLICY : QUEUE MANAGEMENT

STRATEGY 6 : STARTING AND STOPPING WAVES AND SIGNAL CONTROL

Description

A stopping wave travels back from the downstream (critical) junction to reach the upstream junction. A starting wave also travels back to the upstream junction. This strategy addresses the situation where the starting wave reaches the upstream junction after the stopping wave. The strategy requires offsets between the junctions to be adjusted so that a green signal is given at the upstream junction during the time that the stopping wave is ahead of the starting wave.

Objectives

i) to reduce the likelihood of queues blocking upstream junctions.
ii) to maintain capacity at upstream junctions.
iii) to minimise total travel time in the network.

TACTIC: ADJUST OFFSETS FOR QUEUE MANAGEMENT

The signal timings at the upstream junction are determined by the start of green at the downstream junction, and the time taken for the front of the queue to move upstream and clear the upstream intersection. Once the vehicles blocking the upstream junction begin to move, green is given there to cross traffic.

SCENARIO

Can be implemented at both sites. Will be simulated as before and after situations.

REFERENCES

May, A.D. et. al. (1988)
Quinn, D. (1992)

NOTES

This can only be done with SCOOT.

POLICY : QUEUE MANAGEMENT

STRATEGY 7 : EXTERNAL METERING

Description

Measures can be taken to meter or restrict traffic input to the critical link of the congested arterial. In this way, it is hoped that demand will be reduced so that congestion either does not happen or will be short lived.

Objective

Minimise total travel time in the network where the network includes the approaches to the boundary and any links onto which there may be diversion.

TACTIC: EXTERNAL METERING

Metering will take place at the ends of the congested arterial, by restricting the through or cross-street green times to enter it. Bus lanes will have to bypass the metering.

SCENARIO

Can be implemented at both sites. The approaches to the ends of the arterial will be included and the simulation must model the queue length on these approaches.

REFERENCE

Quinn, D. (1992)

NOTES

SATURN model might help with reassignment. Might be implemented by introducing a bus lane.

POLICY : QUEUE MANAGEMENT

STRATEGY 8 : VARIABLE MESSAGE SIGNS

Description

In association with Strategy 12, driver information systems can be used to suggest alternative routes and possibly divert drivers around congestion. In the near future, in the absence of route-guidance information within motor vehicles, variable message signs represent a way of communicating with motorists. Radio messages are another way.

Objective

Minimise total travel time within the network which now includes all links approaching the original congested arterial and those links which may receive diverted traffic.

TACTIC: VARIABLE MESSAGE SIGNS WITH EXTERNAL METERING

With metering at the ends of the congested arterial, places for variable message signs will be specified before the approaches to the ends of the congested arterial. The proportion of motorists responding to a sign and who would benefit must be estimated. The proportion is affected by whether the congestion is aggravated by an incident (breakdown or accident) and the effectiveness of radio communication.

SCENARIO

Can be implemented at both sites. Will be simulated as before and after situations.

REFERENCES

Quinn, D. (1992)

NOTES

It is being looked at for the Inner Ring Road in Leeds. Might be just one or two signs to divert traffic at the ends. Radio broadcasts are already used to inform drivers of road conditions and people take more notice of them. It might be too expensive to implement.

POLICY : QUEUE MANAGEMENT

STRATEGY 9 : SHORTER CYCLE TIMES FOR CONGESTION RECOVERY

Description

Once the demand to travel on the congested arterial eases, steps should then be taken to restore the network to its uncongested state.

Objective

Minimise total travel time in the expanded network.

TACTIC: SHORTER CYCLE TIMES

A short cycle time has three advantages, saturation flow is more likely to be able to be maintained during green periods, turning traffic can be cleared from junctions and pedestrians have less delay. Therefore, shorter cycle times can be used during the period of queue clearance, with reversion to the normal cycle time after the queues have cleared.

SCENARIO

Can be implemented at both sites. Will be simulated as before and after situations over the expanded network.

REFERENCE

Quinn, D. (1992)

NOTES

SCOOT does not respond quickly enough. It could be implemented using SCOOT, but it would not be automatic.

POLICY : QUEUE MANAGEMENT

STRATEGY 10 : IDENTIFICATION OF LINKS FOR QUEUE STORAGE

Description

One or more junctions have been identified as critical, and one of the approaches to these junctions will also be critical in that each needs to store a queue. Once the queue reaches the upstream junction, further increase should be prevented by storing any additional demand on adjoining links, known as gated links.

Objective

Minimise total travel time in the network.

TACTIC: FIND GATING LINKS

The critical junction and link have been identified. Now the link(s) which need to store any further demand need to be specified. They will be links whereby the storage of queued traffic will not create further environmental intrusion. Such links will also need to have sufficient length so that further gating links for the original gated links will not be required.

SCENARIO

Can be implemented at both sites. Will be simulated as before and after situations.

REFERENCES

Bretherton, R.D. and Bowen, G.T. (1990)
Quinn, D. (1992)
Shepherd, S.P. (1992)

NOTES

Cannot be done with SCOOT 2.3, however it is possible with SCOOT 2.4. (It is already being done in York). However, TRL need to be informed if you intend to use any form of gating. It could be used to deter rat runs by storing vehicles on the side roads. It needs 150% saturation before being implemented.

POLICY : QUEUE MANAGEMENT

STRATEGY 11 : RESTRICT TURNING INTO CONGESTED ARTERIAL

Description

At an upstream junction, the opportunity to turn into a congested arterial road from a cross street should be restricted by limiting the amount of green time permitting such movements.

Objectives

(i) to maintain a reasonable capacity for the through movement on a congested arterial.
(ii) to prevent drivers from using alternative routes to reach the congested arterial.

TACTIC: ADJUSTMENT OF GREEN TIME SPLIT AT JUNCTIONS

The field sites will be inspected to determine which junctions are likely to have queues still blocking back after applying strategy 1 above. The immediate upstream junctions from these will then be considered for an adjustment of green split with a view to restricting the cross-street green, at least for any movements which turn into the congested arterial.

SCENARIO

Can be implemented at both field trial sites. Will then be simulated as before and after situations.

REFERENCES

Quinn, D. (1992)
Pignataro, L.J. et. al. (1978)

NOTES

Is achievable with SCOOT 2.3 if a predetermined congestion period is known.

POLICY : QUEUE MANAGEMENT

STRATEGY 12 : QUEUE STORAGE

Description

The queue length at critical junctions should be as short as possible. This is achieved by having vehicles stored at 'jam' densities, in as many lanes as possible.

Objective

i) to reduce the likelihood of queues blocking back to upstream junctions.
ii) to maintain capacity at upstream junctions.
iii) to minimise total travel time in the network.

TACTIC: QUEUE STORAGE TO USE MINIMUM ROAD SPACE

Queue length is at a minimum at jam density. Therefore the main flow of vehicles from the upstream junction should join the queue just as the back of it starts to move. In this way, the probability of having to stop more than once on an approach is reduced. Further, the queue length is a minimum if it is stored in as many lanes as possible. If there is a lane added to accommodate a queue, there must be no decrease in the capacity of the critical junction. This may necessitate adding a lane downstream from the critical junction.

SCENARIO

Can be implemented at both sites. Will be simulated as before and after situations.

REFERENCES

May, A.D. et. al. (1988)

NOTES

The longer the link the less the problem.

POLICY : QUEUE MANAGEMENT

STRATEGY 13 : TIDAL FLOW

Description

An arterial road can sometimes operate with tidal flow, that is, the line separating opposing directions of flow on the arterial can be shifted across by one or more lanes to suit flows at different times of the day. An indication to motorists is usually given by overhead gantry-mounted signals but manually placed dividers have been used in some cases.

Objectives

Maximise the capacity of the junctions on the arterial road.

TACTIC : DETERMINE TIMES TO SWITCH REVERSIBLE LANES

The Leeds field site has two critical junctions, Dewsbury Road and Garnet Road, and Dewsbury Road and Tunstall Road. Dewsbury Road could be marked with three lanes between the two junctions. The Gran Madre bridge site in Turin could also have three lanes. In off-peak periods, the centre lane of the Leeds site could operate with two-way right turns. Detector information requires development so that the optimum time to change from off-peak to peak conditions and vice versa can be determined.

SCENARIO

Simulation can be used to test the schemes. Later, they can be implemented as described. Dividers may have to be placed manually until the success of the scheme can be demonstrated.

REFERENCE

DRIVE 1992.

POLICY : QUEUE MANAGEMENT

STRATEGY 14 : FLARED GREEN TIMES IN NETWORKS

Description

In cases of networks, where progression on a congested arterial is not the only consideration, a case can be made to flare green times on cross streets in the direction of the greater flow on them.

Objective

Minimise total travel time in the network.

TACTIC: FLARE GREEN TIMES ON CROSS STREETS

The arterial progression should have offsets to suit stopping and starting waves when there is congestion. For the cross streets, it has been shown that there should be negative offsets in the direction of the greater flow with flaring of green times in this direction.

SCENARIO

Not suitable for implementation in Leeds but possible for Turin. The reason is that the cross streets in Leeds are not well defined and do not have progression.

REFERENCES

Quinn, D. (1992)
Rathi, A.K. (1988)

POLICY : QUEUE MANAGEMENT

STRATEGY 15 : HORIZONTAL QUEUE MODEL

Description

This strategy improves the model within the UTC system so that queue lengths of traffic are estimated accurately. As well as improving the overall performance of the UTC system this will also allow strategies such as the auto-gating strategy, to be implemented as they need an accurate estimate of the amount of space available on each link to store queues.

An important parameter that has to be taken into account in the management of saturated and over-saturated conditions is the occupancy of the approaches. In these conditions vehicles queuing on an approach often reach the upstream intersection blocking it and reducing its efficiency.

To help avoid blocking back a new model has been developed to supply an estimate of the position of the last vehicle in the queue (the horizontal queue). The aim of this model is to relate the horizontal queue evolution with data already available from the vertical queue model (vertical queue, elapsed green time, arrivals profile).

As an example of how this could work consider a simple case where two intersections are controlled by SPOT units (an upstream junction U and a downstream junction D)

The strategy that will be used is that at each control step:

> once its optimal signal setting has been decided, D evaluates the horizontal queue on all its incoming links
>
> the horizontal queue length is transmitted to U
>
> the received queue length is used by U to evaluate the evolution of the link occupancy according to different signal policies
>
> a term is added to the SPOT cost function to penalise policies whose release of traffic into the link make the horizontal queue exceed the storage capacity of the downstream link

This strategy should protect junction U from blocking back phenomena as well as reacting quickly to transient saturation, such as that produced by disruption following PT priority.

Objective

To improve the estimated queue length model so that measures can be taken to avoid blocking back.

TACTIC: IMPROVE SYSTEM MODEL

SCENARIO

This can only be implemented in SPOT. It will be tested in both Leeds and Turin.

REFERENCES

Lanteri, F. et. al. (1993)

POLICY : PUBLIC TRANSPORT PRIORITY

STRATEGY 101 : CO-ORDINATE SIGNALS FOR BUSES

Description

The progression of buses through a series of signal-controlled junctions is quite different from that of other vehicles. This is because buses usually have to stop at one or more places along a co-ordinated arterial. If there are sufficient buses and passengers in them, the co-ordination plan can take account of bus progression as well as that of other vehicles.

Objective

Minimise the total person travel time on the co-ordinated arterial.

TACTIC: CO-ORDINATE SIGNAL PROGRESSION FOR BUSES

A field study will determine the length of arterial road to have co-ordinated signal operation. The proportion of people in buses will have to be significant, and can be expected to vary during the course of a day.

SCENARIO

Can be implemented at both sites. With the bus stop positions already optimised, there may be bus stops which are alternately upstream and downstream from junctions. Will be simulated to determine the saving in total person travel time before and after the signal co-ordination to favour buses.

REFERENCE

Lanteri, F. (1992)

NOTES

Buses turn onto and off the Dewsbury Road as well as travelling along it. This was already implemented in Turin in 1985 as part of Utopia.

POLICY : PUBLIC TRANSPORT PRIORITY

STRATEGY 102 : PRIORITY TO BUSES AT SIGNALS

Description

Junction delay should be minimised and junction capacity should be maximised, but in such a way that account is taken of the presence of buses and their passengers and the need to stop near junctions. A critical junction will be signal-controlled, so priority can be given to buses by extending the green period or by returning to green for buses as soon as possible.

Objective

Minimise the total person travel time through critical junctions.

TACTIC: REDUCE BUS DELAY AT THE CRITICAL JUNCTIONS

Examine in the field, the critical junctions, and determine a suitable method of detecting buses and allowing for them in the timing plan.

SCENARIO

Can be implemented at both sites using existing fleet management system in Turin, and new TIRIS transponders in Leeds. A calculation of the total person delay before and after bus priority is suggested.

REFERENCE

Lanteri, F. (1992)

NOTES

All the bus operators in Leeds have agreed to equip their entire bus fleet with TIRIS transponders and the city council have committed expenditure to install the required inductive loop detectors and communication links.

TIRIS (Texas Instruments Registration and Identification System) is a radio frequency identification system based on low frequency FM transmission techniques. The core of the system is a small transponder or tag which can be attached or embedded in an object. To interrogate the tag a reader sends out a 134kHz power burst to the transponder via an antenna. The power burst charges up the passive (battery free) transponder in about 50 milliseconds. The transponder returns a signal that carries the data that is stored, as a unique 128 bit identifier, within it. The total cycle lasts about 120 milliseconds. The data collected from the transponder can be sent directly to a host computer through standard interfaces. This system works effectively in environments with excessive dirt, dust, moisture and poor visibility. The unit cost of the TIRIS transponders that will be used as bus detectors is approximately 20 ECU. This compares with a cost in excess of 100 ECU for conventional transponders such as those being used in other DRIVE II projects. With a suitable antenna in the road, the TIRIS system has performed successfully at read speeds of 65 m/s (234 km/h).

An automatic vehicle detection system was implemented in Turin in 1985 as part of Utopia.

POLICY : PUBLIC TRANSPORT PRIORITY

STRATEGY 103 : STOP BLOCKING OF BUS STOPS BY QUEUES

Description

The currently implemented SPOT PT priority features do not take into account possible saturation of the approaches, being designed to work best in low-medium traffic demand. In Turin, the bus stops are placed in the neighbourhood of intersections, so the status of the approach can effect the regularity of the service and introduce perturbations to the local SPOT control. When congestion problems occur the PT vehicle is delayed by the congestion and can fail to get priority when it arrives at the stop line. A strategy has been devised to protect the bus stop from excessive queues, clearing the approach at least to the bus stop position. This should guarantee that the bus conforms to the forecast travel time. The delay to the bus introduced by the queue is also reduced resulting in an increase in commercial speed.

Objective

To protect bus stops from excessive queues.

TACTIC:

When a bus is detected by the SIS system the local controller modifies the maximum queue threshold assigned to the approach. The control module is then forced to introduce a strong (though transient) limitation to the queues on the approach and the bus is expected to travel without delay to the bus stop.

SCENARIO

Can only be implemented in Turin as the vehicle detection method used in Leeds cannot probably provide arrival forecasts of sufficient accuracy.

REFERENCE

Lanteri, F. (1992)
Lanteri, F. et. al. (1993)

NOTES

POLICY : TRAFFIC CALMING

STRATEGY 201 : LINKED TRAFFIC SIGNALS

Description

In an area where signalised junctions are relatively close together, they will be linked by an traffic signal control plan such as SCOOT or SPOT. Such a plan can be designed for a speed of progression equal to or less than the speed limit for the road. In traffic calming, there is an opportunity to set a progression speed lower than the speed limit, with a degree of automatic enforcement when faster vehicles arrive too early at downstream junctions for the green signal. In Australia, there have been experiments to show motorists the correct progression speed by means of a display above the road.

Objective

i) To reduce the variance of speeds on the arterial.
ii) To achieve a design mean speed related to the speed of progression.

TACTIC: DETERMINE A SUITABLE SPEED FOR SIGNAL LINKING

If a speed to link signals on an arterial road is too low, drivers may take other less suitable routes, and if it is too high, they may endanger other road users. As a first try, a linked speed of the speed limit should be studied.

SCENARIO

Can be implemented at both sites. In Leeds there is a speed limit change from 40 mph to 30 mph on the study site. Simulation should be tried first for a progression speed of the speed limit and the mean and variance measured. The exercise should be repeated for a progression speed set at 5mph (Leeds on the faster section) or 10 km/h (Turin) less than the speed limit. The 30 mph section will retain the same progression speed throughout.

REFERENCE

Harvey, T. (1992) p. 8.
Lanteri, F. et. al. (1993)

NOTES

The links on the Dewsbury Road might be too far apart for this strategy to be effective. Studies indicate that 250m is the maximum effective separation. On the Dewsbury Road four of the nine sets of signals are more than 250m apart. The strategy would be most effective on the stretch between Garnet Road and Burton Avenue as the signals are close enough together there. It might be possible to try and reduce the speed on the 40mph section down to 35 or 30mph.

POLICY : TRAFFIC CALMING

STRATEGY 202 : FORCING SPEEDS TO BEST VALUES FOR PLATOON FORMATION

Description

Traffic calming measures are used to get the traffic to flow at speeds required to produce platoons of vehicles that flow freely along the entire length of the arterial. By controlling the timing of the release of the platoons, via traffic signals, from either end of the section of arterial, gaps can be created that provide pedestrians with safe opportunities for crossing the road. Traffic calming measures are used to ensure that the platoons do not travel at excessive speeds and to control dispersion. Refer also to strategy 7.

Objectives

i) To produce free flowing platoons of vehicles that experience a minimum of delay
ii) To improve safety for pedestrians who wish to cross the road
iii) Reduced road widths can be used to either increase pavement widths, provide parking bays or cycle lanes

TACTIC :

Can be implemented using speed tables, electronic enforcement, road markings, or roundabouts.

SCENARIO :

Can be implemented at both Leeds and Turin field trial sites. In Leeds a VMS system will warn the drivers if their speed is excessive. If they fail to slow down then a speed enforcement camera will photograph the vehicle licence plate and the driver will be prosecuted. In Turin, a system of traffic signals will advise drivers of the best speed as recommended by the SPOT units. A futuristic system that lets the SPOT system control the vehicle speeds via a communications link and automatic vehicle speed control will also be simulated to assess its utility.

Both NEMIS and the ITS Graphical Model need to be modified to simulate these strategies.

REFERENCES:

Hopkinson, P. J. et. al., (1989)
Baker, M. et. al. (1991)

POLICY : TRAFFIC CALMING

STRATEGY 203 : SIGNALISED PEDESTRIAN CROSSINGS

Description

Signalised pedestrian crossings are used to give pedestrians priority over motor vehicles. When part of traffic calming, they should be installed where the pedestrian numbers are sufficient. A green signal for pedestrians should be given to suit vehicle progression, but in such a way that long pedestrian waiting times for green do not induce large numbers of pedestrians to run across without the green signal.

Objective

i) to reduce vehicle stops.
ii) to reduce vehicle delay.
iii) to reduce pedestrian delay.

TACTIC: SIGNALISED PEDESTRIAN CROSSINGS - LOCATION AND SIGNAL TIMING

A field study is required to check pedestrian crossing and vehicle counts during various times of a typical day. Signals mid-block can be expected to be justified only if there is a significant generator of pedestrian trips, such as a school or shopping centre. Other pedestrian signals can be combined with vehicular signals at junctions. The timing plans for SCOOT or SPOT should then be designed so the maximum pedestrian waiting time does not exceed a pre-set value.

SCENARIO

Can be implemented at both sites, although pedestrian waiting behaviour is likely to differ. Simulation will be as before and after situations.

REFERENCE

Harvey, T. (1992) p.8.

NOTES

Pedestrian crossings are often where they are for historical reasons. There might be justification for removing some crossings because they are no longer used much. However there is often a lot of opposition from the local community when such a scheme is proposed.

Pelican crossings can also reduce the inter-signal gap, thus improving signal based calming.

POLICY : QUEUE MANAGEMENT

ENVIRONMENT 1001 : SEPARATE STAGE (PHASE) FOR TURNING TRAFFIC

Description

Strategy 3 will provide separate lanes for turning traffic. The question then is whether to provide a separate stage for this traffic at signals at critical junctions in order to increase capacity.

Objective

As in strategy 3, the objective here is to try to reduce the junction degree of saturation, by providing a separate stage for turning traffic.

TACTIC: MAXIMISE CAPACITY WITH A SEPARATE STAGE FOR TURNING TRAFFIC

The timing plans at critical junctions will be reviewed to determine whether there would be any benefit from adding a separate stage for turning traffic.

SCENARIO

Can be implemented at both field sites. Will then be simulated as an additional strategy on top of Strategy 3. Again the objective for evaluation should be whether there is a further reduction in total travel time in the network.

REFERENCE

Akcelik, R. (1981)

POLICY : QUEUE MANAGEMENT

ENVIRONMENT 1002 : MAXIMISE SIGNALISED JUNCTION CAPACITY

Description

Maximising the capacity of individual signalised junctions (intersections) reduces the road space required to store queues and therefore there is less likelihood of blocking back. The techniques available to do this are:

(i) mark as many lanes as possible both upstream and downstream of the junction;
(ii) restrict pedestrian stages (phases) so they do not control the capacity;
(iii) restrict parking and loading upstream and downstream;
(iv) provide slip lanes on approaches;
(v) move bus stops from upstream to downstream or vice versa as appropriate.

Objectives

(i) maximise the capacity of a movement.
(ii) ensure, wherever possible, that vehicular movements form the stages determining junction capacity.
(iii) achieve full lane utilisation.
(iv) remove, if possible, left turn movements from the set of movements determining capacity.
(v) place bus stops in the better location to retain maximum junction capacity.

TACTIC: MAXIMISE CAPACITY BY FIELD INSPECTION

The field sites will be inspected to determine which junctions are critical. These are the ones which have the greatest intersection degree of saturation. Their identification should come from journey time surveys and junction counts. A field inspection will then determine which measures as above will be effective.

SCENARIO

Can be implemented at both field trial sites. Will then be simulated as before and after situations.

REFERENCES

Quinn, D.J. (1992)
Akcelik, R. (1981)

NOTES

Already done in Leeds. It could be significant. Might be a slight disbenefit to commercial vehicles. Extra lanes increases driver/pedestrian stress. Less stopping reduces driver stress.

POLICY : QUEUE MANAGEMENT

ENVIRONMENT 1003 : TURN BANS

Description

Prohibitions on turning vehicles should be considered both at a critical junction, to increase capacity there, and at an upstream junction, so that the cross-stream through movement is not unduly restricted.

Objective

(i) To increase the capacity of critical junctions by banning certain turning movements.
(ii) To reduce total travel time in the network.
(iii) To minimise environmental intrusion.

TACTIC: TURN BANS AT CRITICAL JUNCTIONS

The timing plans at critical junctions will be reviewed to determine whether there would be any increase in capacity by prohibiting certain turning movements. Some drivers will take a new route so the capacity at other junctions to where there has been diversion will be checked. Any such diversion should not be into environmentally-sensitive streets.

SCENARIO

Can be implemented at both field sites. Will be simulated as before and after situations.

REFERENCES

Pignataro et. al. (1978)

NOTES

This is being investigated in Leeds. There is a problem at the Dewsbury Road/Tunstall Road junction with pedestrians being involved in accidents. These accidents might be reduced if a right turn ban was introduced.

POLICY : QUEUE MANAGEMENT

ENVIRONMENT 1004 : SEPARATE TURNING LANES AT CRITICAL JUNCTIONS

Description

Environment component 1002 will provide as many lanes as possible at critical junctions. In this strategy, the turning movements permitted in a lane will be reviewed to try to increase capacity.

Objective

A critical junction will have a sequence of critical movements. The objective of this strategy is to try to reduce the degree of saturation of any of these movements by using particular lanes for turning so that the degree of saturation of such a movement is reduced and hence the degree of saturation of the junction as a whole.

TACTIC: MAXIMISE CAPACITY BY USING SEPARATE TURNING LANES

The field sites have been inspected to determine which junctions were critical. The timing plans at these and immediate upstream junctions of congested links will be reviewed to find whether there would be any benefit from designating new turning lanes.

SCENARIO

Can be implemented at both field sites. Will then be simulated as before and after situations. The objective for evaluation should be to minimise total travel time in the network.

REFERENCES

Akcelik, R. (1981)

NOTES

Already being considered in Leeds. However there is not enough room in some cases.

POLICY : PUBLIC TRANSPORT PRIORITY

ENVIRONMENT 1101 : INCREASE BUS STOP SPACING

Description

The spacing between bus stops should be sufficient for buses to accelerate to a normal cruising speed before having to decelerate for the next stop. Bus journey times are actually a minimum with the maximum spacing, but if this spacing is too great, passengers will abandon the bus service for another form of transport or not travel at all. Spacings of 0.5 km are a reasonable standard, but many urban services operate with smaller spacings. This strategy will consider whether the spacing is too small, and the benefits if it were greater.

Objectives

i) minimise total travel time for passengers.
ii) maximise passenger numbers.

TACTIC: OPTIMISE BUS STOP SPACING

A field study should firstly determine which bus stops are lightly used. Then which of these if any could be combined without losing riders needs to be found.

SCENARIO

Can be implemented at both sites. The before and after situations will be simulated.

REFERENCES

Lanteri, F. (1992)
Giannopoulos, G.A. (1989).

NOTES

Typical spacing for bus stops in Dewsbury Road is 0.4 km.

POLICY : PUBLIC TRANSPORT PRIORITY

ENVIRONMENT 1102 : REDUCE TIME SPENT AT BUS STOPS

Description

The time spent by buses at bus stops may include boarding passengers waiting for other passengers to alight, and then boarding, passing a driver and either showing a prepaid ticket, which may need to be cancelled, or paying cash and receiving change. In this strategy, boarding should commence as soon as the bus stops by having an entrance separate from the exit. More prepaid tickets will also speed up the process.

Objective

Minimise the total person travel time in buses.

TACTIC: REDUCE THE TIME SPENT AT BUS STOPS

Field surveys will reveal the proportion of time spent by a bus at a bus stop and the proportion spent while waiting in traffic. The former is often a high percentage (25%) of the time stopped. In particular, The extent that boarding passengers wait for alighting passengers is required. If significant, it is hard to imagine an operator physically altering every single bus in the fleet. To induce the sale of more prepaid tickets will require a marketing effort through a discount for their purchase, so this will be a cost to be considered in the evaluation of this strategy.

SCENARIO

Can be implemented at both sites, although the ticketing methods are quite different. The simulation is required between the present situation and an improved process, where alighting does not delay boarding and average boarding times are reduced to a new lower value.

REFERENCE

Giannopoulos, G.A. (1989)
Pretty, R. L. and Russell, D.J. (1988)

NOTES

All Yorkshire Rider dual door buses will be removed by the end of the year. Estimated that 30-40% of passengers use prepaid tickets during the peak period.

POLICY : PUBLIC TRANSPORT PRIORITY

ENVIRONMENT 1103 : CREATE BUS LAYBYS

Description

Laybys at bus stops enable other buses and other traffic to overtake a stopping bus. Most drivers of vehicles other than buses recognise the need to give way to a bus leaving a bus stop. Laybys should be created wherever there is sufficient verge width.

Objective

Minimise total person travel time on the arterial road.

TACTIC: CREATE LAYBYS ON THE ARTERIAL ROAD

A field inspection will show where any laybys can be created. There will need to be sufficient footway remaining for pedestrian traffic.

SCENARIO

Can be implemented at both sites. The simulation will be on a before and after basis for the introduction of the maximum number of laybys.

REFERENCE

Lanteri, F. (1992)

NOTES

Buses can have problems getting out of laybys in Leeds. Yorkshire Rider claim it is a big problem, Yorkshire Buses claim it is no problem. There is an inverse layby that projects out into the road in Halifax.

POLICY : PUBLIC TRANSPORT PRIORITY

ENVIRONMENT 1104 : BUS STOPS UPSTREAM OR DOWNSTREAM FROM JUNCTIONS

Description

In most urban areas, bus stops are generally located close to junctions in order to maximise passenger accessibility. The question to be decided is whether they should be downstream or upstream from the junction.

Objectives

i) reduce total travel time, including stops, for buses and passengers.
ii) minimise interchange walking time for passengers.
iii) minimise conflicts with other traffic.

TACTIC: BUS STOP LOCATION NEAR JUNCTIONS

Bus stops should generally be close to junctions unless there is a major generator of bus trips away from a junction, e.g. school or shopping centre. The arguments for locating stops upstream or downstream include:

i) upstream so buses can be loading or unloading while waiting for a green signal;
ii) downstream so buses are not delayed in reaching a bus stop by queuing traffic;
iii) downstream so buses at bus stops do not reduce the capacity of an intersection approach;
iv) downstream so bus detectors upstream from junctions are not upstream from bus stops;
iv) alternating upstream and downstream to aid bus progression through linked signals;
v) near the same corner as a cross-street bus stop.

This study will look at all bus stop locations near junctions. The locations will be inspected in the field first to check for a constraint on upstream or downstream.

SCENARIO

Can be implemented at both sites. To find the best locations, it will probably be easiest to optimise individual locations first and then try to find the overall set of optimum locations. The simulation will be on a before and after basis.

REFERENCES

Lanteri, F. (1992)
Giannopoulos, G.A. (1989)

NOTES

It is very hard to move bus stops, due to public opposition. Can get red waves for buses by having stops just before the lights.

POLICY : PUBLIC TRANSPORT PRIORITY

ENVIRONMENT 1105 : WITH-FLOW BUS LANES

Description

In designing with-flow bus lanes, consideration needs to be given to whether there are sufficient buses to justify setting aside a lane for their use. If not, could the lane be shared with other vehicles? Taxis, cars with ride sharing or goods vehicles are the most common selected for sharing. If taxis and high-occupancy vehicles are selected, what occupancy is required to enter the lane?

Objective

Minimise total person travel time on the arterial road.

TACTIC: DESIGN OF WITH-FLOW BUS LANES

A classified traffic count including the distribution of occupancies of cars by time of day is required. A field inspection is needed to find any possible lengths of road which may suit a bus lane. There need to be more than two lanes available in a direction of travel being considered. From a base case of no bus lane, the other possibilities to be considered in order are a bus lane, a bus and taxi lane, a transit lane for buses, taxis and vehicles with three or more occupants, and a transit lane for buses, taxis and vehicles with two or more occupants. A lane for buses and goods vehicles could also be considered. For all cases except the bus lane, there must be a layby at all bus stops. The bus lane may be justifiable to operate on a part-time basis, so the hours must be decided.

SCENARIO

Can be implemented at both sites. The enforcement of the transit lane must be considered so that there will be a degree of disobedience and also some eligible vehicles will be in normal lanes. A before and after simulation is required.

REFERENCES

Lanteri, F. (1992)

POLICY : PUBLIC TRANSPORT PRIORITY

ENVIRONMENT 1106 : INFORMATION AT BUS STOPS

Description

Prospective bus passengers require information about which is the correct bus for their trip, when does it leave the bus stop, and what is the fare. Some bus stops give no more information than the presence of a post signed 'BUS STOP.' Others stops have a timetable attached, possibly with a description in words or with a diagram of the route(s) to be followed. It would also be useful to have the name of the stop displayed.

A very few may even give a simplified list of the fare(s) required, urging passengers to have the correct fare ready. In this strategy, more information is to be given with a view to reducing the time spent at bus stops.

Objective

(i) Minimise the time spent by buses at bus stops.
(ii) Minimise the total person travel time of buses.
(iii) Minimise the total person travel time on the arterial.

TACTIC: INCREASE THE INFORMATION AT BUS STOPS

Field surveys will show what information is presently available at bus stops. Surveys can also show the average time spent by passengers boarding, and this can be compared with other locations where more or different information is supplied.

SCENARIO

Can be implemented at both sites, although there will presently be very different systems of information. In Leeds, most stops give only the services passing; if a timetable is given the places passed are described in words, whereas a diagram would be easier to understand especially for strangers. Fare information is not given. Simulation will be required between the present situation and an improved system of information.

REFERENCE

Giannopoulos, G.A. (1989)

NOTES

There is quite a lot of work going on in other DRIVE projects to provide real time information at bus stops.

POLICY : PUBLIC TRANSPORT PRIORITY

ENVIRONMENT 1107 : BUS LANE WIDTH

Description

It is often the case that cyclists are allowed to share a bus lane. Because of an inherent incompatibility, bus lanes are wider than necessary without the sharing. Cyclists can be catered for under other strategies, so this strategy reduces the width of any bus lane to no more than 3.5 m.

Objective

To maximise the saturation flow of an approach to a junction.

TACTIC: REDUCE BUS LANE WIDTHS

Reduce the width of existing and possible bus lanes to a width of 3.5 m and reallocate the road space to achieve maximum saturation flow.

SCENARIO

Can be implemented at Leeds. A theoretical calculation on a before and after basis should be sufficient.

REFERENCE

Lanteri, F. (1992)

NOTES

Generally agreed that you cycles and buses should not be in the same lane.

POLICY : PUBLIC TRANSPORT PRIORITY

ENVIRONMENT 1108 : ZERO BUS LANE SET-BACK

Description

With-flow bus lanes are normally set-back (terminated) at some distance before a critical junction, so that there is no loss of capacity at the junction. The amount of set-back needs to be determined.

Objective

Maximise the approach capacity at critical junctions.

TACTIC: DETERMINE THE SET-BACK OF BUS LANES

Any bus lane will probably need a set-back before a critical junction. The amount of set-back will be determined. If the bus lane continues through other junctions, these must be examined to ensure they have not become critical because of the loss of a lane to buses. In that case further set-back(s) will be necessary.

SCENARIO

Can be implemented at both sites. A set of trial-and-error calculations by simulation will probably be satisfactory to find the optimum set-back(s). If a bus lane has a set-back before a junction and resumes just after it, the kerb lane after the set-back must be marked to allow only left-turning vehicles to use it.

REFERENCE

Lanteri, F. (1992)

NOTES

The DoT recommendations should be looked at.

POLICY : PUBLIC TRANSPORT PRIORITY

ENVIRONMENT 1109 : FORM BUS CONVOYS

Description

A group of buses stops simultaneously at a bus stop and departs together in a convoy.

Objective

Minimise total person travel time on the arterial road.

TACTIC: BUS CONVOYS FOR THE ARTERIAL ROAD

Buses can be divided into groups to serve different general destinations. The bus stops are similarly divided into correspondingly defined positions.

SCENARIO

Can be implemented at both sites. Some bus stops in Leeds already have designated bus services which may stop there. The groupings of services should be reviewed, and then a simulation carried out on a before and after basis.

REFERENCE

Lanteri, F. (1992)

NOTES

De-regulation of bus services in Leeds means that all the different bus companies would want to have the lead bus in the convoy. They would also have to co-operate with one another. This is unrealistic.

POLICY : TRAFFIC CALMING

ENVIRONMENT 1201 : BICYCLE ROUTES

Description

Cycling should be removed from the through carriageways of arterial roads. Frequently, cyclists are placed with buses in bus lanes, but this is hardly a situation of calmed traffic. Rather, cyclists should be on service roads, on bicycle ways, in bicycle lanes or on alternative routes.

Objective

To reduce the use by cyclists of through carriageways on arterial roads without reducing the amount of cycling in the urban area.

TACTIC: FIND NEW ROUTES FOR CYCLISTS

Firstly, the amount of cycling on the arterial road should be found by survey. Then a set of appropriate alternative routes should be found, as listed above.

SCENARIO

Can be implemented at both sites. The effectiveness of the treatment should be measured by stated preference survey for route choice of present cyclists, and the results used to assess the benefits in terms of reduced accidents involving bicycles, and travel time savings for cyclists.

REFERENCE

Harvey, T. (1992)
Proctor, S. (1991)

POLICY : TRAFFIC CALMING

ENVIRONMENT 1202 : PREVENTING RAT-RUNS OFF THE ARTERIAL

Description

Traffic calming measures are used to make rat-running off the arterial less attractive.

Objectives

i) To improve safety for drivers and pedestrians in the streets around the arterial.
ii) To reduce pollution
iii) To improve the environment of the streets around the arterial.

TACTIC :

Ramps are added to entrances of all side roads to reduce the speed of turning vehicles and provide a level crossing facility for pedestrians.

SCENARIO :

Can be implemented at both Leeds and Turin field trial sites.
Both NEMIS and the ITS Graphical Model need to be modified to simulate.

REFERENCES:

Baker, M., Pharoah, T., Shapley, G. and Taylor, D. (1991)

POLICY : TRAFFIC CALMING

ENVIRONMENT 1203 : PLANTING

Description

Planting of trees and shrubs in the median and beside the carriageways is a measure primarily to beautify the landscape. However, the measure has been used for traffic calming and is the principal purpose in this instance.

Objective

To reduce vehicle speeds, both the mean and variance.

TACTIC: PLANT TREES AND SHRUBS WITHIN THE ROAD RESERVATION

The areas where trees and shrubs could be planted must be determined by a survey, based on the requirements for moving traffic and parking already decided. Trees probably should not be planted in the median because they might represent a hazard but could be used at the roadside. Shrubs would be appropriate in both locations. Any planting also must not impede vision for drivers entering or crossing the road.

SCENARIO

Can be implemented at both sites. The evaluation will have to be based partly on anecdotal evidence from other locations such as Cologne, Germany, Eindhoven, The Netherlands, Rennes, France, and Wandsworth, England. In addition, short interviews of the stated preference type could be used.

REFERENCE

Harvey, T. (1992)

NOTES

This strategy is very difficult to evaluate. Very little work appears to have been done on what the effect on the effect of trees on driving behaviour.

POLICY : TRAFFIC CALMING

ENVIRONMENT 1204 : MEDIANS

Description

Continuous medians have advantages in traffic calming. They give pedestrians a refuge for crossing the road at any place. They prevent U-turns except at suitable places and allow only left (right in Turin) turn entry and exit to driveways and minor side streets. The arterial road is probably best thought of as having a continuous median with designated breaks rather than with a median only at points to provide specific pedestrian refuges.

The width of the median should in general be as wide as possible above a minimum of 1.2m.

Objective

To reduce vehicle stops.

TACTIC: DESIGNING A MEDIAN AND DECIDING THE PLACES FOR MEDIAN OPENINGS

An extensive field study is required to find the extent of crossing and the manoeuvre at present median openings. The width of median should be designed. The median openings should then be determined on the basis of minimising them. An analysis is then required of where the existing manoeuvres will be relocated.

SCENARIO

Can be implemented at both sites. Simulation will be as before and after situations.

REFERENCE

Harvey, T. (1992), p.8.

NOTES

This is difficult to achieve in Leeds as it would be unpopular with local residents. If there was a continuous median down the length of the Dewsbury Road, many residents would be unable to make right turns into their homes or nearby side streets.

POLICY : TRAFFIC CALMING

ENVIRONMENT 1205 : PARKING BAYS

Description

Away from approaches to junctions, there may be an opportunity to narrow the carriageway and insert parking and loading bays.

Objective

To reduce vehicle stopping.

TACTIC: RATIONALISE KERBSIDE PARKING AND LOADING

On most arterial roads with continuous lanes, the kerb lane away from junctions may not be needed to maintain the capacity of the road. Therefore it may be used for parking or loading. If possible any such parking bays should be indented, unless the parking is to be part-time in off-peak periods. The lane nearest the kerb will still be used for moving traffic, and will have vehicles in it carrying out parallel parking manoeuvres. This still represents less intrusion on the moving traffic, because otherwise two lanes are affected: the kerb lane for parking and the next lane for the manoeuvre. A field study is required to determine where the carriageway can be narrowed to provide parking and loading bays. The present demand for parking must be measured.

SCENARIO

Can be implemented at both sites. Simulation will be as before and after situations.

REFERENCE

Harvey, T. (1992), p.8.

NOTES

The Red Routes recently tried out in London could be described as a strategy involving parking bays as they banned parking on arterial roads and introduced extra parking bays off the main road. However, red routes are not a traffic calming scheme. The results coming out of the red route experiment do seem to indicate that as well as improved travel times, safety is also significantly improved.

POLICY : TRAFFIC CALMING

ENVIRONMENT 1206 : SERVICE ROADS

Description

A service road separates local from through traffic and so aids traffic calming. With a wide arterial road, it may be possible to construct service roads at least over part of the study area. Service roads may be one-way or two-way. To avoid most of the conflict at entrances and exits, one-way service roads will be considered throughout.

Objective

To increase the mean speed of traffic on the through carriageways.

TACTIC: ADD SERVICE ROADS

Examine the study area and decide if there is room anywhere for a service road. If there is room, there should be an expectation of a reasonable number of people wanting to start or end a motor vehicle trip on the service road. Such locations would include schools, shops, industrial sites and parks which encourage walking trips in them.

SCENARIO

Can be implemented at both sites. Simulation will be as before and after situations.

REFERENCE

Harvey, T. (1992)

NOTES

It would be impossible to build extra service roads in Leeds within the timescale of the project.

POLICY : TRAFFIC CALMING

ENVIRONMENT 1207 : INSTALL CUSHIONS AT PEDESTRIAN CROSSING POINTS

Description

Cushions are raised portions of carriageway with a flat top only extending over part of the carriageway. Buses would not have to travel over the raised pavement. Cushions are appropriate at pedestrian crossing points. The length of the cushion would be of the order of 4 m and the height about 100mm.

Objective

To reduce the speeds of motor vehicle traffic.

TACTIC: CUSHIONS AT PEDESTRIAN CROSSING POINTS

A principal source of conflict on arterial roads away from junctions is that between pedestrians and motor vehicles. In the absence of signals to give pedestrians priority, a good procedure is to slow the vehicles. Even with signals for pedestrians, it can be assumed that the signals will be operating in the flashing mode during part of the signal cycle. Buses will not be affected.

SCENARIO

Cannot at present be implemented in Leeds because the site is a principal road. Also, signals with a flashing operation are known only in Leeds. The speed reduction will have to be estimated from reports at other sites.

REFERENCE

Harvey, T. (1992)

NOTES

According to UK regulations it is illegal to install humps, cushions or plateaux on principal roads. The Dewsbury Road is a principal road, so this strategy cannot be used at this field trial site.

REFERENCES FOR APPENDIX A

Bretherton, R.D. and Bowen, G.T. (1990) *Recent enhancements to SCOOT - Version 2.4*, Third International Conf. on Road Traffic Control. IEE Conf. Publication 320, pp.95-98.

Akcelik, R. (1981) *Traffic Signals: Capacity and Timing Analysis*, Australian Road Research Board. Res. Rep. ARR No.123. 1981

Baker, M., Pharoah, T., Shapley, G. and Taylor, D. (1991) *Traffic Calming Guidelines*, Devon County Council.

Giannopoulos, G.A. (1989) *Bus Planning and Operation in Urban Areas*, London ,Avebury.

Harvey, T. (1992) *A Review of Traffic Calming Techniques.* Deliverable No.3, DRIVE II Project V2016 - PRIMAVERA.

Hopkinson, P. J. et. al., (1989) *Development of Traffic Calming in a heavily trafficked shopping street*, Traffic Engineering and Control p.482-486, October 1989.

Lanteri, F., Biora, F. and Shepherd, S.P. (1993), *Implementation Aspects Report*, Deliverable No. 8, DRIVE II Project V2016 - PRIMAVERA.

May, A.D. (1991) *Queue Management Project: Strategies for the Management of Queues at Upstream Junctions*, WP346, Institute for Transport Studies, University of Leeds.

May, A.D., Montgomery, F.O. and Quinn, D.J. (1988) *Control of Congestion in Highly Congested Networks*, Proc. CODATU IV Conference, Jakarta, June, 1988

Papageorgiou, M. et. al. (1989) *Modelling Real-Time Control of Traffic Flow on the Boulevard Peripherique in Paris*, IFAC Control, Computers, Communications in Transportation, Paris, pp.205-211.

Pretty, R. L. and Russell, D.J. (1988) *Bus boarding rates.* Aust.RdRes. 18(3), pp.145-52.

Proctor, S. (1991) *Accident reduction through area-wide traffic schemes*, Traff. Engng & Control, pp.566-573, December.

Quinn, D.J. *A Review of Queue Management Strategies.* Deliverable No.1, DRIVE II Project V2016 - PRIMAVERA.

Rathi, A.K. (1988) *A control scheme for high density traffic sectors*. Transpn Res.B, 22B(2), pp. 81-101.

Shepherd S.P (1991) *The Development of a Real-Time Control Strategy to Reduce Blocking-Back During Over-saturation Using The Micro-simulation Model NEMIS*, presented at the 24th ISATA Conference Florence, Italy 20-24th May 1991.

Shepherd, S.P. (1992) *A Review of Traffic Signal Control*, WP349, Inst. for Transport Studies, University of Leeds.

Shepherd S.P. (1993) *The Application of Ramp Metering Strategies to Signalized Networks*, paper presented at International Conference on Applications of Advanced Technologies in Transportation Engineering, Seattle, USA, July 25 - 28, 1993.

APPENDIX B : RESULTS OF RANKING BY PANEL OF EXPERTS

The SECFO strategy assessment procedure.

The strategy assessment procedure makes use of the views of an expert panel in a "Delphi style" approach to the assessment of impacts likely to result from the implementation of an RTI strategy. Over the course of a day the expert panel (strategy assessment team) is initially presented with information relating to a specific reference area, usually a city or transport corridor. One or more alternative RTI strategies are then put forward for comparison with a trend or "do-nothing" case.

The experts are asked to compare the performance of the various strategies against the trend case according to a predefined set of impact categories. An example of an impact category might be travel time, or drivers' stress. The experts rate the performance of the alternative strategies using a simple system of scoring. This less formal approach to impact assessment contrasts with that used in more traditional socio-economic approaches to evaluation. In a cost-benefit or multi-criteria analysis, for example, measurements of changes in impacts are frequently derived chiefly from the results of modelling.

In strategy assessment, each alternative strategy could be compared simply by examining separately the score achieved in each individual impact category. Although it is possible that one strategy may dominate all others in every category, this is not a likely outcome. In practice therefore it is not generally possible to produce an unambiguous ranking of strategies using the scoring information alone. In order to be able to sum scores across different categories of impact - and thus be able to rank the strategies using a single indicator- it is necessary to know how much a unit of one impact is to be compared with a unit of another. To achieve this the experts are also asked to provide a set of relative weights for the various impact categories.

An overall score for each strategy is produced by summing, across impact categories, the product of the group average weights and scores. The experts are encouraged to put forward and discuss alternative views concerning both the likely size and importance of the different impacts expected to result from each strategy. There is also an opportunity for experts to raise any points of uncertainty they may have concerning either the strategies or the range of impact categories.

RANKING OF PROJECTS BY VALUING OF IMPACTS

Scores of between ±2 were given for each strategy impact. The scores were allocated as follows

Significant benefit	2
Slight benefit	1
No change	0
Slight disbenefit	-1
Significant disbenefit	-2

The following impact groups were used :

1. Travel time for persons and goods
2. Travel time for commercial vehicles
3. Fuel consumption / air pollution / noise pollution
4. Vehicle operating costs
5. Driver comfort/stress
6. Pedestrian/bicyclist comfort/stress
7. Safety
8. Mode choice

The following Affected Groups were considered for each impact

Pedestrians
Bicyclists
Car drivers
Bus drivers
Taxi drivers
Lorry drivers
Car passengers
Bus passengers
Taxi passengers
Bus operators
Taxi operators
Lorry fleet operators
Emergency vehicles
Residents
Business premises

EVA Consortium (1991). Evaluation Process for Road Transport Informatics. European Communities, Project V1036, Programme DRIVE.

RANKING BY PANEL OF EXPERTS

Strategy	Description	Score
QM		
1-4	AUTO-GATING / METERING	8.12
5	DOUBLE CYCLE TIMES AT CRITICAL JUNCTIONS	6.48
6	STARTING AND STOPPING WAVES AND SIGNAL CONTROL	6.24
7	EXTERNAL METERING	4.91
8	VARIABLE MESSAGE SIGNS	4.12
9	SHORTER CYCLE TIMES FOR CONGESTION RECOVERY	2.24
10	IDENTIFICATION OF LINKS FOR QUEUE STORAGE	0.42
11	RESTRICT TURNING INTO CONGESTED ARTERIAL	-3.39
12	QUEUE STORAGE	-3.82
13	TIDAL FLOW	n/a
14	FLARED GREEN TIMES IN NETWORKS	n/a
1001	SEPARATE STAGE (PHASE) FOR TURNING TRAFFIC	6.91
1002	MAXIMISE SIGNALISED JUNCTION CAPACITY	5.76
1003	TURN BANS	4.73
1004	SEPARATE TURNING LANES AT CRITICAL JUNCTIONS	3.27
PT		
101	CO-ORDINATE SIGNALS FOR BUSES	2.97
102	PRIORITY TO BUSES AT SIGNALS	2.73
1101	INCREASE BUS STOP SPACING	7.64
1102	REDUCE TIME AT BUS STOPS	7.33
1103	CREATE BUS LAYBYS	6.36
1104	BUS STOPS UPSTREAM/DOWNSTREAM FROM JUNCTIONS	4.97
1105	WITH FLOW BUS LANES	2.06
1106	INFORMATION AT BUS STOPS	1.64
1107	BUS LANE WIDTH	0.61
1108	ZERO BUS LANE SET BACK	-6.61
1109	FORM BUS CONVOYS	n/a
TC		
201	LINKED TRAFFIC SIGNALS	2.85
202	FORCING SPEEDS TO BEST VALUES FOR PLATOONS	1.33
203	SIGNALISED PEDESTRIAN CROSSINGS	-2.18
1201	BICYCLE ROUTES	2.61
1202	PREVENTING RAT-RUNS OFF THE ARTERIAL	0.91
1203	PLANTING	0.73
1204	MEDIANS	0.42
1205	PARKING BAYS	-0.91
1206	SERVICE ROADS	n/a
1207	CUSHIONS AT PEDESTRIAN CROSSINGS	n/a

STRATEGIES APPLICABLE FOR LEEDS FIELD TRIAL SITE

Strategy	Description	Score
QM		
1-4	AUTO-GATING / METERING	8.12
5	DOUBLE CYCLE TIMES AT CRITICAL JUNCTIONS	6.48
6	STARTING AND STOPPING WAVES AND SIGNAL CONTROL	6.24
7	EXTERNAL METERING	4.91
8	VARIABLE MESSAGE SIGNS	4.12
1001	SEPARATE STAGE (PHASE) FOR TURNING TRAFFIC	6.91
1002	MAXIMISE SIGNALISED JUNCTION CAPACITY	5.76
1003	TURN BANS	4.73
1004	SEPARATE TURNING LANES AT CRITICAL JUNCTIONS	3.27
PT		
101	CO-ORDINATE SIGNALS FOR BUSES	2.97
102	PRIORITY TO BUSES AT SIGNALS	2.73
1101	INCREASE BUS STOP SPACING	7.64
1102	REDUCE TIME AT BUS STOPS	7.33
1103	CREATE BUS LAYBYS	6.36
1104	BUS STOPS UPSTREAM/DOWNSTREAM FROM JUNCTIONS	4.97
1105	WITH FLOW BUS LANES	2.06
1106	INFORMATION AT BUS STOPS	1.64
1107	BUS LANE WIDTH	0.61
1108	ZERO BUS LANE SET BACK	-6.61
TC		
201	LINKED TRAFFIC SIGNALS	2.85
202	FORCING SPEEDS TO BEST VALUES FOR PLATOONS	1.33
203	SIGNALISED PEDESTRIAN CROSSINGS	-2.18
1201	BICYCLE ROUTES	2.61
1202	PREVENTING RAT-RUNS OFF THE ARTERIAL	0.91
1203	PLANTING	0.73
1204	MEDIANS	0.42
1205	PARKING BAYS	-0.91

STRATEGIES APPLICABLE FOR TURIN FIELD TRIAL SITE

Strategy	Description	Score
QM		
1-4	AUTO-GATING / METERING	8.12
5	DOUBLE CYCLE TIMES AT CRITICAL JUNCTIONS	6.48
6	STARTING AND STOPPING WAVES AND SIGNAL CONTROL	6.24
7	EXTERNAL METERING	4.91
8	VARIABLE MESSAGE SIGNS	4.12
13	TIDAL FLOW	n/a
14	FLARED GREEN TIMES IN NETWORKS	n/a
1001	SEPARATE STAGE (PHASE) FOR TURNING TRAFFIC	6.91
1002	MAXIMISE SIGNALISED JUNCTION CAPACITY	5.76
1003	TURN BANS	4.73
1004	SEPARATE TURNING LANES AT CRITICAL JUNCTIONS	3.27
PT		
101	CO-ORDINATE SIGNALS FOR BUSES	2.97
102	PRIORITY TO BUSES AT SIGNALS	2.73
1101	INCREASE BUS STOP SPACING	7.64
1102	REDUCE TIME AT BUS STOPS	7.33
1103	CREATE BUS LAYBYS	6.36
1104	BUS STOPS UPSTREAM/DOWNSTREAM FROM JUNCTIONS	4.97
TC		
201	LINKED TRAFFIC SIGNALS	2.85
202	FORCING SPEEDS TO BEST VALUES FOR PLATOONS	1.33

APPENDIX C : RESULTS OF SIMULATIONS

C.1 LEEDS TRIAL SITE

C.1.1 CALIBRATION

Data from the March 1992 field trial surveys, detailed in Deliverable No.4, was used to calibrate the models.

C1.1.1 Calibration of AM peak (0800 to 0900)

Four measures were used to assess whether the micro-simulation model was accurately producing the observed behaviour, as surveyed on-street. Care was taken to ensure that non of the information in these measures had been used to construct the data files for the micro-simulation model. These four measures were:

- Mid link traffic flows, in two directions, for two strategic positions in the network. The first position was between Westland Road and Middleton Grove on Dewsbury Road and the second between Cross Flatts Grove and Tempest Road on Beeston Road.
- Private vehicle journey times on four routes in the network. Two of the routes were both directions between Tommy Wass junction and Hunslet Hall road junction. The other two were a clockwise and anti-clockwise circuit of Old lane, Beeston road, Tempest road and Dewsbury road.
- Bus journey times on two bus routes. These routes were the inbound and outbound directions between Tommy Wass junction and Hunslet Hall road junction.
- Maximum observed queue lengths at the Parkside/Garnet, Dewsbury/Tunstall and Tunstall/Garnet junctions.

Few of the default parameters for the NEMIS model needed to be changed in order to replicate the observed behaviour. Those that did need fine-tuning included:

1) Maximum speed for each vehicle class. The default values were 20m/s which was thought to be too high for UK traffic conditions. These values were modified to form a distribution of such speeds between 15 and 18m/s.

2) Car-following parameters for each vehicle class. The default parameters were for fast, short vehicles. The class parameters for one vehicle type were modified to model the behaviour of a slower, longer vehicle. This modification better represented the mixture of vehicle types using the traffic network.

3) Minimum speed during acceleration and deceleration for each vehicle class. The default parameters were too abrupt. Vehicles tended to travel at high speeds when approaching the back of a queue and then abruptly slow down. A more gentle deceleration profile was found to better reproduce observed UK behaviour.

Tables 1 to 4 present the final calibration results for the AM peak period.

A number of statistical tests are available to ensure that, given the observed variables, the observed and modelled results are equivalent. For the flow figures a one sample t-test is appropriate. For the travel time results a two-sample t-test is appropriate, with the assumption of equality of variance (established by use of a 5% F-test for equality of variance). This test shows no significant difference between observed and modelled measures at the 5% level of a two tailed t-test.

There is general close agreement between the observed and modelled flows. The worst result is for Beeston road westbound which is 13% in error, but when considered in terms of absolute number of vehicles (+32) the difference is small. There is also close agreement between the observed and modelled maximum queue lengths. The only point of note is the entry for Dewsbury road/Tunstall road, observed maximum which has two figures recorded. The first figure, 25, is the maximum queue observed during the first half hour of the morning peak (08:00-08:30), whilst the second, 45, is in the second half hour (08:30-09:00). During this second half hour there was a broken down vehicle in the vicinity of the junction. In the light of this fact, the most reliable comparison figure is the first, i.e. 25.

Survey point	Observed	Modelled
Dew. rd (Inbound)	1105	995 (-10%)
Dew. rd (Outbound)	578	584 (+1%)
Beeston rd (Westbound)	239	271 (+13%)
Beeston rd (Eastbound)	386	389 (+0%)

Table 1 Comparison of observed and modelled flows over 45 mins

	Observed	Modelled
A	307 (46)	311 (83)
B	356 (25)	334 (43)
C	404 (59)	395 (56)
D	486 (57)	425 (85)

Table 2 Comparison of observed (vehicles) & modelled private vehicle journey times (s)

Junction	Approach	MAX Observed	MAX Modelled
Dew. rd/Tunstall rd	Inbound	(25)(45)	20
	Outbound	13	15
	Tunstall	25	14
Stratford st PELICAN	Inbound	5	9
	Outbound	1	7
Dew. rd/Garnet rd/ Parkside rd	Inbound	28	34
	Outbound	18	16
	Garnet	14	14
	Parkside	6	7

Table 3 : Observed and modelled maximum queue lengths

Direction	Observed	Modelled
Outbound	434 (108)	490 (76)
Inbound	511 (100)	505 (105)

Table 4 - Observed and Modelled mean Public Transport Vehicle journey times (s)

C1.1.2 Validation of INTER peak (1500 to 1600)

To produce a set of micro-simulation data files appropriate for the inter peak period the AM peak data files were used as a template. The changes which were made are:

1) A different origin, destination matrix. This matrix better represents the traffic volumes and patterns appropriate to the inter peak period.

2) A revised fixed time signal plan. In the inter peak period slight modifications were required to the signal timings used in the peak period. In the peak period, the assumption was made that stages ran to their maximum length, given the high traffic demand. In the inter peak plan the stages ran for less than their maximum length, producing a slightly shorter junction cycle time.

3) New bus statistics. A new set of surveys were carried out to establish the mean and variance of the waiting time at each bus stop along the arterial. The bus frequencies were also slightly revised.

Tables 5 to 8 present the final calibration results for the inter peak period. Unfortunately an independent survey of bus journey times is not available for comparison.

Survey point	Observed	Modelled
Dew. rd (Inbound)	898	955 (+6%)
Dew. rd (Outbound)	900	848 (-5%)
Beeston rd (Westbound)	441	410 (-7%)
Beeston rd (Eastbound)	383	415 (+8%)

Table 5 Comparison of observed and modelled flows over 1 hour

	Observed	Modelled
A	398 (30)	372 (37)
B	516 (31)	493 (58)
C	304 (71)	228 (24)
D	238 (58)	268 (26)

Table 6 Comparison of observed (vehicles) & modelled private vehicle journey times (s)

Junction	Approach	MAX Observed	MAX Modelled
Dew. rd/Tunstall rd	Inbound	17	13
	Outbound	12	16
	Tunstall	15	14
Stratford st PELICAN	Inbound	5	5
	Outbound	5	5
Dew. rd/Garnet rd/ Parkside rd	Inbound	20	20
	Outbound	12	15
	Garnet	8	14
	Parkside	11	6

Table 7 : Observed and modelled maximum queue lengths

Direction	Observed	Modelled
Outbound	N/A	436 (63)
Inbound	N/A	517 (73)

Table 8 - Observed and Modelled mean Public Transport Vehicle journey times (s)

C1.1.3 SCOOT Calibration

Using the facilities offered by the SCOOT-NEMIS interface it is possible to have the micro-simulation package mimic the on street traffic. What is required before the use of such a facility is an assurance that both the micro-simulation model and SCOOT UTC system have the same representation of the traffic in the system. Normally this is achieved by validating the SCOOT model's parameters against observed traffic behaviour on-street. The parameters which are available are:

1) Journey time;
2) Filter journey time;
3) Maximum allowed queue;
4) Saturation occupancy;
5) Filter saturation occupancy;
6) Main downstream link;
7) Start lag;
8) End lag;
9) Default offset;

Normal practice is to follow the guidelines as laid out in the SCOOT handbook. Recommendations are given for procedures to provide an initial value for each parameter for each applicable link. Subsequent to this an on-street survey is conducted, also on a link basis to refine some of the initial values. Clearly a strict application of the same procedures may not be necessary for the validation of the parameters associated with the *virtual* Dewsbury road network. Each of the above parameters will be taken in turn:

1) Journey time

This is the time taken by an average vehicle travelling in a free-flow platoon to travel from the detector to the stop line. No sensible initial value is suggested by the handbook, instead an on-street sample of approximately 10 vehicle journey times is recommended.

Within NEMIS a vehicle will eventually, if not acted upon by an external force, travel at the maximum speed given for its vehicle class. Clearly the presence of other, free-flowing vehicles, will affect this behaviour. The minimum, over all vehicles classes, for maximum vehicle speeds is 15m/s. Thus a reasonable estimate of this value will be link length in metres divided by a speed of 14 m/s. The lower speed is a reflection of the time taken to reach a maximum permitted speed. A further refinement of this value is possible, see below.

2) Filter journey time

This is the time taken for a vehicle to travel from the stopline to the detector, during a green filter arrow. Recommendations are made to calculate this short duration in a similar manner to that of journey time above.

In practice, the experience of engineers within the local authority and reference to detailed junction diagrams is sufficient to set this value.

3) Maximum allowed queue

This is the maximum queue which can be accommodated between the detector and the downstream stopline. An initial value is calculated on the assumption that vehicles queue with a headway of 6m. On street validation of this parameter is performed by either counting the number of cars if such a queue exists or, in the more usual case, factoring up a large queue which does not quite reach the detector. Account should also be taken of queuing disciplines at the stopline, ie dedicated turning lanes.

This assumed headway of 6m for queuing vehicles is used within the NEMIS model. Little refinement, in the abstract, can be made to this parameter value. Adjustments were, however, made as part of a follow-up exercise, see below.

4) Saturation occupancy

This is the rate at which queues discharge during effective green. The value is quoted in Link Profile Units and can be affected by a number of factors. The range of reasonable saturation occupancies is 8 to 11 for a single laned link and 10 to 14 for a two laned link. The handbook gives some quite detailed explanations on how to estimate an initial value for a link's saturation occupancy. In this exercise the following features are taken into account by increasing (+) or decreasing (-) the outflow: Detector flow masking (+); Mid link turning traffic (+); Good queue discipline (+); Bus stop near stop line (-); Steep gradient (-) and sharp turns (-). On street validation is performed by a comparison of the observed behaviour and messages from the SCOOT traffic model, primarily M10 (queue at end of red), M11 (queue clear time) and M14 (queue evolution) messages. The saturation occupancy value is adjusted, on-line, from a sample of 10 readings. This exercise is repeated two or three times or until a correspondence is established. Clearly this is a significant parameter within the SCOOT queue model.

Within NEMIS the saturation flow of a lane, with no conflicts, is 1800 vehicles per hour. This equates to saturation occupancy, per lane, of 8.5 LPU's. The queue clear time can similarly be estimated at 6m/s. In order to validate this parameter in the light of other factors (conflicts etc) a separate detailed exercise was carried out, see below.

5) Filter saturation occupancy

This value is the maximum flow rate over a detector by filter traffic. As might be expected this value is closely related to the saturation occupancy of a link and is validated in a similar manner.

As for the filter journey time the expertise of the local authority engineers was thought to be sufficient.

6) Main downstream link

This information is used to determine when a downstream link may block the exit from a link (so called exit blocking). In the case of on-street validation and the *virtual* Dewsbury road this value can be set by engineers with knowledge of the site.

7) Start lag

This value is the delay in seconds, between the time of a stage change occurring and the time that the queue starts to discharge. Once again, the experience of local engineers was thought to be sufficient for the *virtual* Dewsbury road.

8) End lag

This value is the delay in seconds, between the time of a stage change occurring and the time that the queue stops discharging. Again, the experience of local engineers was thought to be sufficient for the *virtual* Dewsbury road.

9) Default offset

This is the difference in the effective green start times for the main stage at the entrance to the link and the main stage at the exit of a link. The value is primarily used in situations where a detector has gone faulty and the SCOOT model has no information on which to base an offset decision. A recommended value is the stopline to stopline journey time minus 10 seconds.

Within NEMIS a detector should not go faulty so this information is of little value in the context of the *virtual* Dewsbury road. The implemented value was therefore the recommended value.

As mention above, a distinct exercise was carried out to try and further validate some of the above parameters. Two prime objectives of SCOOT are to minimise delay and stops and also maintain a given level of saturation at each node. A decision was made that a consistent measure of queue length at the end of red would achieve this. The reasons for this was that:

1) Queues are a reliable measure of both delays and stops;
2) This information was readily available from SCOOT (M10 message);
3) This is a reliable measure from the micro-simulation;

The procedure adopted was to collect on a cycle-by-cycle basis the modelled queue length from SCOOT in LPUs (the M10 message) and the queue length from the micro-simulation in vehicles. The ratio of SCOOT queue to micro-simulation queue should be in the region of 18. The starting point for this exercise was a recommended set of SCOOT parameters, modified in light of previous experiences and knowledge of NEMIS (see above). After each data collection exercise, the SCOOT/micro-simulation ratios were examined on a link by link basis. Changes were then made to various SCOOT parameters in order to try and bring these ratios closer to 18. The parameters which were used are:

1) Saturation occupancy of the link. This rate of discharge does not take account of the potential for UK right turning traffic, in conflict with opposing flows, to vary this rate from cycle to cycle. If the ratio was in excess of 18 then there was evidence that this value should be increased. This ensured that the same volume of traffic discharged in both SCOOT and the micro-simulation during the previous green stage.

2) Travel time for the link. If the ratio was in excess of 18 then there was evidence that this value should be increased. A greater travel time means that the queue will grow at a slower pace, giving a shorter queue at the end of red.

3) Maximum queue length. This is the number of vehicles which a link can accomodate between the detector and the stop line. When the SCOOT model predicts a queue in excess of this value then further detector information is ignored and exit blocking is triggered. Clearly if SCOOT is predicting a MAX queue whilst the micro-simulation model is still sending traffic to the detector then there is an inconsistency in this SCOOT parameter.

A check was made at all times to ensure that modified values were reasonable.

The next section details the results of the final calibration exercise. Figure C1 shows a scatter plot of queue length at the end of red in NEMIS vs queue length at the end of red in SCOOT, for all links in the SCOOT network. What is required is a linear relationship along the lines of

$$Q_{SCOOT} = \beta \ Q_{NEMIS}$$

$$with \ \beta \approx 18$$

An intuitive inspection of figure C1 suggests that this is a plausible relationship, with the exception of link P. Taking a link in isolation, link c, we have figure C2. A linear regression gives an estimate of β of 17.9. Performing a regression for the remaining links gives the results in table 9.

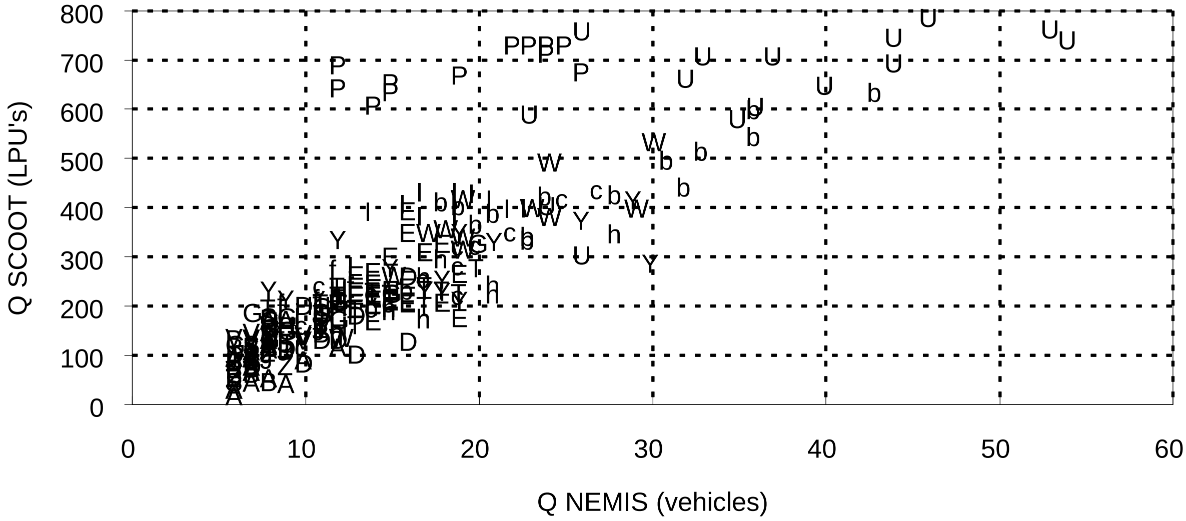

Figure C1 : Scatter Plot of NEMIS queues vs SCOOT queues for the whole network

Another method of interpreting these results is to calculate an average LPU per vehicle in a queue ie:

$$LPU_{vehicle} = \frac{Q_{SCOOT}}{Q_{NEMIS}}$$

An average and standard deviation of these values is then taken across all queues observed (between 7 and 24). A sample t-test is then used to compare the observed mean with the expected mean. Table 10 gives these figures and those links whose average is significantly different from 18 are highlighted.

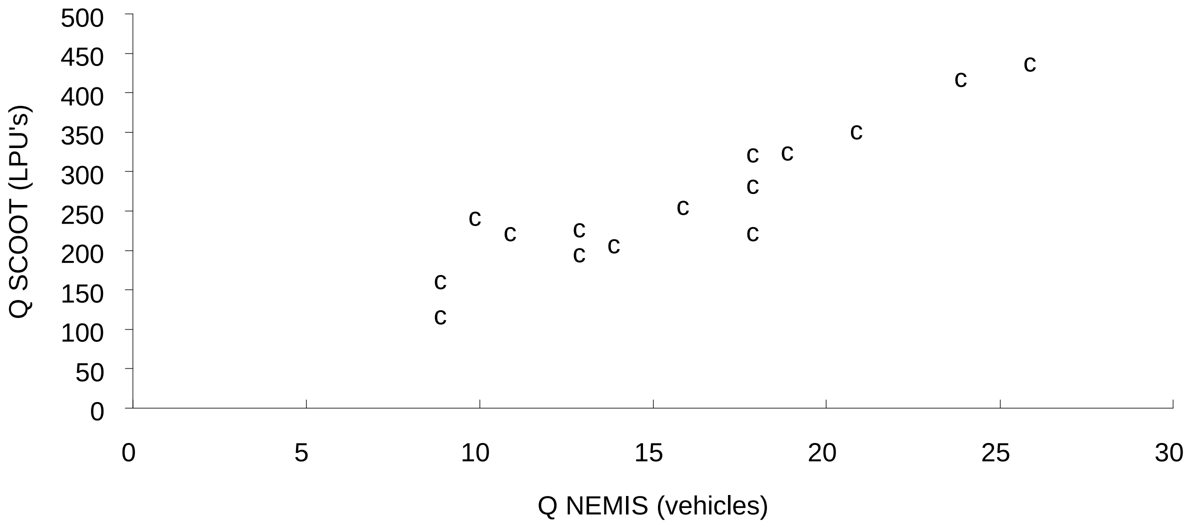

Figure C2 : Scatter plot of NEMIS queues vs SCOOT queues for an isolated intersection

The figures reported in tables 9 and 10 are all reasonable with the possible exception of link P. A possible explanation for this is given in figure C3. The arrows represent the direction of flow whilst the numbers are the modelled flows in vehicles per hour. What happens is that a significant proportion of the traffic which flows over the detector turns into a side street and never reaches the stop line. Thus SCOOT is modelling a higher arrival flow at the stop line and hence longer queue than in the micro-simulation. This effect was overcome by artificially inflating the saturation occupancy of link P so as to increase the rate of queue discharge from the link. The maximum queue parameter was also increased to forestall inappropriate exit blocking. This is not, however, an ideal solution to the problem.

Link	β	Link	β	Link	β
A	17	I	24	b	17
B	18	P	**37**	W	20
D	16	S	22	Z	18
E	19	U	18	c	18
G	21	T	17	f	22
H	22	V	22	h	15
J	20	Y	16	i	21

Table 9 : Regression analysis for SCOOT queue scale factor

Link	Mean (sd)	Link	Mean (sd)	Link	Mean (sd)
A	17.6 (7.3)	I*	25.3 (4.1)	b	18.7 (3.1)
B	18.4 (6.4)	P*	41.3 (11.3)	W	20.0 (3.4)
D	18.5 (6.3)	S	22.5 (5.3)	Z	18.6 (4.0)
E	19.3 (4.1)	U	19.5 (5.1)	c	18.4 (3.3)
G*	24.4 (5.7)	T	19.3 (5.2)	f*	22.6 (4.2)
H*	23.2 (3.4)	V*	24.7 (6.8)	h*	15.5 (3.1)
J	20.0 (3.2)	Y	20.6 (8.4)	i*	20.4 (2.6)

Table 10 : Means and standard deviations for the SCOOT queue scale factor

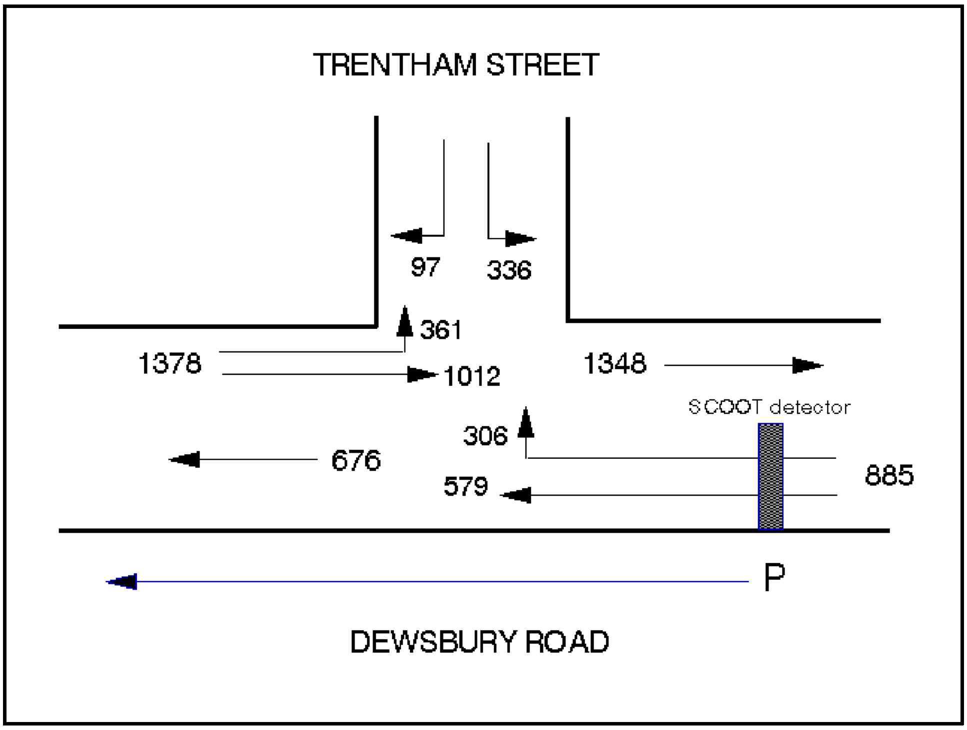

Figure C3 : Flows at Dewsbury Road / Trentham Street junction

A further calibration exercise was necessary to model the environment with a bus lane. Only those links which are modified to accommodate a bus lane were investigated. The corresponding results for such links are given in table 10. These results are much more consistent because the behaviour of vehicles discharging from these links is much more regular, with UK right turns being banned. This ensures a more consistent cycle to cycle discharge rate in the micro-simulation.

Link	β	Link	β	Link	β
Y	16.9	U	15.6	b	18.8

Table 10 : Regression analysis for SCOOT queue scale factor for bus lane

C1.1.4 Calibration of SPOT model with NEMIS

The SPOT database contains data describing the controlled junctions and a set of parameters for the control algorithm. Basic information relates to the network topology and to the traffic lights stages. When necessary, data from the NEMIS model were used to describe the intersections. The TRANSYT fixed plan (88s cycle), used to compare the results of the simulations, was loaded as reference plan for the SPOT units; security constraints on minimum stage and intergreen duration were set, according to the indications from HETS; a certain degree of freedom was left to the maximum stage duration, to allow for normal "variable cycle" SPOT operation.

From the results of the NEMIS assignment model, average flow levels and turning percentages were derived for each link; NEMIS data had been previously calibrated using the results of the field surveys. A saturation flow of 1800 veh/h/lane was estimated, in accordance with the NEMIS car-following law.

A series of tests have been performed to check the correctness of the SPOT model and to examine the performance of the controllers. This has been done in three steps:

- test of the single SPOT units
- test of the network of connected SPOTs
- test of the SPOT units connected to the NEMIS simulator

The goal of the first step was to verify that each controller was able to achieve a local optimum. Average constant flows were used as inputs, and a careful weight tuning was required to balance queues and stops on the various links. It was observed that in these conditions each SPOT tends to reach a steady-state behaviour, very close to the EQUISAT cycle. It was also noted that, due to the different saturation degree of the junctions in Dewsbury Road, a considerably different cycle length was required; the cycle was particularly longer at the intersections where a high volume of traffic could be introduced into the network.

The second test was intended to check the SPOT behaviour in a more realistic condition on an arterial, where the arrivals on the main link are represented by platoons of vehicles released by the upstream junction, rather than by average levels. A better calibration of the queue weight was required for the secondary links, and the problem of synchronization between adjacent intersections was afforded at this stage. It was decided that, due to the presence of considerable side flows at the central nodes of the arterial (Tunstall Rd. and Garnet Rd. intersections) and to the effect of a random demand on three pelican crossings, the "synchronization weight" should not be used at first; its benefit could be investigated through the simulations. Fig. 1 and 2 show the cycle duration obtained at the different junctions from a 40 min. run. The input intersections (SPOT 4 and 10) operate almost at fixed plan, because of the high flows involved and the effect of the constant inputs; the other controllers resent of the presence of platoons, and exhibit quite a variable cycle.

In the last test, the SPOT units were connected to NEMIS as in the final simulation environment. A final calibration procedure was required with the aim of tuning the Observer module of the SPOT units, which estimates in real time the junction parameters (saturation flow, turning percentages). The queue length at the end of red on various links was used as an indicator to compare the behaviour of NEMIS to the SPOT estimation, and some corrections to the value of the saturation flow were required. Fig. 3 and 4 illustrate the number of queued vehicles at the end of red on a section of Dewsbury Rd. and on one principal side road (Tunstall Rd.) during a 1 h. simulation run. It can be seen that a good agreement was achieved; major differences are due to vehicles stuck for turning manoeuvres or to stopped PT vehicles (not considered in the SPOT Observer). No great differences were exhibited in the estimation of the turning percentages.

Finally, the values of the travel times, both on the whole links and from the detectors to the stop line, which are also used by the SPOT model, were compared and adjusted using observations of platoons of vehicles in NEMIS simulations. Although this final calibration requires the use of real data before the actual implementation on the test-site, it allows SPOT to be used as a reliable simulation tool.

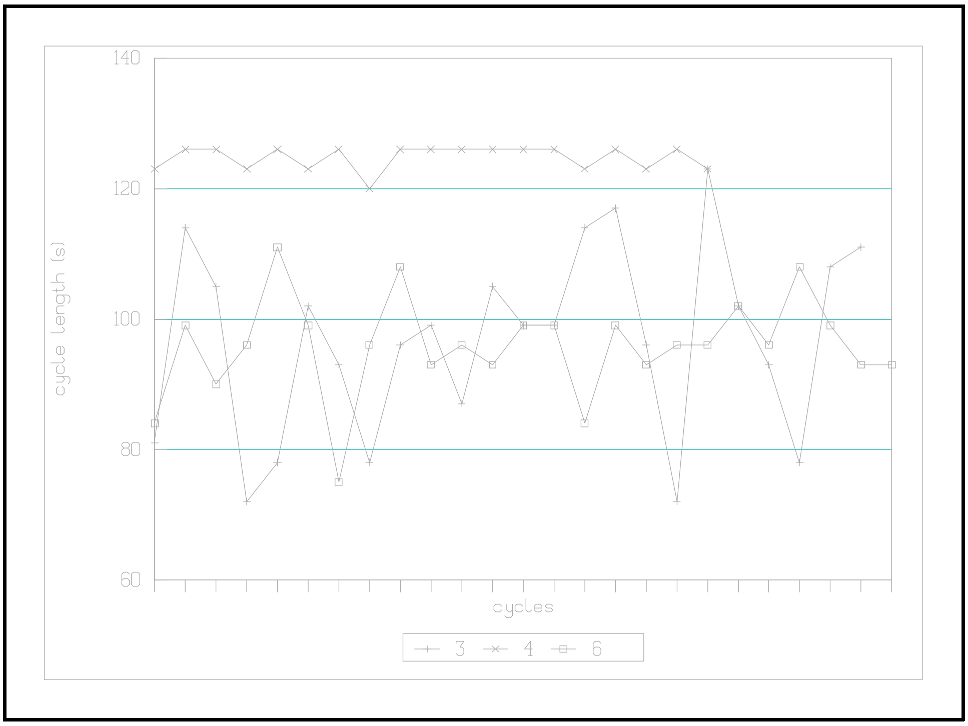

Figure A3: *Cycle length under SPOT operation*
SPOT 3: Dewsbury Rd. - Tunstall Rd.
SPOT 4: Tunstall Rd. - Garnet Rd.
SPOT 6: Dewsbury Rd. - Garnet Rd.

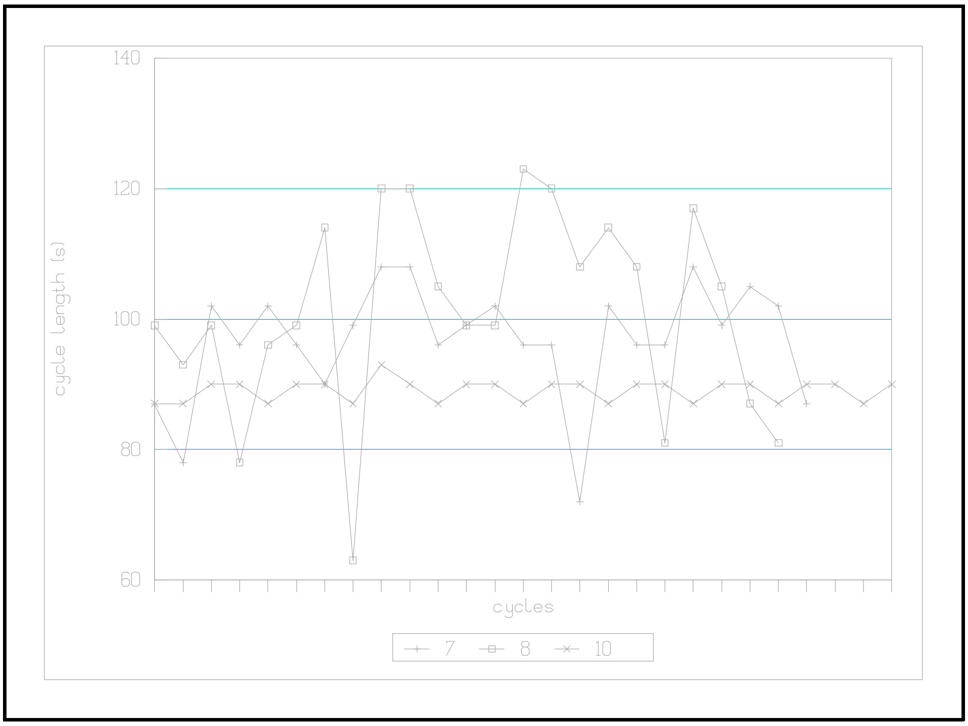

Figure A4 : *Cycle length under SPOT operation*
SPOT 7: Dewsbury Rd. - Middleton Grove
SPOT 8: Dewsbury Rd. - Westland Rd.
SPOT 10: Dewsbury Rd. - Old Lane

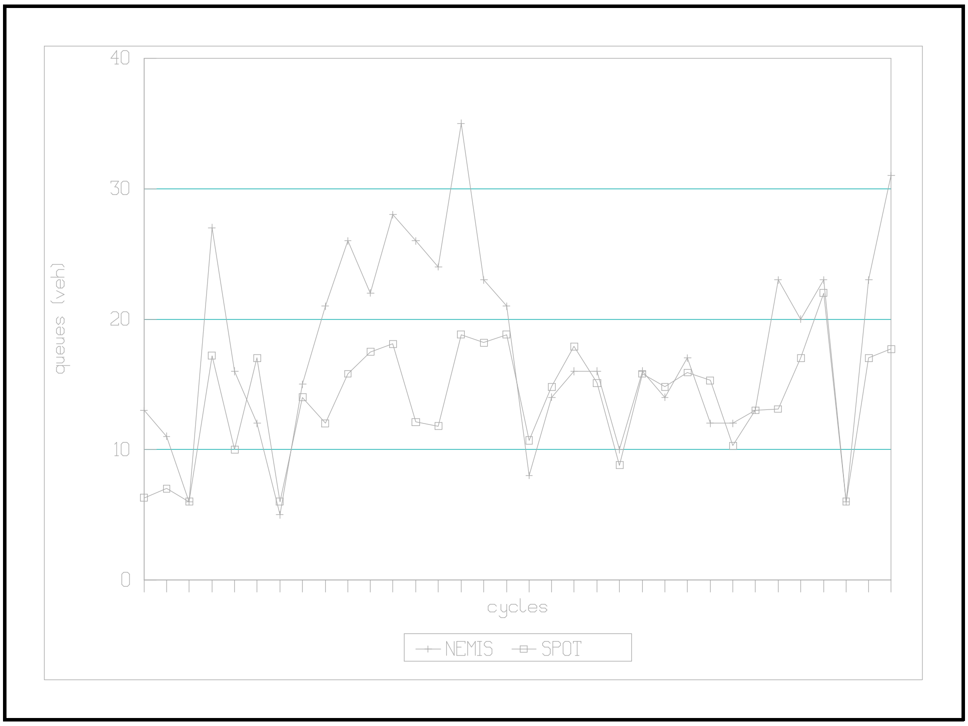

Figure A5 : *Queues at the end of red calibration (Dewsbury Rd. outbound at Garnet Rd. intersection)*

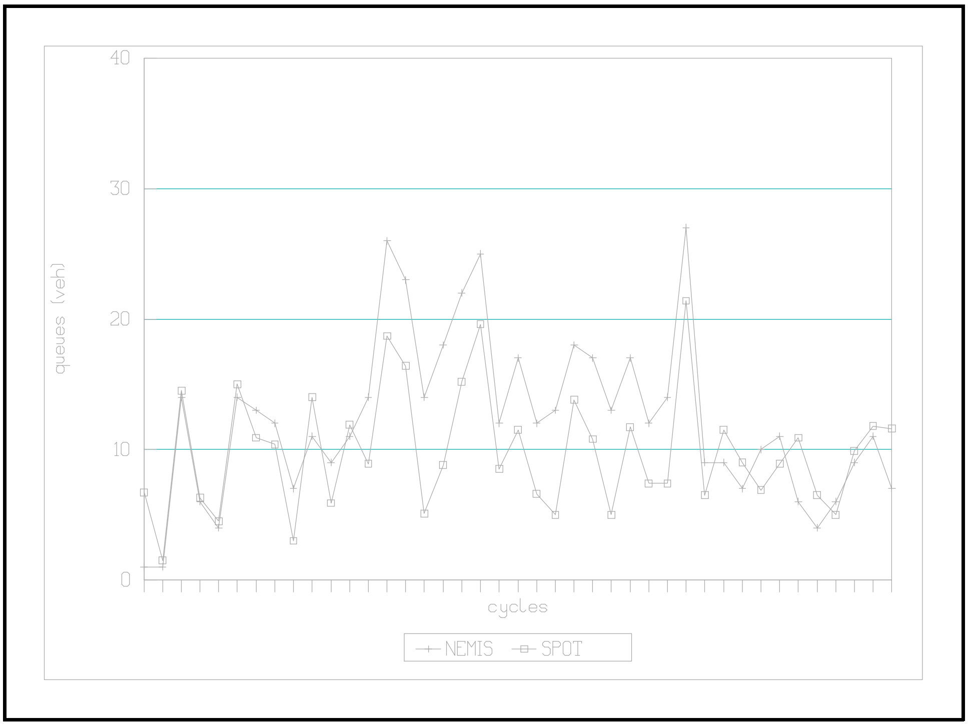

Figure A6: *Queues at the end of red calibration (Tunstall Rd. inbound at Dewsbury Rd. intersection)*

C2 TURIN TRIAL SITE

C2.1 CALIBRATION

C2.1.1 Testing of Autogating Strategies with SPOT units on the Gran Madre test-site

As a first test of the auto-gating strategies implementation into the SPOT units, some simulations were conducted on the Gran Madre test-site. The effectiveness of the strategies was investigated and some potential problems in the implementation on arterials were highlighted.

Two SPOT units were connected to control the junctions of the test-site, and average input flows were used. Both MX strategy and Local Feedback KX strategy were tested, leading to the same conclusions. The following results refer to the latter. After the system had reached steady-state conditions, a sudden increase of congestion was simulated on the internal link connecting the two junctions. According to the strategy, the situation should be monitored by the downstream controller and used to force the upstream SPOT to reduce the green stage for the main incoming flow. Storing vehicles on the upstream links should lead eventually to a recovery from the congestion.

Once the process started, however, it was observed that the constraint on the maximum green duration, used to force the stage length reduction, conflicted with the operation of the upstream SPOT, trying to find a local optimum. Instead of only one critical stage, the whole cycle was reduced, and the junction, normally operating at half-cycle with respect to the other one, eventually continued to supply vehicles to the congested link through frequent, short cycles. In this way, no effective recovery was achieved, while the queue on the input link started to drift upwards.

In the following figures, the queue length and the stage duration during the congested period is shown. The dramatic reduction of the upstream cycle can be observed, and the effect of the platoons of vehicles joining the queue on the critical link is evident. It should be noted that problems derive from the fact that the strategy, as implemented in SPOT, sets a constraint but does not affect the controller optimisation procedure. It was thought that better results could perhaps be obtained preventing the possibility of so short a cycle, i.e. setting a lower limit to the stage reduction. This could be better investigated on the main test-sites through simulations using NEMIS.

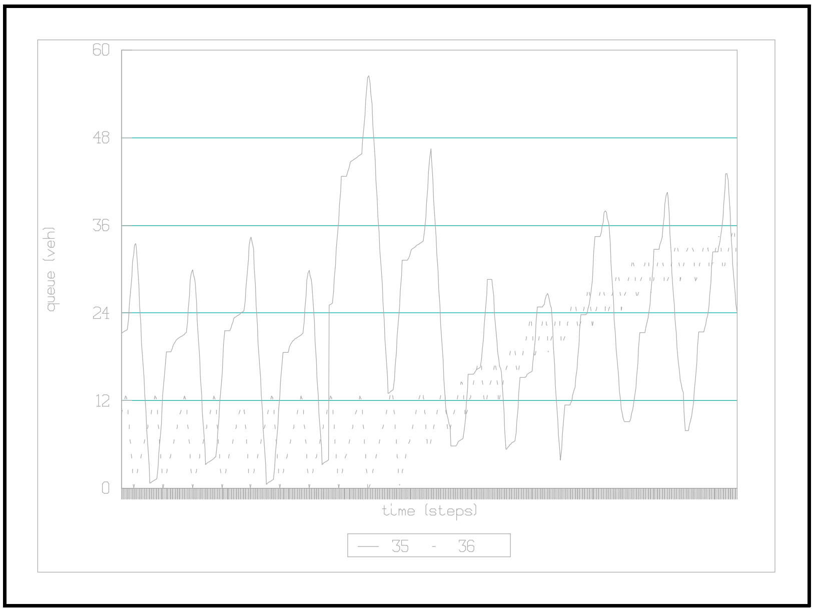

Fig 1.11: *Queue evolution during the congestion period*
35: congested link
36: "storage" link

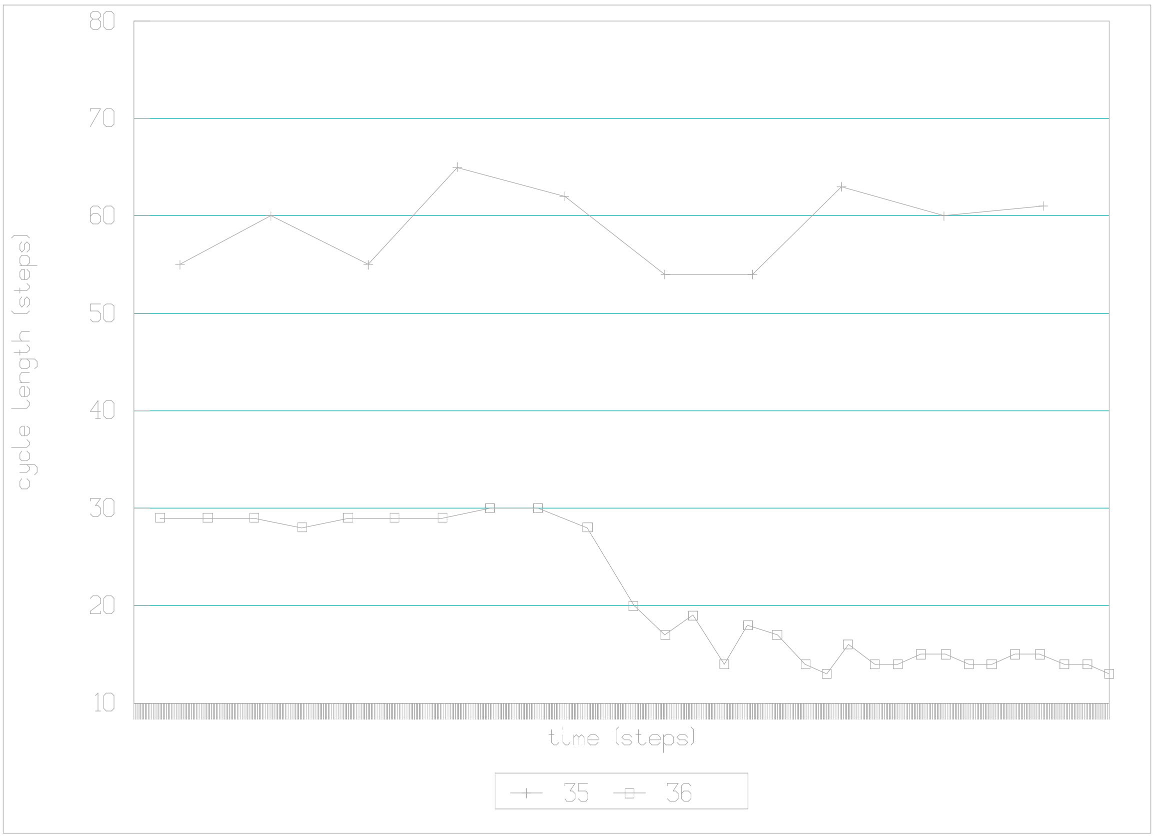

Fig 1.12: *Cycle duration during the congested period*
35: downstream junction
36: upstream junction

Table used for MCA and score obtained when the Criterion Utility of the impact is obtained.

Speed without delay		link		**SAFETY**		**PERFORMANCE INDICATOR**	
16,00		network					
				obj	48,00	**obj**	**150,00**
Time at high speed		link		score		**score**	
16,00		network					
Blocking back		link					
16,00							
Fuel con.		link		**EFFICIENCY**			
6,00		network					
				obj	54,00		
Stop		link		score			
6,00		network					
Speed		link					
6,00		network					
Speed sd		link					
6,00							
Travel time		link					
6,00		network					
		OD					
Delay		link					
6,00		network					
Occupancy		link					
6,00							
Bus travel time		link					
6,00		route					
Blocking back		link					
6,00							
HC Emissions		link		**ENVIRONMENT**			
12,00		network					
				obj	48,00		
CO Emissions		link		score			
12,00		network					
NOx Emissions		link					
12,00		network					
Fuel con.		link					
12,00		network					

APPENDIX D : SAFETY EVALUATION USING NEMIS

D1 Introduction

As a part of any evaluation process a safety evaluation should be carried out. This appendix investigates the possibility of using the outputs from NEMIS to crudely estimate the changes in accident rates that would result from implementing each strategy. These accident rates can then be used in both the Cost-Benefit Analysis and Multi-Criteria Analysis of the simulations.

Obviously these formulae will not be very accurate, they can only really indicate the likely direction of change. The only accurate way of discovering the safety impacts of the strategies will be to carry out systematic observations of conflicts during field trials.

D2 Estimates of accident rates

The reasons road accidents occur is a very complicated issue. Intuitively, they must depend upon a large number of factors, such as time of day, weather conditions, behavioural patterns etc. Many of these factors will average out over a long time period, leaving an underlying rate that probably only depends on a set of more basic parameters such as vehicle flows or vehicle speed distributions. In this report three different methods of estimating accident rates are examined.

In the UK the COBA-9 program is often used to provide a cost-benefit analysis of the implementation of new trunk road schemes. It provides a number of alternative formulae for estimating accident rates. These formulae are either based on vehicle distance travelled or on flows and vary according to the type of road.

The Department of Transport also publishes an annual report of accident statistics which gives accident rates for different classes of road. These could be used to derive appropriate formulae for predicting accident rates.

Finally, an alternative approximation is given by a recent TRL report which states that an increase in mean speed of 1 mph will result in a 5% increase in accident rates.

Obviously these are all very crude approximations. There is now evidence that accident rates vary according to other parameters such as smoothness of vehicle flow, however it is too early to quantify these effects and it is beyond the scope of PRIMAVERA to do so.

D3 COBA-9 predicted accident rates

The Dewsbury Road network being studied by PRIMAVERA consists of a collection of urban roads of class A and other. One section of the Dewsbury Road itself is dual carriageway. Table D1 gives the COBA-9 accident rates for the road types under study. Two figures are available, one for links and junctions the other for links alone. The reason for this is that COBA-9 also provides a more precise formula for estimating accident rates at junctions if detailed flows into the junction are available. Table D2 gives the likely split in casualties, between fatal, serious and slight, for each accident.

Table D1 : Default COBA-9 Link Accident Rates

Road Class	Personal Injury Accidents per million vehicle km Combined link/junction	Personal Injury Accidents per million vehicle km Link Only
Urban A	1.22	0.34
Urban B	1.55	0.49
Urban Other	1.77	0.67

Table D2 : COBA-9 Severity Split - Casualties per accident

Road Class	Fatal	Serious	Slight
Urban A	0.029	0.292	0.917
Urban B	0.028	0.300	0.903
Urban Other	0.014	0.270	0.879

Table D3 : COBA-9 Costs of Accidents

Casualty Type	Cost per Casualty (£)
Fatal	565,900
Serious	15,950
Slight	320

D4 Evaluation of accidents at junctions

COBA-9 provides an equation for estimating the accident rates at junctions.

$$A = a f^b \qquad (1)$$

where f is either derived from a cross product formula (C) or an inflow formula (I). For a cross product formula f is the value obtained by multiplying the combined inflow from the two major opposing links by the sum of the inflows on the other one or two minor links. The inflow formula is the value of the total inflow from all the links into the junction. If local accident rates are known then COBA-9 calculates a local value for a, with b being fixed by the national value. All the flows are measured in kv/day. The values of a and b are given in Table D4.

Table D4 : COBA-9 Values for a and b

Junction Type	Number of arms	Highest Link Standard	Formula Type	Junction Type	a	b
Major/Minor	3	S	C	2	0.195	0.46
	3	D	C	4	0.195	0.46
	4	S	I	6	0.361	0.44
	4	D	C	8	0.240	0.71
Signalised	3	S	I	14	0.223	0.61
	3	D	C	16	0.291	0.51
	4	S	C	18	1.378	0.20
	4	D	C	20	0.291	0.51
	5	S	I	22	0.254	0.62
	5	D	I	24	0.160	0.97

D5 Department of Transport Accident Statistics

Each year the Department of Transport publishes statistics on accidents obtained from returns of police accident records. One of the tables produced gives the accident rates by road class and severity. The most recent figures are given in Table D5. For 1991 a rate of 96 accidents per 100 million vehicle km for built-up A roads is given, while for built-up other roads the rate is 92 accidents per 100 million vehicle km.

Table D5 - Accident Rates by Road Class per 100 million vehicle kilometres

Road Type	1987	1988	1989	1990	1991
Built-up A roads	115	112	108	106	96
Built-up Other roads	111	110	99	100	92

D6 Analysis of the Dewsbury Road Trial Site

Police accident records (STATS19) for the Dewsbury Road have been provided to help assess the safety problems. These records can also be used to determine the accuracy of the COBA-9 formulae. The records show that there have been 844 reported accidents in the study area over the last five years. Of these accidents 204 occurred on the Dewsbury Road itself.

Extensive surveys of the Dewsbury Road site have been carried out to help calibrate the NEMIS model and to provide data for comparison after the strategies have been implemented. Data from these surveys on actual vehicle flows can be used as inputs into the COBA-9 formulae. As part of the field trials, conflict studies will be carried out as these provide a much more rapid assessment of likely accident rates.

D7 Prediction of accidents at junctions on the Dewsbury Road

To predict accident rates at junctions requires the flows into each junction for a typical twenty-four hour period. During the data collection survey, the hourly flows and turning movements at seven junctions on the Dewsbury Road were collected, but only for the two peak periods 0700-1000 and 1500-1800. Hourly flow data was also collected for 24 hour periods at four points on the Dewsbury Road. From this flow data it can be deduced that the flows for the 24 hour periods are approximately 2.5 times that for the combined peak flows. Therefore 24 hour flows for the seven junctions can be estimated for inclusion in the COBA formulae. This has been done as follows:

Junction Name	Junction Type	Major Inflows	Minor Inflows	f	Pred. Accid.	Actual Accid.
Tommy Wass	20	23037	13959	321.6	5.53	5.2
Westland Road	16	25385	2678	68.0	2.50	1.6
Middleton Road	16	28438	3073	87.4	2.84	1.4
Tempest Road	4	27665	2373	65.6	1.33	2.0
Parkside/Garnet	18	26101	8301	216.6	4.04	2.4
Tunstall Road	14	23879	5066	28.9	1.74	4.4
Hunslett Hall Road	18	18141	4611	83.6	3.34	2.8
Totals					21.32	19.8

As can be seen from this table, the overall number of accidents predicted is quite good, however for individual junctions large differences can occur. The junction with Tunstall Road is of particular concern having an accident rate two and a half times greater than that predicted.

D8 Predictions based on national accident statistics

The length of the Dewsbury Road being studied is approximately 3.25 km. The daily flows along the road are approximately 23,000 vehicle per day, therefore approximately 27,000,000 vehicle km are travelled per year. Assuming the flows have remained the same over the past five years, the national statistics predict the following numbers of accidents for each year.

	1988	1989	1990	1991	1992	Total
Predicted Accidents	30	29	29	26	26	140
Actual Accidents	36	37	44	42	45	204

Therefore it can be concluded that the accident rate on the Dewsbury Road is approximately one and a half times the national average for similar road types. Therefore the Dewsbury Road is not a typical urban A road and using a general formula based on national statistics will not produce very accurate answers.

D9 Conclusions

For the simulations the flows along each link will not change, therefore the best approach is probably a combination of the COBA-9 formulae for estimating the accident rates on each link for the base case, based on the link flows, followed by an estimation of the expected percentage change in vehicle mean speeds on each link using the speed change formula.