DRIVE II PROJECT V2016 : PRIMAVERA

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

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EXECUTIVE SUMMARY

The design of the evaluation study for the PRIMAVERA project (DRIVE II) is critical to establishing and measuring the impact of the integrated transport strategy not only in simulated trials, but more importantly, in the field. We intend to show through the evaluation study that significant and meaningful results can be obtained through the careful choice of impact variables and their associated evaluation criteria. Useful field trial information can thus not only be collected and measured, but be used as a basis for sound and rigorous statistical analysis, thereby demonstrating in a directly quantifiable way the success of an integrated strategy. Field trials should also be considered an essential element in the evaluation study as it is only through practical implementation that the performance of an integrated strategy in the presence of certain types of variability (virtually impossible to simulate) can be properly assessed.

A definition of the ATT systems to be tested is given in Section 1, this includes a description of which items of ATT hardware will be used. The overall objectives of the field trials are then given in Section 2. The field trials are seen as essential in addition to simulations as at least one of the DRIVE objectives (ie safety improvement) cannot be thoroughly assessed through simulation. A description of the UK site (Dewsbury Road) and two Turin sites (Gran Madre and Corso Grosseto) is given in section 3 together with both expected impacts and these we intend to measure or estimate. The final selection of criteria was made on the basis of those which are most likely to reflect the impact of the ATT strategy, are consistent with overall DRIVE objectives, can be sensibly measured and for which a quantifiable impact can be defined. Five specific impact variables are mentioned by the auditors in the MODIFY section of their report. The proposals outlined here rather extend this list for example suggesting overall traffic flow and vehicle occupancy as relevant indicators.

Clearly not all possible impacts have a monetary value attached, although many are quantifiable for example in terms of time or other units. Where this is not the case we suggest wherever possible the use of surrogate variables which can be quantified, thereby reducing to a minimum the amount of purely qualitative data to be analyzed. An additional advantage to such an approach is that, since qualitative data is almost always costly to obtain (for example using questionnaires), the evaluation study should become financially parsimonious to implement.

The overall field trial design is outlined in Section 3.4, following the format recommended by DRIVE II project V2040 and the CORD blueprint for evaluation. Further details for the implementation of field trials are given in Appendices A3 and A4. A brief description is given in Section 4 of the transferability of field trial results to a wider application.

As safety issues are seen as substantial factor in assessing the success of the integrated strategy we recommend in Section 5 the use of conflict analysis as a method of monitoring safety gains. One of the difficulties in using Police accident records is the small quantity of data available and the long period required (following traffic modifications) before any impact can be detected. The use of conflict analysis techniques will overcome this difficulty, providing detailed quantifiable information on the number, frequency and severity of potential (rather than actual) accidents. This data will be suitable for statistical analysis to detect significant changes in safety levels as an expected gain from the integrated strategy and used to supplement police accident data. The results of a preliminary survey of Dewsbury Road for conflict studies purposes is given within Appendix A6.

Details of the computer simulation plan using NEMIS are given within Section 6 and Appendix A7. By necessity a slightly differing set of criteria will be measured than those defined for field trials. As it will not be practically possible to simulate all possible strategy combinations, the choice of likely combinations is discussed.

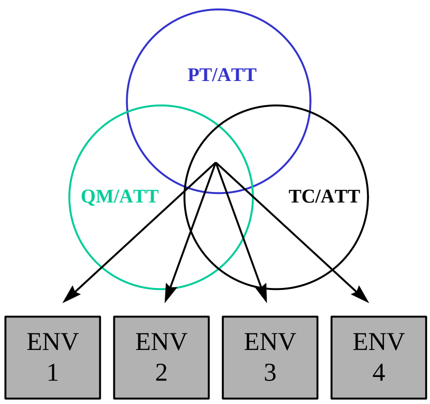
Finally in Section 7 the methodology for evaluating scheme performance is described, which we propose as a mixture of cost-benefit and multi-criteria analysis using guidelines set out in the EVA manual.

1. DEFINITION OF ATT SYSTEMS

It is not the aim of PRIMAVERA to test and evaluate individual ATT elements, but rather to evaluate the integrated effect of several ATT techniques. The ATT elements which will be combined are largely from the queue management sector and comprise the SCOOT and SPOT systems (with NEMIS interface) together with other measures such as selective bus detectors. In addition use will be made of a speed camera (Leeds site) and VMS signs (Leeds and Turin), further details of which are given in Section 3.4.12. These ATT "tools" can then be used to develop different strategies together with queue management techniques, for example different gating procedures to relieve congestion.

A more detailed description of how SCOOT and SPOT will be used for data collection and scheme evaluation is contained within Appendices A1 and A2. In order to emphasise the ATT Context of Primavera, the ATT Content of Public Transport (PT/ATT) and ATT content of traffic calming (TC/ATT) are being incorporated with Queue Management (QM/ATT) to form different integrated strategies.

It is not anticipated that any highway engineering works will be carried out at the main Turin site, Corso Grosseto, thereby giving a `fixed' background environment against which several of the integrated strategies can be assessed. At the second, smaller Turin site of Gran Madre a short reserved lane will be added before the bus stop giving two environments ie the base case and modified case. For the Dewsbury Road site the highway engineering elements are being included in 4 possible background environment scenarios as follows



With the 4 environments defined

	PT	TC
ENV 1	+	+
ENV 2	+	-
ENV 3	-	+
ENV 4	-	-

Where a + or - indicates the presence or absence of additional Highway engineering Public Transport or Traffic calming measures. Env 4 actually represents the `base' situation ie the Dewsbury Road site with no additional engineering measures.

There is strong justification for using at least 4 different environments (and probably more) if the results of the implementation of the integrated strategy are to be generalised to other sites across Europe. This is because the state of the network after implementation of the integrated strategy will be a product of the network before implementation together with an `Environment' effect, Integrated strategy effect, Growth effect and Variation effects as follows.

$$N_A = N_B \cdot S_i \cdot E_j \cdot G \cdot V$$

With the following definitions

- N_A - State of network after implementation of the Strategy including traffic flows, travel times, environmental effects, safety aspect and so on.
- N_B - State of network before implementation, measured according to the same set of criteria.
- S_i - Effect of the i'th strategy, ie the combined effect of QM/ATT, PT/ATT and TC/ATT measures.
- E_j - Effect of the j'th environment, ie the effect of the background combination of all civil engineering measures, including signals, bus lanes and so on.
- G - Growth/change effect ie to what extent would variables such as traffic flows, travel times etc have grown or changed in the `do nothing' scenario.
- V - Variation effect including known sources of variation such as traffic variability, seasonal variation etc plus random variation.

When defining a mathematical model for the Evaluation process it should be noted that there may be a possible interaction effect between the strategy (S_i) and Environment (E_j) as some strategies may be more suited to particular Environments.

2. OBJECTIVES OF THE FIELD TRIALS

The general objectives of the DRIVE program are to improve transport efficiency, improve safety and reduce environmental effects such as air/noise pollution. Using the NEMIS interface software, integrated strategies will be developed and tested (using simulations) which maximise these three DRIVE goals. Clearly some strategies may perform better in one or more of these goals than others. At the end of the simulation study we will select one or more integrated strategies which gives the best overall improvement in all three areas. At least one strategy will then be tested in the field trials at Leeds and Turin. The objective of the field trials is therefore to test whether expected gains in efficiency, safety and environmental effects as seen in computer simulations will occur in practice with the extra sources of variation and complexity which may arise in the field.

3. FIELD TRIALS PLAN

3.1 Description of Dewsbury Road and Turin Test Sites

Dewsbury Road forms a radial route into the city of Leeds from the south between the M1 and M621 motorways. The road is a wide four lane single carriageway between the Ring Road and Garnet Road. To the north of Garnet Road the road narrows to a two lane single carriageway. At its junction with the M1 motorway, Dewsbury Road becomes a dual carriageway for a short length before entering the south Leeds interchange. To the south-east of Dewsbury Road the majority of the side roads are all cul-de-sacs for local access. Two roads are through routes, one to the M1 motorway and the other to a housing estate. To the north-west of Dewsbury Road a large number of roads provide access to residential areas and may be considered potential through routes.

Two test sites are to be used in Turin city to assess the practical application of simulated strategies. The smaller site, Ponte Vittorio Emanuele I consists of a bridge on the river Po. The bridge connects two urban arterials which are affected by urban traffic and penetration flows during peak hours. The bridge has a small capacity and the two intersections at the ends of the bridge are often blocked by the queues on the bridge itself. This site has been chosen as being particularly appropriate for pilot testing of techniques to deal with oversaturation management, especially these involving the dynamic synchronization between adjacent intersections.

A more in-depth operational and impact evaluation will be carried out at the larger second site in Turin, the Corso Grosseto. This is part of the system of penetration arterials connecting the main extra-urban sources of traffic (motorways and airport) to the city centre. The test-site consists of the trunk of Corso Grosseto leading to Piazza Rebaudengo (five controlled intersections on the Corso Grosseto axis plus two sets of traffic lights in Piazza Rebaudengo) and the surrounding area. During peak hours the road is affected by long queues which often block crossing flows and impede bus access to the bus stop. A more detailed description of the Turin and Leeds test sites is contained within Deliverable No 4.

3.2 Interdependencies with Other Projects

The PRIMAVERA programme is not directly involved with any other projects or sub-projects.

3.3 Definition of the Impacts in the Test Sites

Specific variables which could be used to assess the impact of an integrated strategy are outlined in Tables 1 and 2 below, together with the expected benefit, likely impact group, sampling frame for the Before study and costable elements. In deciding which variables to monitor, our greatest interest is in those most likely to reflect impacts of ATT measures as incorporated in the integrated strategy. However each benefit will not be linked to a single ATT measure, but rather to the synergy of combined ATT measures. Some of the particular issues which are raised in measuring the impact for each variable follow.

3.3.1 Expected Impacts in Principle

Before analysing the measurement and costability of each impact variable we define the expected benefits from the strategy. The expected magnitude of each benefit will be assessed following the simulation study.

3.3.2 Impacts to be Measured/Estimated

As discussed in Section 3.4.10, we expect that not all impacts anticipated in principle can be productively measured.

From the expected impacts defined in Section 3.3.1 the impacts which will actually be measured are shown in Table 2. The most notable difference is in the estimation of air pollution where we intend to estimate the impact using NEMIS rather than using field trials. This decision was reached after considering the complexities of measuring air pollution in practice and the difficulties in analysing the data collected.

Table 1: Expected Benefits from Integrated Strategy

Impact Variable	Expected Benefit
Journey Time Speed	Reduction in overall journey time or maintained journey time with reduced variability. Benefits expected from generally lower and more controlled speeds through the system.
Vehicle Operating Cost and Fuel Consumption	Reduced operating costs and fuel consumption gained from fewer oversaturated junctions and reduced number of stops.
Comfort	Increased comfort as reflected in fewer (unscheduled) stops and benefits from reduced congestion.
Safety	Increased safety levels as a benefit of lower and more controlled speeds of vehicles.
Air and Noise Pollution	Reduced estimated pollution levels as a benefit of reduced congestion, fewer unscheduled stops and controlled speeds through the system.
Crossing delay/ Uncertainty/Visual Intrusion/Severance	Reduced levels in each of these impact variables as a benefit of reduced congestion, lower and more controlled vehicle speeds. Reduced pedestrian crossing delays.
Stress	Reduced driver stress as a benefit of levels of congestion and more controlled speeds. Reduced resident stress as a benefit of reduced and controlled speeds, reduced estimated noise/pollution and reduced pedestrian crossing delays.
Traffic Flows	Traffic flows may be seen to increase overall as more vehicles move more efficiently through the system. However this should not occur at the cost of other impact variables such as journey time.
Vehicle Occupancy (No of people in vehicle)	Whilst little or no change may be expected in car occupancy, bus occupancy may be expected to increase as a benefit of PT/ATT measures.
Operational Impacts	Increased reliability of bus journey times.

Table 2: Measuring Implemented Strategy Impacts

VARIABLE	DISAGGREGATE IMPACT GROUP	SAMPLING FRAME FOR BEFORE STUDIES COMPLETED	COSTABILITY (UNITS)
Journey Time Speed	Vehicle Category (total 5) - cyclist, car, bus, light commercial, heavy commercial	Before study - 12 days, 193 runs by Mo. 16 routes surveyed on 1 day. Hours 0800 - 0900, 1500 - 1600, 1700- 1800. 6 runs/hr each direction. After study to use MOs and NPM. Extra information available from Bus Survey. ATC to be used for speed.	Minutes km/h
Vehicle Operating Cost	Vehicle Category (excluding cyclist) - car, bus, light commercial, heavy commercial	Not surveyed in before study - Information from/bus operators - COBA - No of stops data as surrogate	£/ECU
Comfort	Vehicle Category	Not surveyed in before study. To use "number of stops" data as a surrogate	Multicriteria Form (MCF) or No of Stops
Safety	Severity - slight/serious/fatal	Before study - all accidents in study area 1/1/87→ 1/1/92 After study - Conflict analysis and accident statistics	No and severity of conflicts/accidents
Air Pollution	Residents, Pedestrian, Cyclist Groups	Not to be surveyed in the field - use Simulation Study (NEMIS)	No-MCF
Crossing Delay	People categories	Small pedestrian survey carried out for before study. Simulation + small field trials for after study.	Minutes or MCF
Stress	Residents, Pedestrians Drivers: vehicle category	Use no. of stops and queue lengths as estimates (crossing time/ traffic speed/traffic flow for residents)	MCF
Traffic Flows	Vehicle category	Before study as follows: ATC's - 11 sites, both directions, 15 mins, 1 month (March 1992) MCC's + Junction. 1 weekday. 0700-1000, 1500-1800. 15 mins (information collected for 7 vehicle types) Subsid. MCC's on minor roads. Left/right turn 0700-1000, 1500-1800. 1 weekday. 15 mins (3 vehicle types collected) All before surveys - TUES/WED/THURS 3/92. Extra bus information available.	Total vehicles otherwise MCF
Vehicle Occupancy	Cars/Buses	Not surveyed in before study - Use small field survey	People Numbers
Scheme Cost			CBA/£/ECU

Table 3: Definition of Criteria of Effectiveness and Response

IMPACT	CRITERIA OF EFFECTIVENESS	CRITERIA OF RESPONSE	DATA COLLECTION	PROPOSED STATISTICAL TEST
Journey Time (JT)	Reduced JT for route/link	Mean JT for route/link: Peak/interpeak	Number plate matching/floating observer	z or t for difference in means
	Reduced variance in JT for route/link	Variance (JT) for route/link: Peak/interpeak		F for difference in variance
Speed	Reduced speed for route/link	Mean speed for route/link: Peak/interpeak	Loop Detectors	z or t for difference in means
	Reduced variance in speed for route/link	Variance (speed) for route/link: Peak/interpeak		F for difference in variance
	Fewer "speeding" vehicles for route/link	Proportion of vehicles exceeding certain speed for route/link: Peak/interpeak		z or t for difference in proportions
Vehicle Operating Cost (OC) and Fuel Consumption (FC)	Reduced OC and FC for vehicles for whole route	Mean FC for buses for whole route	Data from bus operators	z or t for difference in means
	Reduced congestion for vehicles route/link	Total number of stops for vehicles, route/link: peak/interpeak	Manually in field	Contingency for no. of stops
Comfort	Increased comfort for drivers/passengers	Mean no. of stops for vehicles route/link: peak/interpeak	Manually in field	Contingency for no. of stops
Safety	Increased safety for cars/pedestrians for route/link	Accident rate for route	Police accident records	
		Conflict study for junctions	Manually in field	
Crossing delay/ Uncertainty/ Visual intrusion	Reduced or no change in crossing delay	Mean crossing delay for link	Manually in field	z or t for difference in means
	Reduced queue lengths at junctions	Mean queue length for link: peak/interpeak	Manually in field	
	Reduced mean traffic flow (TF) for link	Mean TF for link: peak/interpeak	Loop detectors	
	Reduced mean speed for link	Mean speed for link: peak/interpeak	Loop detectors	
Stress	Reduced stress for drivers & passengers for whole route	Mean no. of stops and queue lengths for whole route: peak/interpeak	Manually/floating car	z or t for difference in means
Traffic Flows	Reduced or no change in traffic flow for whole route	Mean traffic flow for whole route: peak/interpeak	Loop detectors	z or t for difference in means
Vehicle Occupancy	Increased bus occupancy. No change in other vehicle occupancy	Mean vehicle occupancy for whole route: peak/interpeak	Loop detectors	z or t for difference in means
Operational	Improvement in bus journey time reliability.	Variance in buses journey time peak/interpeak	Manually in field	z or t for difference in means

3.3.3 Impacts to be Estimated by other Workpackages

The impact of the integrated strategy on air pollution will be estimated as part of the simulation study for the reasons discussed above.

3.4 Field Trial Design

3.4.1 Introduction

The field trials plan has been constructed using the framework produced by DRIVE II project V2040 ie using the "12-steps" approach, although some of the steps are covered within the CORD blueprint for evaluation and so have been discussed in other sections of this report. The DRIVE project HOPES were contacted for specific advice and input for evaluating safety effects. Our specific criteria and criteria of effectiveness are outlined in Table 1 and have been designed to reflect the overall objectives of the DRIVE program ie improving efficiency, safety and environmental effects.

We intend during the field trials to provide measurement of the impact variables for both ex ante and ex post evaluation as accurately and inexpensively as is feasible. Where possible these will be directly quantifiable for comparison purposes. The EVA DRIVE I - V1036 document has been consulted with regard to which variables can be translated into monetary units.

Whilst the simulation study will run a large number of tests at increasing levels of complexity this will apply less with field trials as only a very restricted number of strategies will be implemented.

It is not our aim to report on the impact of a single ATT element, but rather to evaluate the inter-dependency of the combined components of the ATT system. It is anticipated that this combined effect (ie synergy) will be greater than the contributions which could be made by each of the elements. The definition of the ATT architecture is given in Section 1.

3.4.2 Form of Comparison

Whilst during the simulation study we intend to form a comparison between the effects of several integrated strategies, during field trials we will compare the criteria of effectiveness against the norm ie the system in normal operational use. We are constrained by financial and practical limitations against implementing more than a very small number of strategies in the field. Moreover we believe that the quality and quantity of data from a thorough assessment of one or two strategies outweighs that which would be collected from short trials of many strategies (given our budgetary constraints).

3.4.3 Definition of the Criteria of Response

For the impact variables previously defined we outline which criteria of response will be used to form estimates. For some criteria there are more than one criteria of response reflecting different impacts in sections of the study area. The criterion of response corresponding to each criterion of effectiveness (and impact variable) are shown in Table 3, together with the anticipated method of data collection and proposed statistical test.

3.4.4 Definition of the Blocks of Transport Contexts

The more precisely the transport block is defined, the easier it becomes to identify individual sources of systematic variation such as the `day of week' effect. It is recommended in the CORD report that a balance is achieved between the requirements of blocking and the overall cost of the field trial. With the exception of the safety impact (which is addressed separately in Section 5), we intend to observe each of the criteria of response for the morning peak (0800-0900), afternoon interpeak (1500-1600) and evening peak (1700-1800). It is anticipated that loop detectors will be used to collect a large part of the data needed. If time limitations and costs allow, these will be left in place for 8 weeks, giving 8 replications for each block.

As indicated in Table 3 (and the disaggregate impact groups of Table 2), criteria of response will be collected for several subgroups, for example, vehicle categories. Data collected manually in the field such as the number of stops) will form the same blocks but contain fewer replications due to financial constraints.

3.4.5 Allowing for Integration Effects

We anticipate that there may be significant interaction effects between the integrated system, blocks and background environments. Our interest would not be primarily in the block or environment effect but rather in the interaction effect itself.

3.4.6 Formulation of the Model of Response

The general model to be used to estimate the scheme effect is given in Section 1 and includes each of the factors we anticipate will affect the value of the response criteria. The specific elements of the model will vary according to the impact in question. For some impacts we may be able to measure or estimate model elements quite accurately (such as speed) whereas for others (eg crossing delay) the variation element may be more difficult to quantify.

3.4.7 Definition of the Test Sites

A description of the architecture of the test sites is given in Section 2. A small scale study survey of the sites will be carried out before the conflict safety studies take place in order to 1) identify suitable junctions for observation and 2) collect data which will allow sample size calculation. The aims of the full scale study will be both technical and operational ie we will have an interest in both the performance of the technical equipment and the operational impacts of applying a strategy developed by simulation. However it is not our intention to form a comparison between the relative merits of the SPOT/SCOOT systems.

3.4.8 Sample Size Calculations

In addition to the sample size calculations given in Section 5 other sources for required sample sizes include the MVA study, TAM recommendations, CEC DRIVE I project V1049 Field Trials Manual and advice from the DRIVE II HOPES project. Note that some sample sizes (and corresponding data accuracy) are constrained by financial and practical limitations.

3.4.9 Experimental Plan

Since only a very small number of integrated strategies is to be tested in the field we do not envisage that a complex experimental plan will be needed. However for the Dewsbury Road site 4 different traffic environments will be used (as outlined in Section 1). We propose to change the environment in a sequential manner, although the order in which this is carried out will be determined by the contractor. Further details of the field trials plans are contained within Appendix A3 for both Turin and Leeds sites. These include preliminary estimates of timings (where possible) together with the contributions of particular items towards the evaluation plan.

3.4.10 Integrity of the Field Trial

We are aware that there may be sources of error which it is either impractical or too costly to measure or eradicate and these will be taken into consideration when drawing conclusions from our results. As far as completeness is concerned we have made a deliberate decision not to measure changes in modal split or attempt to quantify re-assignment issues and are estimating impacts such as stress and severance using surrogates rather than questionnaire studies. We are also aware that the strategy may have a wider impact on pedestrians, residents, shopkeepers and side roads than we will be able to measure.

We are also conscious of errors which may be made in actually measuring the criteria of response. A large amount of data will be collected using GK5000 and GK6000 loop detectors. The quoted error rates for these are an accuracy of ± 1% of total flow for volumetric counts and ± 2 mph for speed counts. Whilst police accident records are felt to underestimate accidents, considerable research has been conducted into the validation of the conflict study process. Errors which may arise in number plate matching include those from mismatched partial plates and in recording the data. Additional sources of variation may occur from incidents such accidents or illegal parking which are difficult to predict but can be recorded with the data.

3.4.11 Measurement of the Criteria of Response

The data collection methods for the criteria of response are shown within Table 3. When the corresponding criteria of effectiveness have been calculated, these may be tested statistically in their original units. The method of evaluating the success of the scheme using the resulting measurements of these criteria of response is discussed in more detail in section 7. A summary of these criteria of response which will be collected on a link basis and those to be collected on a route basis is given in Table 4.

Table 4: Summary of criteria of response to be collected on link/junction and whole route basis for field trials

Level of data collected	
Link/Junction	Route
Mean Journey Time	Mean Journey Time
Variance Journey Time	Variance Journey Time
Mean Speed	Mean Speed
Variance Speed	Variance Speed
Proportion "speeding" vehicles	Mean Fuel consumption for vehicles
Total No of stops	Total No of stops
Conflict study	Accident statistics
Mean Queue length	Mean traffic density
Mean Traffic Flow	Mean traffic flow
	Mean Vehicle occupancy
	Variance bus journey time

3.4.12 Specification of Equipment, Resources and Management

Certain practical constraints apply to the field work yet to be done, and these are summarized here together with other commitments which will operate.

a) Some of the ATT aspects of Traffic Calming and Public Transport priority will be implemented through the SCOOT and SPOT systems. These systems basically optimise the split of green times and offsets at upstream/downstream junctions using on line information. These systems are responsive to the current traffic situation whilst traditional traffic light control would use historic data. One ATT element of TC will be implemented using offset control via SCOOT and SPOT which will effectively control speeds along a link.

b) It is planned to install SCOOT initially at Dewsbury Road and test one strategy in the months of Jan/Feb 1994. This will then be replaced by the Italian SPOT system and an alternative strategy assessed. Due to contractual arrangements there will be no financial incentive to removing the SPOT system before the end of 1994. If the system clearly shows some benefit it is therefore envisaged that SPOT may remain in operation for some time and be subject to subsequent evaluation studies if funding becomes available.

c) The ATT element of PT will consist in part of selective detection such as the relatively inexpensive bus detector system TIRIS. This will transmit information into loops within the road which can then be fed back to SCOOT/SPOT and be translated into measures such as holding or hurrying the green light. A major bus operator in Leeds has indicated that they are willing to buy TIRIS for their entire fleet. A similar system (SIS) is already in operation for the whole of the Turin PT bus fleet.

d) During 1993 a private developer will complete civil engineering works for the SCOOT systems ie the installation of ducts etc. Other elements of the system are already in place at the Leeds control centre. Following the necessary highway works there will follow a `run in' period to get the whole system working reliably.

e) The simulation program NEMIS interfaces with SCOOT/SPOT and effectively mimics the real network. In simulation trials, information will be fed from NEMIS to SCOOT/SPOT which will then determine green time splits/offsets for the network within NEMIS. Simulations would be carried out before the implementation of SCOOT/SPOT in the field as the system has been partially installed at Leeds.

f) At the field trial stage we expect that only one or two `final' test strategies will be implemented. These final strategies will have been selected by testing a much larger number of integrated strategies (with a limited number of background environments) using NEMIS. The ATT/TC measures will be modelled in simulations by reducing speeds on side streets. Note that it is not the purpose of PRIMAVERA to optimise highway engineering TC measures as these will have been decided upon and will be implemented at the Dewsbury Road site at any rate. However the scheduling of their implementation is at present undecided and this could take place either before or after the installation of SCOOT.

g) A substantial proportion of the Leeds based `Before' studies have already taken place (in March 1992) with one Highway Engineering PT measure in operation ie the short outbound bus lane.

However if funding allows we intend to collect further before data on variables specifically mentioned by DRIVE auditors eg crossing delay.

h) Small scale field surveys are to be carried out to assess the `growth' factor for the `do nothing' scenario. Other sources of information could be estimates from similar sites or projections from local authority data.

i) Use will be made of a combined speed camera and VMS system at the Dewsbury Road site near the pelican crossing. This will involve placing a VMS sign about 200m from a speed camera and the sign would be activated, displaying a suitable message if a speeding vehicle approaches. If the vehicle ignores the message the speed camera will photograph the speeding vehicle and the driver subsequently prosecuted. This is expected to generate clear safety benefits from an ATT calming measure.

j) VMS signs are also to be used in Turin as part of the speed control strategy.

3.5 Potential Additional before studies Required

If the impact of each integrated strategy is to be measured on the 10 variables identified so far (alterations to the list may be made later), then potentially the following additional `before' studies will be needed.

Variable	Before Study Required
Journey time	Number plate matching Pedestrian delays Buses Speed distributions from UTC
Vehicle Operating Cost	Either: Data from Bus company (if released) OR: Information from program eg COBA if available
Comfort	Survey Bus load factor/No of bus and car stops as surrogate
Safety	Conflict study
Air Pollution	Estimate with simulation trials using NEMIS
Crossing Delay	Small field studies to back up NEMIS simulations
Stress	Use surrogates No of stops/queue lengths (Driver stress), Waiting time/speed/traffic flow (Pedestrian stress), some of which have been surveyed.
Visual Intrusion	Survey queue length.
Vehicle Occupancy	Field study needed.
Bus journey time variability	Data to be extracted from UTC information.
Speed	Spot speeds for speeding vehicles

4. IMPACTS IN THE WIDER SENSE

4.1 Inter-dependencies of the Integrated System

It is one of the prime objectives of the PRIMAVERA project to develop an integrated system and so the inter-dependencies of various elements are of major importance. Measuring and evaluating this synergy effect therefore has greater priority than assessing the contributions of individual elements.

4.2 Generalisation of Field Trial Results

The extent to which field trial results can be generalised will necessarily be constrained by the integrity of the field trials as outlined in Section 3.4.10. However generalisation will be possible to a substantial degree as sites will be studied both in the UK and Italy. Moreover, the use of different environments (as described in Section 1) will mean that our results will have significance for other urban radials with differing highway engineering characteristics. In particular, the OCTOPUS SERC Project (No 446597) is to investigate strategies developed within PRIMAVERA on five UK urban arterials (including Dewsbury Road) using NEMIS simulations. Statistical analysis of this larger sample will enable more generalised conclusions to be drawn and recommendations made for adoption by practising traffic engineers.

5. EVALUATION OF SAFETY IMPACT

5.1 Introduction

The DRIVE II project HOPES has been consulted with regard to our plans to evaluate the safety impact of the integrated strategy. The simulation studies will only provide estimates of the safety benefits and so field trials are essential to monitoring the benefits of the strategy. Police accident records have already been obtained for the seven year period preceding the anticipated time of field trial study and we expect that these will also be made available for the period following implementation. These will be supplemented at both Leeds and Turin sites with a conflict study carried out at particular junctions along the route. We will also be looking for safety benefits in terms of reduced mean speeds, both for individual links and for the route as a whole. A recent report by the Department of Transport ("Killing Speed and Saving Lives") indicates that between 22% and 32% of the accidents studied had excessive speed as a contributory factor. Moreover, a TRL study indicates that a reduction in mean speed everywhere of around 1km/h could save 5% of all injuries and 7% of fatal accidents. Clearly a drop in mean speed of 1km/h appears very small but could have an important safety effect. As indicated in Appendix A5 an enormous sample size would be required to measure a drop of this size accurately using floating observers. However using data collected from number plate matching and ATC's this may be possible. A report (given in Appendix A6) has been made of an initial study of the Dewsbury Road site with respect to the application of conflict study techniques.

Following our discussions with HOPES, the following points have emerged with regard to the safety evaluation:

5.2 Sites of Interest

This is primarily Dewsbury Road itself at the UK site, but we may also be interested in effects on side streets. Due to financial constraints we are likely to have to restrict the study to between 3 and 6 sites along Dewsbury Road. This restriction may result in our missing any change in safety effects at other junction sites (or in the surrounding areas). Plans are also being made for conflict studies to be carried out in Turin, although the preliminary stage of this is the training of Turin staff in the technique.

5.3 Preliminary Study

A trained observer is to conduct a preliminary investigation of the most suitable sites for study, noting the complexity of the junction and number of observers required. The preliminary study is to include one day's collection of data at each of the earmarked sites. The information gathered can then be used as a basis for determining the location, extent and manpower required for more extensive before and after studies.

5.4 Choice of Sites for the Before and After Study

These are to be determined as part of the pilot study. A balance is needed between the "regression to mean" effect which may occur at high incident sites and the need to collect meaningful quantities of data. The regression to mean effect could result in the after study exaggerating the safety effects of the strategy as a reduced number of conflicts may occur at that particular site in the "do nothing" scenario. Whilst the whole of Dewsbury Road, and to some extent the surrounds are of interest, financial constraints are likely to mean that the final choice of sites will be along Dewsbury Road itself. Similar financial constraints are expected to apply to the area of impact in Turin.

5.5 Staffing Requirements

Staff carrying out the conflict study must be fully trained. At present 1 trained member of staff is available at the Institute and a further 2 are expected to be trained from HETS, giving a total of 3 who may be available for the before and after studies. Depending on the number of junctions finally chosen, a survey plan is required for the rotation of staff, sites and days. Rotating staff and sites helps to overcome human bias in the results (which validation has shown is not large in any case) but also reduces boredom and fatigue for the observer. Particularly complex sites may require 2 observers, although an alternative is to survey 1 part of the junction one day and the other part on another day. Ideally video cameras would be used as support to observers. Although no trained staff are currently available in Turin, plans are in progress for a training programme to be carried out in the city.

5.6 Timing of Conflict Survey

During the day it is not sufficient to study the peak period only, as in the free flow conditions of the off-peak period more conflicts (or conflicts of a different type) may be observed. As it is expensive and exhausting for observers to record from, say 7.45 am to 6.30 pm, it has been suggested that we use the interpeak and evening peak periods (ie 10.00 am to 6.30 pm). Observers are likely to require a break every hour. Ideally we would survey a full 7 days to reflect the full range of traffic conditions. However conflict studies are often restricted to five days per week. The specific week and days selected for the after study would ideally correspond to those for the before study as this will help reduce daily and seasonal variation.

5.7 Type of Conflict of Interest

We intend to study car-car and car-pedestrian conflicts in the serious category although other types of conflict could be surveyed. The data on car-pedestrian and car-cyclist conflicts will give a useful indicator of stress for these groups.

5.8 Estimating the Scheme Effect

Experience has shown that data should not be considered on too disaggregate a level, but rather a broad view should be taken of the conflicts profile "after" compared with that "before" scheme implementation. It is possible to test statistically whether there has been a significant change, but a non-significant change should not be ignored particularly if it accompanies reduced mean speeds and other beneficial effects.

6. COMPUTER SIMULATIONS PLAN

6.1 Introduction

Computer simulations will take place using the NEMIS Program which provides an interface to the SCOOT and SPOT systems. It will therefore be possible using NEMIS to simulate different strategies on the computer as they would be expected to perform in the field under SCOOT or SPOT. Further details of the SCOOT and SPOT systems are contained in Appendices A1 and A2. Due to practical, financial and time constraints the number of strategies applied in the field at both Leeds and Turin sites is likely to be very small. However the simulation trials will allow a much larger number of integrated strategies to be assessed.

6.2 Data Collection by NEMIS

A detailed description of the output files and data generated using NEMIS is given within Appendix A7. Although vast amounts of information of a very detailed nature can be produced by the program, the summary files giving overall statistics for the network will be of most use. As the data generated will not replicate the field trials exactly, the evaluation framework for simulations will be slightly different from that for field trials (using, for example, speed statistics as a surrogate for safety effects). Further details of the evaluation methodology for the simulations is contained in section 7.

6.3 Criteria of response and level of Aggregation

The criteria of response and level at which the data will be collected are summarized in Table 5. Comparing these with the criteria of response for field trials (Table 4), the main differences are in the simulation of data for emissions, average stop time, fuel consumption and bus travel times.

Table 5: Summary of criteria of response to be simulated on link/junction and network basis

Level of data to be collected	
Link/Junction	Route/Network
Mean speed "Speeding" vehicles Spot speeds (mid link) Queue length Fuel consumption Mean stop time Variance in speed Mean Journey time Variance Journey time Delay Mean flows Mean Bus travel time Emissions (NO_x, HC, CO)	Mean speed "Speeding" vehicles Vehicle Operating cost (private/public) Fuel consumption Mean stop time Mean journey time (Network/OD pair) Delay Mean Bus travel time Emissions (NO_x, HC, CO)

6.4 Timing of simulation studies

The Dewsbury Road network has already been calibrated within NEMIS and initial simulation results obtained. These are given in more detail in Clark and Montgomery (1993). Essentially data from the surveys which took place in March 1992 were used for calibration purposes. In particular the measures of traffic flow, private vehicle journey times, queue lengths and public vehicle journey times were utilized. The initial task of simulating base conditions and the four environments (as outlined in Section 1) will be followed by simulations of the integrated strategies. Further work is being undertaken to finalise the list of strategies for testing. Although a large number will be tested, since it takes at least half a day to run the simulation, careful consideration is being given to which strategy combinations will prove the most fruitful. It is anticipated that all simulations will have been completed by the end of Oct 1993.

6.5 Choice of likely strategy combinations for SCOOT

As there are a total of 13 individual strategies (including the base case), 4 different environments and 3 sets of conditions (ie AM peak, inter-peak and PM peak) for Dewsbury Road. This gives a total of 156 possible required, as outlined in Appendix A8.

As practical constraints will not allow the simulation of all 156 possibilities, we intend to prioritise these into three categories and simulate as many as resources will allow. The priorities for the QM techniques, PT priority and TC strategies are described in detail within Appendix A8. To summarise, we intend to simulate at minimum:-

Base Case:	100%
QM Techniques:	25% (50%)
PT Priority:	50% (75%)
TC Strategy:	21% (33%)

where the figure in brackets indicates the maximum percentage we expect to be possible and the lower figure is the minimum we intend to achieve. A timing schedule between 4 weeks and 13 weeks is also described in Appendix A8, the schedule depending upon the level of priority and the number of simulations completed per day.

6.6 Simulations using the SPOT system

A separate schedule has been constructed for the simulation of each test site in Turin and the Dewsbury Road site (as outlined below) using the SPOT system. These are around in greater detail in Appendix A8.

6.6.1 Simulated test site - Turin

Two environments are to be considered the Turin - Gran Madre site, these being the base case and addition of a reserved bus lane ("Modified" environment). Seven strategies from the QM/PT areas will be simulated individually at first (see Appendix A8 and Internal Audit Report 24/11/92) and these will then be formed into 2 integrated method strategies for simulation.

A more thorough evaluation study is planned for Corso Grosseto, with three integrated strategies to be simulated from combinations of 2 QM strategies, a bus stop protection scheme and 2 TC strategies. All the strategies for Turin to be tested by simulation may then be applied in the field.

6.6.2 Simulated test site - Leeds

A total of eight individual QM/PT/TC strategies are to be simulated using NEMIS/SPOT for the Dewsbury Road site. The QM strategies are to be simulated for AM, Interpeak and PM conditions whilst the PT and TC techniques will be simulated for the AM period only. As outlined in Appendix A8, these individual strategies will then be combined to form four integrated strategies. Two of these will consist of QM/PT measures and be simulated for AM only whilst the remaining two strategies combine QM/PT with TC and will be applied at all three time periods. The total number of simulations will be increased for the Leeds site, however, due to the four background environments against which strategies will be tested.

7. EVALUATING SCHEME PERFORMANCE

7.1 Introduction

It is expected that evaluation for both field trials and computer simulations will be achieved using both Cost Benefit Analysis (CBA) and Multi-Criteria Analysis (MCA). The aim of the simulation study is to test and develop integrated strategies and then provide comparisons between strategies. The field trials however are intended to evaluate the implementation effects of a strategy on a `before' and `after' basis. The criteria of response which will be collected in field trials are described in section 3 and those for simulations in Section 6. Due to slight differences in the aims and data collection between field and computer trials, a separate evaluation scheme will be used for each.

7.2 Cost Benefit Analysis

For the purposes of overall scheme evaluation the measurements for criteria of response can be translated into monetary values as suggested in the EVA manual.

These have in some cases been obtained from the COBA program and include the following examples:-

Table 6: Examples of costing non-monetary impacts

Travel Time:	Working Persons	dispatch time	8.5
		access-egress time	17.0
	(Units = ECU/pers.h)	wait-search time	21.8
		pure travel time	17.0
	Non-Working Persons	dispatch time	2.1
		access-egress time	4.3
	(Units = ECU/pers.h)	wait-search time	8.5
		pure travel time	4.3
	Vehicles	cars	0.8
		buses	7.9
	(Units = ECU/veh.h)	lorries	3.1
Safety	All Persons	fatality	744,177
		seriously injured	105,593
	(Units = ECU/persons)	slight injury	7,080
	(ECU)	material damage	1

Source: EVA Manual

Costing the impact variables in this way could then form the basis of an overall-cost benefit analysis for the scheme.

The same costs can be used for both field and simulation trials. However it is yet to be decided whether different costs should be used for UK and Turin results. For example the value of pure travel time in 1990 was:-
14.26 ECU/person hour for the UK
18.28 ECU/person hour for Italy
but the European average is 17 ECU/person hour.

Some of the issues which need to be resolved in terms of CBA for simulations are as follows

a) Travel time per vehicle class can be collected and multiplied by an average number of passengers, however data must be obtained for an average number of passengers for each time of day.

b) Vehicle Operating costs can be split into fuel and non-fuel costs as suggested by the EVA manual.

Fuel consumption costs may be based on petrol at 0.36 ECU/litre (1990) but this figure may now be out of date. Some modifications have been carried out to NEMIS to incorporate a fuel consumption model.

	Non-fuel costs
Cars	0.09 ECU/Veh.km
Lorry	0.14 ECU/Veh.km
Bus	0.45 ECU/Veh.km

c) Implementation costs - for simulation purposes it is not necessary to know the cost of the base or common scenario, for example in Leeds all strategies will have in place SCOOT 2.3. However different strategies may perform better under different environments which do not exist eg traffic calming of side streets, bus lanes etc. Public transport priority measures which include selective bus detection could have additional ATT costs for implementation. Further work is therefore needed in defining the cost of the strategy which should be separated into ATT and Environment costs.

d) Air Pollution/Emission - as these will not be measured in field trials the simulations will provide important estimates of the scheme effect. The following figures are available from EVA

Carbon monoxide	3	ECU/ton
Nitrogen Oxides	443	ECU/ton
Hydrocarbons	348	ECU/ton

e) Overall the CBA for simulation is based on 4 main areas - implementation costs, travel time, vehicle operating costs and emissions. However the main weakness with the simulation study lies in the assessment of safety, which may have to concentrate day on speed estimates.

7.3 Multi-Criteria Analysis

Multi-criteria analysis will be used in addition to CBA to give a more structural analysis of gains and losses from the strategy. Whilst we will consider the value of an overall performance indicator (both or field and simulation trials), it is expected that strategy `scores' on the contributory variables will give useful and important insights into the scheme performance. These contributory variables fall into the 3 main DRIVE goal categories of safety, efficiency and the environment. Weights will be assigned to each of the variables according to their perceived relative importance. The exact weights to be used have yet to be decided and will be produced following discussions between PRIMAVERA partners, the relevant Local Authorities and possibly politicians. Draft versions of the simulation and field trials MCA tables are given in Tables 6 and 7 which are contained within Appendix 9.

7.4 Criterion Utilities

Criterion Utilities must be defined for each of the variables included in the MCA. Initially these are expected to follow the same pattern as those illustrated within the EVA manual.

An initial estimate has been made of the expected size of the impact we may anticipate from field trial implementation. These are shown below and were formed using.

a) Results of a `Delphi' study carried out in the early stages of the PRIMAVERA project, together with other expert opinion.
b) Initial simulation results

Impact	Conjecture
Bus journey times	down 10%
Other journey times	down 10%
VOC	down 10%
Accidents	down 10%
Pollution emission	down 15%
Pedestrian Crossing delay	no sig change
Flows	up 2%
Car Occupancy	no sig change
Bus Occupancy	up 5%

As further simulation results are produced, these figures may be subject to revision.

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APPENDIX A1 : Evaluation using the SCOOT System

A1.1 Introduction

This note describes what data can be extracted from the SCOOT UTC system for possible use in the evaluation of integrated traffic management strategies applied to the PRIMAVERA Dewsbury Road field trial site in Leeds. It will be possible to use data from both the simulated NEMIS runs via the SCOOT/NEMIS interface and from the actual field trials. If we find that SCOOT data gives a reliable indication of what is happening within the simulation then there is the possibility of using SCOOT to enhance our field trial data collection.

The primary purpose of the SCOOT UTC system is to optimise signal timings in a network, according to current traffic conditions, to reduce overall delay. To calculate these optimised timings SCOOT collects a vast amount of data from loop detectors around the network which is then processed to produce a traffic model.

Hounsell et al (1990) have reported on the development of a computer program to extract this information, both the raw and SCOOT processed data, into a traffic information database. It was felt that this information could be used for a variety of purposes. The original program ran on an IBM compatible microcomputer and extracted information from a SCOOT system running on a Plessey computer. The database was manipulated via a dBASE package. The program has been subsequently developed further by TRL, to allow it to run on other SCOOT computers. It has been given the name ASTRID and is available under license for a cost of £5000. Nottingham University Transport Research Group have also been analysing SCOOT data, this time from the instrumented city project in Leicester. They are not using ASTRID, but have developed their own software for processing SCOOT messages downloaded to a PC connected to the SCOOT computer via a modem.

Our field trial site in Leeds consists of a 3km section of the Dewsbury Road, which contains 7 OTU's (Outstation Transmission Unit) with 32 detectors, controlling seven intersections and three pelicans. Our SCOOT 2.3 system currently runs on a FERRANTI 700 industrial computer.

It would be interesting to compare what SCOOT thinks is happening on our simulated site with what our simulation tells us is actually happening. When our real field trials in Leeds start towards the end of this year, SCOOT could automatically provide us with some of the standard parameters used in any evaluation, such as traffic demand, traffic flow, delay, number of stops, queue lengths etc.

SCOOT provides data at a variety of levels of time aggregation (4 seconds, cyclic, 5 minute aggregations etc., and depending on the data item involved at the detector, link, node and region levels. The following table summarises the available data:

Quantity	Units	For	How Often
Flow	LPU/hour	Link	Every 5 mins
Delay	LPU/hour	Link	Every 5 mins
Stops	LPU/hour	Link	Every 5 mins
SCOOT Congestion	Intervals/hour	Link	Every 5 mins
Queue lengths	LPUs	Link	One per cycle
Queue clear time	Seconds	Link	One per cycle
Stage timings	Seconds	Node	Every 5 mins
Stage lengths	Seconds	Node	Every 5 mins
Offsets	Seconds	Node	Every 5 mins
Cycle time	Seconds	Node	Every 5 mins
Performance index	-	Network	Every offset optimisation

Traffic demand is measured and processed by SCOOT in Link Profile Units (LPUs), a hybrid measure of traffic flow and detector occupancy. On-street measurements have shown that, on average 1 vehicle is equivalent to 17 LPUs and SCOOT uses this conversion factor when giving traffic flows in vehicles/hour. In fact, LPU/flow conversion factors can vary between sites by up to ± 50% from 17, depending on local traffic, geometric and detector characteristics. Therefore link specific conversion factors will have to be determined during the calibration process in order to produce accurate measures. The actual definition of an LPU is as follows. SCOOT loop detectors perform a scan every $^{1}/_{4}$s and if a vehicle is detected during the scan a bit is sent to SCOOT. This results in a binary stream of blocks of 1s and 0s being sent to SCOOT. Each block of consecutive 1s arriving at SCOOT is converted in LPUs as follows. For the first bit a 7 is added, for the second bit a 6 is added, for the third bit a 5 is added etc., all the way down to 0 added for eight or more bits. This is summarised in the following table.

Consecutive detections in $^{1}/_{4}$s scans	LPUs
1	7
2	13
3	18
4	22
5	25
6	27
7	28
8	28
>8	28

Therefore the LPUs will vary if either the number of vehicles crossing the detectors changes or if their speed changes or if the speed distribution of vehicles crossing the detectors changes.

The PRIMAVERA field trial evaluation methodology is based on a set of impacts. It is consistent to try and evaluate the simulations by using the same set of impacts produced by the traffic control measures. The rest of this report goes through each impact and determines whether data from SCOOT can be used to indicate how the impact has changed.

A1.2 Journey Times

Further investigation is needed as to whether any deduction can be made from the SCOOT data about journey times.

A1.3 Vehicle Delay

Traffic delays are predicted by the SCOOT traffic model from the information on traffic demand and known signal timings. However, there does not appear to be any way of discriminating between private vehicles and public transport.

It should be possible to construct a measure of pedestrian delay based on the signal timings at the intersections and pelican crossings.

A1.4 Vehicle Operating Cost

The EVA manual (1991), p.39, reports that Vehicle Operating Costs are usually broken down into five cost elements:

- fuel consumption,
- depreciation due to usage,
- consumption of lubricants (oil),
- wear of tyres and
- maintenance and servicing including spare parts.

They state that in most evaluation frameworks all these elements apart from fuel consumption are assumed to be only dependent on the distance travelled, which in our case will not change by applying our ATT strategies. Therefore the only element we need to consider in determining changes to vehicle operating costs is fuel consumption.

Robertson et al (1980) put forward the following expression for estimating fuel consumption from the signal plan produced by the signal optimization program TRANSYT.

$F = 0.1\,L + 1.5\,D + 0.008\,S$ where

F - total fuel consumed (l)
L - total distance travelled (km)
D - total vehicle delay (vehicle hours)
S - total number of stops/starts

These values are based on a cruise speed of about 37 km/h. The TRANSYT User Guide, Vincent et al (1980), gives a slightly different formula based on the same data ie

$F = a_1\,L + a_2\,D + a_3\,S$

where $a_1 = 17 - 0.455\,V + 0.0049\,V^2$ (l/100 pcu=km)
$a_2 = 1.4$ (l/pcu-hour)
$a_3 = 770.10^{-8}\,V^2$ (l/pcu-stop)

with V being the constant cruise speed (km/h).

If we assume that we know the changes that our measures will make to each link's cruise speed then we can use this formula to determine the amount of fuel consumed.

A1.5 Comfort and stress

The EVA manual (1991), p.40-41, reports that comfort must be considered intangible. It cannot be quantified and no general criteria can be given. However, it does suggest that comfort will be related to travel time, reliability and delays. We might therefore consider using the number of stops as an indicator of comfort.

A1.6 Safety

Safety is measured by changes in accident rates. Very little precise data seems to be available that could be used to accurately predict the changes in accident rates or the severity of accidents due to the application of a new integrated ATT traffic management strategy. One possible indicator appears to be the average speed of vehicles. Finch et al (1993) are shortly to publish a Transport Research Laboratory research paper which indicates that for each 1 mph increase in average speed accidents rise by about 5 per cent.

TRANSYT predicts the average journey speed, so it might be possible to use SCOOT parameters to estimate average speeds that could then be used to predict accident rates. Another possible indicator is flows.

A1.7 Air Pollution

It should be possible to estimate vehicle emissions in the same way as fuel consumption. May and Clausen (1976) modified TRANSYT to get it to predict vehicle emissions of CO, hydrocarbons and nitrous oxides.

An alternative approach might be possible if average speeds can be estimated from the SCOOT data. These could then be used in conjunction with emission tables from the CORINAIR project, which give emissions of a variety of pollutants according to the average link speed. It would be interesting to compare these values with those coming out of NEMIS.

A1.8 Traffic Flows

SCOOT measures traffic flows in LPUs/hour on all the links.

A1.9 Average Density

Two occupancy based parameters are used by SCOOT as a measure of congestion. The units for both measures are full intervals per five minute period, where a full interval is a four second interval during which the detector on a link is continuously occupied. The first parameter is simply the number of these intervals detected, the second parameter is the number of full intervals during which the back of the queue on the link was greater than half of its maximum value. The first parameter measures the amount of queuing over a SCOOT loop due to either congestion or an incident, (eg a broken down car), the second parameter measures the amount of queuing solely due to congestion.

A1.10 Queues

Estimates of queue lengths on each link are produced directly by SCOOT.

A1.11 Blocking-Back

It should be possible to estimate when blocking back is occurring from the SCOOT data.

A1.12 Conclusions

SCOOT has the potential to automatically collect much useful data required for the evaluation of our strategies. Whether this data will be accurate enough to allow us to distinguish the different effect of our strategies is a matter for further study.

APPENDIX A2 : Evaluation using the SPOT system

A2.1 SPOT Architecture and data acquisition

The SPOT unit has been conceived to perform both as a last generation traffic light controller within the UTOPIA system and as a research instrument, being able to support the measurement and collection of a wide range of traffic data.

Moreover, the software can be easily modified in order to implement, if necessary, new control strategies and/or different types of data collection.

A2.2 Summary of Evidence

The SPOT unit functions can be subdivided into three modules:

- Data acquisition
- State observation
- Traffic light optimisation

The unit is able to log data generated by these three functions. Thus, it is possible to reconstruct accurately both the traffic conditions and the policy decided by the controller.

Details of data produced by the three modules above are as follows:

Data acquisition:

In the typical configuration, the unit is connected to a set of loop detectors. Usually they are placed on the main carriageways of the intersection, using one detector (single loop) per lane. There are input loops at the beginning of each incoming carriageway and output loops at the beginning of each output carriageway, just after the intersection centre.

The data acquisition module samples the status of the loops, detecting the presence of the vehicles. As far as possible, the module eliminates double counts due to overtaking or wrong position of vehicles within the lanes.

Data produced by this model are:

- Vehicle counts for each detector group (detector group is the set of the detectors placed on a carriageway cross-section); the aggregation time is 1 step (3 seconds).

State estimation

The "state observer module" each step (3 seconds) performs an estimation of the state variables and of the main parameters of the intersection:

- Queues on the incoming carriageways, disaggregated per link (logical objects grouping the incoming vehicles which will use the same traffic light stage).

- Vehicles arriving at the stop line.

- Release saturation flow (maximum rate of the outgoing flow, for each link).

- Turning percentages.

- "Births" and "Deaths" (parameters used for recovering the errors in traffic counts due to unmeasured secondary flows, lack of sensors etc.)

Traffic light optimisation

This module decides the best sequence of stages from the current time up to 40 steps (120 s). This computation is repeated each step. Its fundamental output is the sequence of the commutations for the next 40 steps.

A2.3 Current form of data and their availability

The standard SPOT firmware is currently configured for saving the data mentioned above in files on the unit's silicon disk. Using suitable procedures, it is possible to remove the data from the unit and process them on a personal computer running MS-DOS operating system. Tools for this activity are available.

Currently, the data are subdivided into two binary files, OSSERVO.BIN and SATURA.BIN; it is possible to configure the unit to store only one or both of the files.

Virtually, the files cover a measuring period of one day, starting from midnight. At midnight, data files are renamed and stored, making them available for the analysis.

In practice, the covered period can be different, depending on the total amount of storage RAM on the silicon disk card and on the type of recording required (complete or partial).

SATURA.BIN

Each step (3 seconds) this information is recorded in a fixed frame record:

- absolute time (seconds starting from midnight);
- stage currently running;
- for each link; queue (estimation of the "vertical queue").

OSSERVO.BIN

The file has a variable record structure. Each type of record (usually called "message" in the SPOT terminology) is identified by a character, and contains different data which can be used both for traffic representation and algorithm tuning and debugging. Each group of data is recorded every cycle (note that in the SPOT system the cycle length is not fixed, so that the interval between a record and the next one can vary).

Some data could be considered redundant; the reason for recording them is to allow for a complete tuning and debugging of the modules.

The main group of information is as follows:

- traffic counts for each (instrumented) outgoing carriageway:
  - number of vehicles counted during the green stages releasing on the outgoing carriageway (taking into account the crossing time);
  - number of vehicles counted during the whole cycle;
  - number of vehicles expected to be counted on the outgoing carriageway, forecast using the incoming links queue estimation (for debugging purpose);
- Estimated parameter representing the performance of the sensors:

% of "births": vehicles appearing on the outgoing carriageway without being-observed by the input detectors.

% of "deaths": vehicles expected to pass on the output detector which are not observed.

- Traffic counts for each (instrumented) incoming carriageway:

  - number of vehicles counted during the cycle.

- Estimated parameters:

  - "births" and "deaths" on the input detectors.

For each "link" (see definition above):

  - Estimation of the release saturation flow.
  - Queue last at the end of the green.

- For each turning movement originated by the link:

  - Flows counted on the corresponding green stage
  - turning percentage (link-> turning movement).

Other information, concerning mainly the behaviour of the observer module and used for debugging purposes, is also available.

A2.4 Existing tools for data analysis

A graphic tool for the representation of data is available. It can represent, in the form of a time-moving graph, the main estimated parameters, like queues, turning percentages, saturation flows etc, together with the cycle actuated. The program, as all the tools developed for the SPOT system, can be executed on a MS-DOS personal computer.

Other programs have been developed for decoding the data files and transforming them in simple ASCII tables, which can be imported and processed by standard spreadsheets, in order to obtain statistics and graphs and compute indicators.

A2.5 Considerations about the performance indicators measurement

Data logged by the SPOT unit could be useful for the evaluation of some indicators in the impact analysis process. In order to improve the evaluation, some extra data should be included in to the existing log files.

Main fields of applications could be:

- Queue management
  - Traffic counts.
  - Value of the queues on the arterial.
  - Release saturation flow.
  - Estimation of stops (to be implemented).
  - Flows and queues on crossing streets (if instrumented).
- Bus priority (if real field trials with selective detection are to be implemented).
  - Time of PT arrival (to be implemented).
  - PT Stop and delay (to be implemented).
- Traffic calming and comfort
  - Flows and queues on particular crossing streets (if instrumented).
  - Number of stops on the arterial.
  - Turning percentages (indicating diverted flows towards surrounding area).
  - Logging of pedestrians calls (to be implemented).

APPENDIX A3 : DETAILED FIELD TRIAL PLANS

A3.1 Field survey plans for Leeds

A3.1.1 Background

The evaluation of the field trails is to be based on a series of "before and after" surveys of performance indicators as set out in this report. A series of "before" surveys were carried out in 1992 and will be used as the basis of the evaluation, with corresponding surveys carried out after implementation. However, events since 1992 have indicated the need for a wider range of "before and after" surveys than was originally envisaged. The following sub-section on the survey details is therefore structured as follows:

- a plan for `after' surveys to match the 1992 `before' surveys;
- a plan for several new "before" and corresponding "after" surveys.

The costs given below assume that the `before' surveys which still remain to be implemented will be carried out once (for each of the three periods of the day) and all `after' surveys will be carried out twice (for each of the 3 periods of the day). This is because `after' surveys are needed to evaluate two integrated strategies.

A3.1.2 Survey details

a) "After" surveys to match the 1992 "before" surveys

(i) Journey time surveys by floating car

A series of journey time surveys were carried out in 1992 using the "floating car" technique. These were to provide "before" data on travel times on links and routes of the test network. Two problems have since arisen. The first is that a need to measure the number of stops made by vehicles has been identified. This data is best collected by floating car survey, but the 1992 survey did not record this information. The second is that subsequent calculations (in the main part of this report) have shown that the 1992 sample size is too small to be able to detect expected changes in mean travel time with any certainty and, given the time which has elapsed since 1992, it is not reasonable to carry out further surveys to augment this "before" sample size.

The preferred solution is to carry out a new set of "before" and "after" journey time surveys by floating car, which will have a larger sample size and include measurements of numbers of stops. These are described as new before and after surveys in sub-section A.3.1.2 b) below.

(ii) Automatic traffic counts

Automatic traffic counts were carried out at 11 sites, by direction, for the `before' surveys in 1992. Those gave classified traffic flow data but did not record spot speed, which are now required. This effectively means that both a `before' and an `after' study still need to be carried out for the main purpose of collecting spot speed data. These are described in the new `before and after' surveys in sub-section A.3.1.2 b) below.

(iii) Junction turning movement counts

Purpose: to collect:
- turning movement data
- traffic composition
- link classified flows

Method: manual, using hand tallies or electronic data capture devices

Comment: implementation as in 1992 `before' study

Contribution to the evaluation (ref Table 3):

Impact	Criterion of effectiveness/response
Vehicle operating costs and fuel consumption	- Changes in OC and FC for whole route
Safety	- Changes in safety/accid. rate - To augment conflict studies
Crossing delay, uncertainty & visual intrusion	Changes in mean traffic flow for links and route
Traffic flows	Change in traffic flows for route and links

Duration: as in 1992 `before' study

Estimated cost £3300 x 2 = £6600 + VAT

iv) Link traffic flow surveys

Purpose: to collect:
- link traffic flows by direction
- composition
- bus load factors

Method: manual, using hand tallies or electronic data capture devices

Comment: implementation as in 1992 `before' study.

Contribution to the evaluation (ref Table 3):

Impact	Criterion of effectiveness/response
Vehicle operating costs and fuel consumption	- Changes in OC and FC for whole route
Safety	- Changes in safety/accid. rate - To augment conflict studies
Crossing delay, uncertainty & visual intrusion	Changes in mean traffic flow for links and route
Traffic flows	Change in traffic flows for route and links
Vehicle Occupancy	Bus occupancy

Duration: as in 1992 `before' study

Estimated cost £3420 x 2 = £6840 + VAT

v) Subsidiary counts

Purpose: to record the use of side streets and minor junctions on Dewsbury Rd.

Method: manual, using hand tallies or electronic data capture devices

Comment: implementation as before study.

Duration: as in 1992 `before' study

Estimated cost £720 x 2 = £1440 + VAT

vi) Queue surveys

Purpose: to determine queue length at principal junctions, especially on Dewsbury Rd.

Method: as in `before' study

Comment: implementation as in 1992 `before' study

Contribution to evaluation:

Impact	Criterion of effectiveness/response
Crossing delay, uncertainty & visual intrusion	Queue length at junctions

Duration: as in 1992 `before' study

Estimated cost £1665 x 2 = £3330 + VAT

vi) Accident data

Purpose: To collect accident data to help estimate any changes in risk to vehicles and pedestrians.

Method: Police accident records

Comment: the 'after' data will be for a much shorter period than the 'before' data (1987-93), which will limit its value in evaluation. Conflict studies will therefore also be performed (see below).

Impact	Criterion of effectiveness/response
Safety	Accidents for cars and pedestrians for route and links

Duration: Data for the period from implementation to evaluation.

Estimated cost zero

b) New "before and after" surveys

i) Journey time and number of stops surveys by floating car

Purpose: to collect:
- link journey times
- route journey times
- number of stops for cars
- (cause of stops)
- (roadside parking)

Method: Floating car

Comment: see A.3.1.2 a) i) above. This survey will provide the required data on number of stops, and some travel time data by link, based on 16 runs per direction per time period. The sample size needed for detecting significant changes in mean travel times are however too large to obtain using floating car alone. Registration plate surveys are therefore suggested below for this purpose.

Contribution to the evaluation: (ref. Table 3)

Impact	Criterion of effectiveness/response
Journey time	- Mean j.t. for route & links - j.t. variance for route & links
Speed	- Mean speed for route & links - Speed variance for route & links
VOC & fuel consumption	- OC and FC for vehicles - no. of stops (cars only)
Comfort	- comfort linked to numbers of stops
Safety	- change in safety/accident rate
Crossing delay, uncertainty and visual intrusion	- mean link speed

Estimated cost £4040 x 3 = £12120 + VAT

ii) Survey of number of unscheduled stops and travel times for buses

Purpose: To collect data on the number of unscheduled stops for buses which result from congestion, and to record bus travel times.

Method: Observers recording stops (and causes) and travel times of a sample of moving buses in the study area.

Comment: Required by the auditors. This was not collected in the 1992 `before' study. A `before' and an `after' study will be carried out. About 20 sample buses are estimated to be needed in each direction per time period.

Contribution to the evaluation:

Impact	Criterion of effectiveness/response
Vehicle operating cost & fuel consumption	Total number of stops for vehicles
Comfort	Comfort related to number of stops
Operational	Reliability of bus travel times

Estimated cost £850 x 3 = £2550 + VAT

iii) Spot speeds

Purpose: to collect data on the number of speeding vehicles

Method: Automatic traffic counters

Comment: See A.3.1.2 a)ii) above. This data may be obtained to the required accuracy (5 m/h speed bands) using automatic traffic counters. Counters will need to be deployed specifically for this to get the required precision of speed data. A `before' and an `after' study would be needed, as this information was not collected in the 1992 `before' study. About 11 sites (perhaps as for the 1992 automatic traffic count programme) would be used, with data being collected by lane. This survey would also output total traffic flows which can be used to augment traffic flow data from manual surveys. The duration would be one week `before' and one week `after'.

Contribution to the evaluation:

Impact	Criterion of effectiveness
Speed	Changes in the numbers and proportions of speeding vehicles

Estimated cost £3000 x 3 = £9000 + VAT

iv) Crossing delay to pedestrians

Purpose: To collect data on the changes in delay to pedestrians crossing the road.

Method: Manual timing of pedestrian crossing times at a sample of locations and times.

Comment: This has been requested by the auditors. A `before' and an `after' study would be needed as this information was not collected in the 1992 `before' survey. Surveys of at least two hours duration would be needed at about 8 representative locations in the study area in each of the three time periods.

Contribution to the evaluation:

Impact	Criterion of effectiveness/response
Crossing delay/uncertainty/visual intrusion	Changes to mean pedestrian crossing delay

Estimated cost £960 x 3 = £2880 + VAT

v) Conflict studies

Purpose: To collect information on changes in the numbers and types of conflict before and after implementation, to enable changes in safety to be estimated.

Method: Manual observation by trained observers; details are set out in a separate document.

Comment: A `before' and an `after' study would be needed. Conflict studies are to be devised and funded separately. At least 5 sites would be needed.

Contribution to evaluation:

Impact	Criterion of effectiveness/response
Safety	Increased safety for vehicles and pedestrians

Estimated cost £7500 x 3 = £22500 + VAT

vi) Journey times by registration plate matching

Purpose: to collect sufficient volume of journey time data to detect changes with confidence

Method: Registration plate matching

Comment: Journey time data for each link and direction would need too large a survey. It is intended that this survey will give journey times between origins and destinations and perhaps two intermediate points.

Contribution to the evaluation:

Impact	Criterion of effectiveness/response
Journey time	- mean j.t. for routes - j.t. variance for routes - mean speed for routes - speed variance for routes
VOC & fuel consumption	- OC and FC for vehicles
Safety	- change in accident rate

Estimated cost £1320 x 3 = £3960 x VAT

c) Control data

Traffic flow data, preferably classified, is needed from one or two automatic sites outside the study area (and away from any re-routing effects of the strategies), to act as a control. These should operate for at least one month before and one month after implementation.

Estimated cost £1320 x 3 = £3960 + VAT

A3.1.3 Timing

New `before' surveys should be timed so that they may be completed just before physical works to implement the field strategies commence, to ensure the `before' traffic is undisturbed. All `after' surveys should commence about two weeks after physical implementation and timing of the system is complete and the system has settled down after any final technical adjustments.

Better results would be obtained if the `before' surveys carried out in 1992 could be carried out again just before implementation.

The `before' and the `after' surveys should as far as possible cover the same days of the week and take place under similar underlying traffic conditions (eg school holidays).

Any activities which could affect traffic demand or driver behaviour, such as radio announcements or news items describing the scheme, should be discouraged.

A3.2 FIELD TRIALS SURVEY PLAN FOR TURIN

A3.2.1 Measurements

Measurements will be carried out partly automatically using SPOT and part manually. Information automatically collected by the SPOT units will be available. This includes:

- traffic counts on each detector (on the main and side roads)
- an estimate of the turning percentage of each junction
- an estimate of saturation flows
- an estimate of the average speed on the detectors (not very accurate due to the fact that a single loop is used)
- an estimate of the delay on each link
- an estimate of the number of stops on each link

Journey times will be also collected through floating cars. The number of routes (probably 2-3) as well as the number of vehicles for each test site has not yet been decided.

Double loops to measure speed along one or two road-sections will be installed.

Data about bus speed, occupancy and frequency will be automatically collected through the S.I.S. system, an automatic vehicle monitoring system that collects data on the public fleet in Turin.

Police accident records are available and will be available for the period of the field trials.

It is the intention of Turin City, (following a training course for staff), to carry out conflict studies.

A3.2.2 Duration of the field trials

As a first plan manual measurements will be collected for 2/3 week days (TUE/WEDS/THUR) for each strategy tested as well as in the do-nothing condition. Data will be collected from 7.30-8.00 until evening.

A preliminary session of measurement made through SPOT could help to identify better the peak and inter-peak hours in order to possibly minimise the period of data collection.

Data collected automatically will be collected for a longer period (1-2 weeks).

A3.2.3 Timing of field trials

Road works for the installation of the detectors should start in September 1993. A probable date for the full installation of the hardware needed for the trials (SPOT units and new Traffic Light Controllers) could be January 1994.

Then each tested strategy, including the do-nothing condition, will take two or three weeks for data collection and changes in the installed software (if required).

APPENDIX A4 : Further Details of Impact Variables for Field Trial Survey

A4.1 Journey Time/Speed

Impact Group

Vehicle Category - 7 were used in some of the before surveys, but this is probably too many and could be reduced to 5, say cyclist/car/bus/light commercial/heavy commercial.
Preferably need speeds/journey time for each of above categories unless the study is restricted to cars only.

Pedestrian journey time data likely to be too costly to collect.

Sampling Frame

Before study for cars completed - sampling frame being partially determined by time/cost expediency. We need to establish the accuracy of data collected. The COBA manual should be checked for further information.
Depending on the design of `After' survey we may need estimates of sources of variability which may not be given from `before' study ie month/day/vehicle/ ambient variability.
Sample sizes should be determined for MO's, and this will form the basis of a separate report section.
`Before' surveys are needed for vehicle categories other than cars.
ATC's will be used to give disaggregate speed and other information by vehicle category. Measurements will be made for both lanes of dual carriageway as it is expected that a different effect may be observed in each ie a more substantial reduction in mean speeds/speeding vehicles in the offside lane and a less marked effect in the inside lane. This will be at the expense of much higher survey costs.

Costability

Journey times and speeds are quantifiable in units and could be included in some form of CBA, however they may need costing according to vehicle impact group to assess scheme effects on each.

A4.2 Vehicle Operating Cost

Impact Group

We may be interested in impact groups from A4.1, excluding cyclists.

Sampling frame

Both before/after sampling strategies are needed and could include:-
1) Monitoring by the bus company
2) Information from a program such as COBA
3) No of stops information
4) Possible use of instrumented vehicles

Data on the number of vehicle stops can be used as an indicator of fuel consumption, comfort and stress. An oversaturated junction with congestion leads to increased stopping and starting. This in turn means increased fuel consumption, stress and discomfort.

Costability

Vehicle operating cost can be directly monitored in £/ECU and is therefore suitable for inclusion in a CBA. A disaggregate costing would be needed to assess the scheme effect on each vehicle type. This information may be already collected by bus companies but may not be released for evaluation due to its sensitive nature following deregulation in the UK.

A4.3 Comfort

We define comfort as driver/passenger comfort during their journey.

Impact Group

Drivers - 5 impact groups from A4.1, including cyclist.
Passenger - car/bus

Sampling frame

Before/after sampling strategies are needed.
To questionnaire Drivers/Passengers would be costly and need a separate experimental design. Instead we could use related variables eg Bus load factor (bus passengers), No of vehicle stops (car and bus passengers).
Comfort then becomes more quantifiable and information may be collected without a separate Questionnaire survey.

Costability

A multicriteria function (MCF) would be needed if a questionnaire was used and the results had a large subjective element.
If related variables are used then comfort becomes more quantifiable, has a lower subjective element, and becomes more easily costable.

A4.4 Safety

More detailed consideration is given to safety issues in Section 5.

Impact Group

If Police Accident Statistics were used then the figures are likely to be too small to assess the impact of the strategy or to disaggregate by people/vehicle category. If `conflict' analysis were used (see below) we need to assess the impact group/level of disaggregation.
Existing Police Accident information is disaggregated by severity - slight/serious/ fatal.

Sampling frame

The Before study was based on accident statistics and if the same criteria were used in an After study, meaningful quantities of data may not be available.
It is therefore proposed to supplement accident statistics with conflict analysis looking at `near miss' data. A preliminary assessment is given in Appendix A6 for before and after studies including the area to be covered, period of monitoring and disaggregate conflict category.

Costability

Using conflict analysis, safety will be directly quantifiable in terms of numbers of near misses in each impact group. However we intend to supplement the safety evaluation with a qualitative assessment of the conflict study results and safety benefits from expected speed reductions.

A4.5 Air Pollution

Impact Group

In theory the impact is likely to be felt by pedestrians, residents, drivers and cyclists.

Sampling Frame

For field trials a strategy would be needed for Before and After studies. Because the impact of the integrated Strategy on Air and Noise pollution is likely to be difficult to measure (due to a large number of extraneous variables) it is unlikely that these variables will be monitored in field trials. Instead air pollution will be estimated in the NEMIS Simulation program and an estimate made of the impact of the strategy. Noise pollution can not be realistically estimated by simulation and will not be measured in field trials due to practical constraints.

Costability

We expect that the estimates of air pollution levels will be directly quantifiable for the impact of each test strategy via the simulation program.

A4.6 Crossing Delay

Impact Group

Pedestrians

Sampling Frame

Strategies are needed for before/after studies.
Crossing delays can be timed in small scale field surveys rather than using questionnaires.
It is important to consider the position of the pedestrian crossing ie main road/pelican/junction/side street/shops/bus stops

Costability

Directly quantifiable in the mins/secs needed to cross by people category/crossing position.

A4.7 Stress

Impact Group

The following groups could be affected in theory.
Pedestrians: age/ability
Drivers: vehicle category
Residents: By location ie main road/junction/side street/bus stops

However we consider that financial and practical constraints will not allow an assessment to be made of the impact on each disaggregate group.

Sampling Frame

There is likely to be a strong relationship between stress and variables such as comfort, pollution, crossing delay and journey time. For pedestrians and drivers we could use the following surrogate measures:-
Driver stress - number of stops, queue lengths
Pedestrians - crossing time/traffic speed/traffic flow

Costability

The surrogate stress variables for pedestrians and drivers may be quantifiable.

A4.8 Traffic Flows

Impact Group

Vehicle Category as defined in (1).

Sampling Frame

A strategy is needed for the `after' study.
Sources of variation can be minimised with planning. Information is needed on traffic variation and `do nothing' growth in traffic.

Costability

Can be quantified in terms of absolute numbers of vehicles in each vehicle category.

A4.9 Vehicle Occupancy

This is defined as the number of people travelling in the vehicle.

Impact Group

Vehicle categories as in A4.1 excluding cyclists.

Sampling Group

Small scale field studies will be carried out. The duration and sites for these are to be determined.

Costability

Vehicle occupancy can be quantified in terms of people numbers.

A4.10 Uncertainty/Visual Intrusion/Severance

We define uncertainty in terms of expected journey time and severance as being socially cut off due to traffic conditions. Some overlap is likely between visual intrusion, severance and crossing delay.

Impact Group

Uncertainty - journey time for people/vehicle categories.
Visual Intrusion - pedestrians
- residents } all categories
- drivers

Severance - residents by location.

Sampling Frame

A survey strategy is needed for before and after studies for all three potential variables. If visual intrusion is measured by queue length the data may be obtained as part of other surveys. Severance is measured as difficulty in crossing the road and may require a residents questionnaire to assess fully. Uncertainty may be reflected in the additional journey time allowance residents, pedestrians and drivers make for possible delays. As the severance and uncertainty variables would be costly and difficult to evaluate we feel it would be impractical to include them in before and after studies.

Costability

Visual Intrusion - queue lengths can be quantified

APPENDIX A5 : Evaluation of Speed/Journey Time Surveys

A5.1 Introduction

One of the areas in which the impact of an integrated transport can be assessed is that of speeds and journey times. The aim of the strategy would be to reduce and calm speeds and reduce journey times where possible, and this is one area where the impact can be directly and quantifiably measured.

Here we outline the general methodology needed to obtain the sample sizes required in order to measure the impact to a particular degree of accuracy. It is possible to derive sample sizes for both `Before' and `After' studies, although to some degree the former have already been carried out. The calculations made here are expected to confirm the accuracy of these before studies, which were conducted using the `Moving Observer' method. The `After' studies may also use moving observers to collect journey time data, although in section 5.5 the use of automatic traffic counters and number plate matching (NPM) is discussed. The problem we address here is that of how many journey times should be sampled.

A5.2 Sample Size Requirement to Estimate the Mean Speed to a Given Accuracy

An overall definition of the sample size required (n) to estimate the mean speed along a link to a given degree of accuracy is given by Fowkes and Watson (1987)

$$n = \frac{var(x)}{\bar{x}^2[cv^2(\hat{y}) - cv^2(F_1) - cv^2(F_2) - cv^2(F_3) - cv^2(F_4)]} \quad \textbf{(1)}$$

where $cv^2(\hat{y})$ is the coefficient of variation in the estimate of average speed on any weekday in any year (the object of our interest).
x is the measured speed along the links
$cv^2(F_1)$, $cv^2(F_2)$, $cv^2(F_3)$ and $cv^2(F_4)$ are coefficients of variation for grossing up factors and sources of variability as follows:-

F_1 grosses up from a particular hour to an average hour
F_2 grosses up from a particular weekday to an average weekday
F_3 grosses up from a particular month to an average month
F_4 has mean 1 but variance which allows for unexplained (Ambient) variability

At present such grossing up factors are not readily available within TAM and so may have to be derived from other survey data. Intuitively it is clear that the more conversions that are required, the greater the sources of variation introduced and therefore the larger the required sample size is likely to be. In the simplest case, we are interested in a particular hour in a particular day and particular month so the use of conversion factors is therefore avoided.

In such a case, (1) is reduced to

$$n = \frac{var(x)}{\bar{x}cv^2\hat{y}} \quad \textbf{(2)}$$

Say we wish to estimate y to within ± 10% of its true value with 95% confidence in the result.

We then introduce the constraint

$1.96\ SD(\hat{y}) = 0.1$

(from established sampling theory and assuming a normal distribution for speeds)

$$then \quad cv(\hat{y}) = \frac{SD(\hat{y})}{\hat{y}} = \frac{0.1}{1.96}\ ,\ so \quad cv^2(\hat{y}) = \frac{0.1^2}{1.96^2}$$

Substituting in (2) gives

$$n = \frac{\dfrac{cv^2(x)}{0.1^2}}{1.96^2} \quad i.e.\ 19.62^2 cv^2(x)$$

$$giving\ n = \underline{384\ cv^2(x)} \qquad \textbf{(3)}$$

This result is consistent with that given by the MVA study `Monitoring Journey times and Vehicle Speeds'. The final figure for the sample size depends on the value of $cv^2(x)$ ie the coefficient of variation in measured speed along the link, and different values will be required for each link of interest in both the Leeds and Turin sites. Examples are given in section A5.4 below. If we are interested in a more accurate result, ie to estimate mean speeds to within ± 5% of their true value with the same 95% confidence then $cv^2(\hat{y})$ becomes

$$cv^2(\hat{y}) = \frac{0.05^2}{1.96^2}$$

and the required sample size is

$$n = 39.2^2\ cv^2(x)$$

$$\text{ie} \qquad \underline{n = 1537\ cv^2(x)} \qquad \textbf{(4)}$$

As already stated (3) and (4) refer to the simplest possible survey design where we are interested in a specific hour/day/month. If we wish to generalise to speeds for any month ie we survey in March but with the estimate speeds for an `average' month then the conversion factor F_3 comes in to play and the corresponding sample size requirement is:

$$n = \frac{cv^2(x)}{cv^2(\hat{y}) - cv^2(F_3)} \qquad \textbf{(5)}$$

A reasonable estimate for $cv(F_3) = 0.02$ (see Fowkes and Watson, 1987) so to estimate y to within ± 10% with 95% confidence we get

$$n = \frac{cv^2(x)}{\left(\dfrac{0.1^2}{1.96^2} - 0.002^2\right)} = \underline{384.75\,cv^2(x)} \qquad \textbf{(6)}$$

and to estimate y to within ± 5% with 95% confidence

$$n = \frac{cv^2(x)}{\left(\frac{0.05^2}{1.96^2} - 0.002^2\right)} = \underline{1546.1\,cv^2}(x) \qquad \textbf{(7)}$$

comparing (3) and (4) with equation (6) and (7) we see that the generalisation to an average month is unlikely to lead to a vastly increased sample size requirement working to a 10% accuracy. At the more precise 5% accuracy requirement a more marked effect may be seen. Of course the precise values of n will depend on *cv(x)*.

The above sample sizes refer to estimation of mean speeds, but our main concern with the evaluation study will be to detect a statistically significant difference in the mean speeds for the before and after studies. As far as the goal of the integrated strategy is concerned, we require that a successful outcome should either reduce mean speeds (through traffic calming measures) or at least retain existing mean speeds with a significant reduction in their variability. The latter would be the result of a more controlled progression of traffic through the system. If we are not concerned with the size of the strategy impact, but merely wish to check whether any significant change has taken place, then it is sufficient to measure mean before and after speeds to a given accuracy as illustrated in equations (1) to (7).

A formal test for a significant difference in mean speeds can then be given by testing

H_0: $(\mu_1 - \mu_2) = 0$
H_1: $(\mu_1 - \mu_2) > 0$ (ie a 1 tailed test as we can only hypothesise that the mean-distribution speed has reduced)

Where μ_1 is the theoretical mean for the `before' speed and $\mu_2$ is the theoretical mean for the `after' speed.

The test statistic is then given by

$$z = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{sd(\bar{x}_1 - \bar{x}_2)} \qquad \textbf{(8)}$$

$$and \quad var\,(\bar{x}_1 - \bar{x}_2) = \frac{s_1^2}{n_1} + \frac{s_2^2}{n_2} \qquad \textbf{(9)}$$

assuming large samples ie n_1, n_2 > 25 and s_1^2, s_2^2 are the sample variances for the before and after studies respectively.

If the sample sizes are less than 25, then a pooled estimate of the variance could be used, provided the variance of the populations could be taken to be equal.

$$ie \quad \hat{s}^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \tag{10}$$

and the test statistic compared to the t-distribution

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\hat{s}^2 \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \tag{11}$$

Since we expect the integrated strategy could affect the variance in speeds the assumption of equal population variances is unlikely to hold, in which case we would apply the Welsch t-test. Using expression (11) by applying degrees of freedom given by:-

$$df = \left[\frac{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2^2}}{\frac{\frac{s_1^2}{n_1^2}}{n_1 - 1} + \frac{\frac{s_2^2}{n_2}}{n_2 - 1}} \right] \tag{12}$$

A5.3 Sample Size Requirement to Estimate a Change in Mean Speed of Given Size

If however we wish to estimate a particular sized decrease in mean speeds (such as a 5% decrease), the sample size requirements are somewhat different.

Say we wish to detect a 5% decrease in mean speed, using a 5% critical value and being 95% confident in the result.

We then wish to test the null hypothesis

H_0: $\mu_2 = \mu_1$ against the alternative
H_1: $\mu_2 = (1 - k)\mu_1$ where k = 0.05 for a 5% decrease

Using the methodology of MVA, where the critical value level and confidence interval are equal, if the sampling distributions of μ_1 and μ_2 can be assumed to be equal, then the critical value occurs halfway between the two hypothesised mean values (μ_1 and $\mu_2 = 0.95\mu_1$)

From the standard normal distribution then

$$\frac{0.95\mu_1 - \mu_1}{SE(\bar{x}_2 - \bar{x}_1)} = 1.64 \tag{13}$$

This result applied only for large samples where a normal distribution can be assumed.

Manipulation of this formula leads to the solution

$$\underline{n = 2152 \ cv^2(x)} \tag{14}$$

Where n refers to the sample size required for each of the before and after studies

A more detailed result is found using the methodology of Fowkes and Watson (1987), giving

$$n = 2 \frac{[cv^2(F_4) + cv^2(x)] \ [z_1 + z_2]^2}{k^2} \tag{15}$$

Where $cv^2(F_4)$ is the coefficient of variation for ambient variability and z_1 is the normal z value for the critical value (5%), z_2 being the normal z value for the confidence level (say 95%).

Using the given parameters, expression (14) reduces to

$$n = 2151.68 \ (cv^2(F_4) + cv^2(x)) \tag{16}$$

which is clearly very similar to (14).

Similar assumptions are made ie those of equal sized before and after samples, the appropriateness of the normal distribution and equality of variances.

However, where the before survey has already been carried out (which is the case for Dewsbury Road) and is of size n_1, it is still possible to derive a sample size of the after study (n_2) under the defined accuracy constraints.

Using the expression given by Fowkes and Watson (1987)

$$\left[\frac{k\mu_1}{z_1 + z_2}\right]^2 = \left[\frac{\mu_2^2}{n_2} + \frac{\mu_1^2}{n_1}\right] [cv^2(F_4) + cv^2(x)] \tag{17}$$

Manipulation under the null hypothesis $\mu_1 = \mu_2$ leads to

$$\frac{n_1 n_2}{n_1 + n_2} = \left[\frac{cv^2(F_4) + cv^2(x)}{k^2}\right] [z_1 + z_2]^2 \tag{18}$$

and substituting known values for n_1, $cv^2(F_4)$, $cv^2(x)$, k^2, z_1 and z_2 leads to a solution for n_2.

It is clear from (18) that for a given value of n_1 it may not be possible to achieve the accuracy levels reflected in z_1 and z_2, if the before sample size was too small. This constraint is illustrated in section A5.4.

A5.4 Computation of required sample sizes

In sections A5.2 to A5.4, general results are given for sample size determination and hypothesis testing. Here we look at particular results using data already available and quoting example results where information has yet to be found.

A5.4.1 To estimate mean speed with a given accuracy

Assuming the simplest survey design

Where it can be assumed that the after survey will take place in the same hour/day/month as the before survey, the simplest survey design applies and the sample size for before study = sample size for after study = n. Using (2)

$$n = \frac{var(x)}{\bar{x}cv^2\hat{y}} \qquad \textbf{(2)}$$

calculations can be made for an accuracy in y of a) ± 10% and b) ± 5% assuming 95% accuracy in the result. Using estimates for *cv(x)* as given in the MVA study, the following results are found:-

	Accuracy in y	
cv	± 10%	± 5%
0.10	4	16
0.15	9	35
0.20	16	62
0.25	25	97

Table A5.1: Sample sizes for given accuracy in y

For urban roads such as the Dewsbury road and Turin sites, a value of *cv(x)* = 0.20 or cv(*x*) = 0.25 is probably the most appropriate as the lower figures refer to rural roads. Clearly an accuracy of ± 5% in the estimate of y will be expensive to obtain due to the large sample size required. It therefore seems most sensible to aim for an accuracy of ± 10%, using 24 journey times for the peak period and 16 journey times for the interpeak period.

The sample sizes given in Table A.5.1 are those required for both before and after studies, however for the Dewsbury road site, the before studies have already been carried out. Further details are given within the technical annex to the "Dewsbury Road Leeds: Report of survey". Figures are given as journey times (rather than speeds) for a total of 16 routes using between 2 and 6 MO's in each of 2 directions during three specified time periods in the day. Assuming that speed estimates can be extracted from the data, we therefore have the dual constraints of estimating y to within ± 10% and a sample size n = 6 (although in some cases this is reduced to 2). A confidence interval can be obtained for the result from (2).

$$n = \frac{cv^2(x)}{\frac{0.1^2}{z^2}}$$ where z is the standard normal variate

For off-peak traffic, assume $cv^2(x) = 0.2^2$

giving $6 = \frac{0.2^2}{\frac{0.1^2}{z^2}}$ ie z = -1.22

This corresponds to a confidence level of 89%

For peak traffic assume $cv^2(x) = 0.25^2$ then

$$6 = \frac{0.25^2}{\frac{0.1^2}{z^2}} \quad \text{ie } z = 0.979$$

corresponding to a confidence level of 83.6%.

If, as seems likely, the surveys take place in the same hour and same day but within a different month then the conversion factor F_3 should be applied. Solving equation (5) using a value $cv(F_3) = 0.002$ (from Fowkes and Watson, 1987) the same degree of confidence for both peak and interpeak speed estimates is found (to 2 dp). This implies we should not be too concerned about large fluctuations in sample size requirement due to seasonal variation.

A5.4.2 To detect a change in mean speed of given size

Using expression (14), say we wish to detect a 5% difference in means with 95% confidence, then the required sample sizes would be 86 (off peak) and 135 (peak) for both before and after studies. However, we may wish to allow for the effect of ambient variability using equation (16). Estimates for $cv^2(F_4)$ have not been produced to our knowledge yet, but it may not be unreasonable to estimate $cv^2(F_4) = 0.01^2$. Using this figure the required sample sizes would become 87 (off peak) and 135 (peak), clearly only a small increase in order to account for the additional variability.
If we wished to observe a 10% reduction in means then using expression (18) ie

$$\frac{n_1 \; n_2}{n_1 + n_2} = \left[\frac{cv^2(F_4) + cv^2(x)}{k^2}\right] \; [z_1 + z_2]^2$$

with values
$cv^2(F_4) = 0.01^2$
$cv^2(x) = 0.2^2$ (off peak)
$cv^2(x) = 0.25^2$ (peak)
$z_1 = 1.64$
$z_2 = 1.64$
$k = -0.1$

We find that the minimum requirement is for $n_1 = 44$ (off-peak) and $n_1 = 68$ (peak) in order to achieve the desired degree of accuracy. As we have the constraint $n_1 = 6$, it is sensible to calculate the most realistic degree of accuracy we are likely to achieve in detecting a 10% change in mean speeds.

From expression (18), if the error is spread equally between type 1 and types 11 errors (ie z_1 and z_2) then given $n_1 = 6$ a critical level of 70% with 70% confidence can be achieved if $n_2 = 16$. This figure is very sensitive and rises to $n_2 = 60$ to achieve a critical level of 72% with 72% confidence. These figures refer to off-peak measurements, for peak traffic a 67% type 1 and type 2 errors would be achieved with $n_2 = 26$ whilst $n_2 = 63$ would be needed to reach a 68% type 1 and type 2 error.

All calculations so far are needed to detect a 10% drop in mean speeds. If it is felt likely that a more substantial gain may be achieved, this would be reflected in a lower sample size requirement (or a higher degree of accuracy achieved).

A5.5 Use of alternative techniques to estimate speed distribution

At the Dewsbury Road site, moving observers were used to calculate travel times as part of the `before' study. A maximum sample of n = 6 was used although for some time periods this figure was as low as n = 2. As discussed in section A5.4 a larger sample would have achieved a greater degree of accuracy and it may not be possible to extract from the results the full distribution of speeds which could most comprehensively reflect changes brought about by the integrated scheme. It is therefore proposed that a supplementary `before' study of speeds will take place using ATC temporary loops. This will give a more detailed speed distribution using 5mph classification bands and disaggregate into broad vehicle categories. The use of `spot speed' detectors is also envisaged at key pedestrian crossing points at the Dewsbury Road site to assess changes in speed at particular locations. It is also our intention to carry out number plate matching surveys on both a before and after basis. This will contribute additional speed information, but more importantly enable a large enough sample size to be collected in order to monitor journey time changes accurately and yield statistically significant results.

A5.6 Summary of mean speed sample size requirements

Projecting figures calculated in preceding sections into a practically achievable goal, the following points emerge.

1. It seems unlikely we will achieve an accuracy of ± 5% in measuring mean speeds using moving observers due to the high sample sizes required for both before and after studies.
2. It would have been desirable to use n = 16 (off peak) or n = 25 (peak) in order to achieve an accuracy of ± 10% in measuring mean speed with 95% confidence in the result.
3. Given that n = 6 for the before study, using n = 6 for the after study an accuracy of ± 10% in measuring mean speed would be achieved with 89% confidence (off peak) or 83% confidence (peak)
4. If we wish to detect a change in mean speed of say 10%, the required sample sizes would be 86 (off peak) and 135 (peak) for 95% confidence using a 95% critical value.
5. Given that $n_1 = 6$, if we use $n_2 = 16$, the same change (10%) would be detected achieving a 70% critical value with 70% confidence (off-peak traffic). For peak traffic $n_2 = 26$ would achieve a 67% critical value with 67% confidence.
6. In view of these constraints we intend to carry out supplementary studies using number plate matching, ATC's and spot speeds. These will allow the collection of sufficient data to meet the sample size requirements for statistically significant results.

A5.7 To Estimate the Scheme Effect on Mean Speeds

Using the general model formulation for scheme evaluation given by (1.1) ie

$$N_A = N_B \cdot S_i \cdot E_j \cdot G \cdot V$$

Here μ_2 and μ_1 are mean speeds after and before respectively, S_i, E_j, G and V are as defined in Section 1.

An estimate of the scheme effect is then given by

$$\hat{S}_i = \frac{\hat{\mu}_2}{\hat{\mu}_1 \cdot \hat{E}_j \cdot \hat{G} \cdot \hat{V}} \qquad \textbf{(19)}$$

If the i'th strategy is tested against different environments then in theory it should be possible to separate the estimate of the j'th environment effect, $\hat{E}_j$ using classical ANOVA techniques. This will only be possible if several strategies are all tested with several environments. In practice, it is likely that only one strategy will be implemented in the field trials and so we are more likely to estimate the effect

$$\hat{S}_i\ E_j = \frac{\hat{\mu}_2}{\hat{\mu}_1\ .\ \hat{G}\ .\ \hat{V}} \qquad \textbf{(20)}$$

ie a combined scheme and environment effect. This is probably a more realistic quantity to estimate as we expect that some strategies will be more suitably "teamed" with particular environments. The quantities $\hat{\mu}_1$ and $\hat{\mu}_2$ in (20) should be estimated as discussed in sections A5.3 and A5.4. $\hat{G}$ gives an estimate of secular growth, ie how much speeds may be expected to increase or decrease over the time period regardless of whether the strategy is implemented. $\hat{V}$ is our estimate of speed variation for the system, including ambient variation, seasonal variation, sampling variation and random variation. These quantities are discussed in more detail in section A5.2.

A5.8 To Test for a Change in Variation of speeds

One of the possible benefits from implementing the integrated strategy is a reduction in the variation of speeds. This is expected to result from the TC/ATT and QM measures introduced, leading to a more controlled and orderly progression of traffic through the system. In addition, much of the theory in sections A5.2 and A5.3 depends upon the `equality of population variance' assumption. For these reasons we give the established test for equality of variance and recommend that such a test be carried out as part of the evaluation procedure.

The null hypothesis is H_0: $\sigma_2^2 = \sigma_1^2$ ie no change in underlying population variance and alternative hypothesis H_1: $\sigma_2^2 < \sigma_1^2$ as we anticipate there may be a drop in variability.

The test statistic is $F = \frac{s_1^2}{s_2^2}$ where s_1^2 and s_2^2 are computed variances from the before and after studies respectively. The F statistic can be checked against standard tables with the critical value depending upon the level of significance and sample sizes used.

A5.9 Detecting a Change in the Proportion of Vehicles Exceeding a Given Speed

One of the aims of the integrated strategy would be to minimize the numbers of "speeding" vehicles at the site. For this reason we intend to use speed distribution information to test whether there has been a significant change in the proportion of vehicles exceeding a given speed, say > 90 kmph.

From field trials (most probably using ATC and NPM techniques) we will gain an estimate of the proportion of speeding vehicles, say $\hat{p}_1$ for the before study and $\hat{p}_2$ for the after study.

$\hat{P}_i = \frac{x_i}{n}$ where x_i is the number of speeding vehicles in the sample size n.

An estimate of the variance is $\hat{p}_1 = \frac{\hat{p}_1 (1 - p_1)}{n}$

We test the hypothesis H_0: $\hat{p}_2 = \hat{p}_1 = p$ (the population proportion)
against the alternative hypothesis H_1: $\hat{p}_2 < \hat{p}_1$ ie there has been a significant decrease in the proportion of speeding vehicles following the introduction of the integrated strategy.

If the normal distribution can be assumed (ie $n\,p > 5$, $n\,p(1 - p) > 5$), then the test statistic is

$$z = \frac{\hat{p}_2 - \hat{p}_1}{\frac{\sqrt{\hat{p}_1(1-\hat{p}_1)}}{n}}$$

which can be checked against standard normal tables ie against z_α where $\alpha = 0.05$ for 95% significance.

If the conditions for use of the normal distribution are not satisfied, then we can use the binomial distribution.

Under H_0, $x \sim B(n, P)$. From binomial tables we can calculate α ie the probability that $\hat{p}_2 = \hat{p}_1$. If H_0 is true and there has been no change in the underlying proportion of the speeding vehicles, α is given by the sum of the probabilities:-

$$p_r(x = 0) + p_r(x = 1) + \ldots Pr(x = x_2)$$

For the same 5% type 1 error (ie 95% significance) we reject H_0 if $\alpha < 0.05$.

APPENDIX A6 : Surveying Dewsbury Road using Conflict Observers for PRIMAVERA

A6.1 Aim

It has been my intention to observe Dewsbury Road under reasonably normal conditions to:

a) arrive at a subjective assessment of the safety at the junctions; and,
b) indicate the numbers of conflicts observers required.

I have observed each signalised junction and Pelican crossing on Dewsbury Road and also the junction at Tempest Road which is unsignalised. I have concentrated on junctions as opposed to links because there are often greater risks associated with junctions and because of constraints on time.

A6.2 Brief description of the junctions

a) Tommy Wass junction

Requires 2 points of observation to ensure 10-15m of Old Lane is observed. Relatively little pedestrian activity. High car flow and low car/ped ratio. Will probably not be able to observe the end of a queue on long queues (during peak times).
No observed red light violation by either vehicles or pedestrians. Pedestrians have scramble phase, thus if the pedestrians are prepared to wait there are no conflict crossings, unless the vehicle has violated the red light.

b) Barkly Road Pelican

Requires 1 observation point.

c) Westland Road

Requires 1 conflict observation points to view the whole junction. But this depends on the importance of Westland Road. One observer could see conflicts on inbound and outbound legs of Dewsbury Road but may not be able to observe any great distance down Westland Road. However this may not be a big problem as the length of the queue on Westland Road is not expected to be large. **Slight conflict** observed between pedestrian and vehicle (outbound Dewsbury Road) on the Pedestrian crossing. Pedestrian took evasive action. TA-value 1.4 sec.

This is a junction where I considered that there might be more of a conflict problem than the first two. There is a certain amount of turning traffic into and from Westland Road. There is no pedestrian crossing on the outbound side of Dewsbury Road, similarly on Westland Road. This means that pedestrians are making crossings in situation where there is moving traffic. (Non conflict free crossings). There is also a bus stop situated close to the junction. This results in the need for vehicles to change lanes and possibly to swerve. It is also a generator of pedestrian movements. In addition the inbound traffic is fast and has to slow rapidly on approaching the junction which could result in a number of traffic conflicts.

d) Middleton Grove

Requires 1 observation point, but again this depends on the importance of observing any distance along the arm of Middleton Grove. One **borderline conflict** observed. Pedestrian vehicle conflict, vehicle (inbound Dewsbury Road) evasive action. Pedestrian on inbound side crossing. Vehicle speed 45kph, TA-value 1.7 sec. Inbound vehicles on junctions 2, 3, and 4 all seem to have high speeds, all are down hill.

e) Tempest Road

Requires 1 observation plot. Not possible to combine with Middleton Grove. Seems to be a great deal of turning traffic into and from Tempest Road. Speed of vehicle flow on Dewsbury Road in both directions appears high, but this may be a particular problem in the inbound direction as the vehicles are leaving the Middleton Road junction, in the outbound direction traffic has to start to slow immediately after the Tempest Road junction. **One conflict observed**. This was non-serious with a TPA-value of 2.0 sec. Vehicle (inbound Dewsbury Road) swerved to avoid vehicle entering junction from Tempest Road. Lots of slowing and turning traffic.

f) Parkside Road and Garnet Road

Requires 2 observation points to be able to see the Dewsbury Road traffic and the traffic on the two side roads. Crossing road particularly difficult when crossing Parkside and Garnet Roads and outbound leg of Dewsbury Road. Does not seem to be a time where there is a conflict free crossing for the pedestrians. In addition red light violation by vehicles were observed on the outbound leg of Dewsbury Road.

g) Stratford Street Pelican

Requires 1 observation point. Much more pedestrians at this crossing than observed at any of the other crossings. Vehicle speed still high, but traffic has a good view of the Pelican on both approaches.

h) Tunstall Road and Garnet Road

Requires 1 observation point. Has scramble phase for pedestrians crossing.

i) Tunstall Road

Requires 1 observer, but cannot see the braking lights down Tunstall Road. **One conflict** observed, non serious.

TA-value 1.3 sec. Pedestrian crossing took evasive action. Vehicle outbound Dewsbury Road, pedestrian view obscured by right turning vehicle.

j) Burton Avenue Pelican

Requires 1 observer. Possibly high vehicle speeds but good view from both approaches.

k) Hunslet Hall Road

Requires 1 observer as long as the queue on Moor Road not required. Turning traffic seems high. Vehicle conflicts might be in the junction as opposed to at the end of queues.

A6.3 Safety

A6.3.1 In all 4 conflicts were observed (in 4.5 hours) only one of which could be considered serious. All occurred on Dewsbury Road both inbound and outbound traffic. In order to make a subjective assessment of the risk associated with a particular junction it would usually involve observation of a number of behavioural, situational and biographical variables, however I have only been able to concentrate on a small number of variables including; the complexity and layout of a junction, traffic speed, the availability of conflict free crossings, vehicle manoeuvres, field of vision and conflicts. The following junctions are considered more likely to yield safety effects:

c) Westland Road 1 conflict slight P/V

d)	Middleton Road	1 conflict borderline P/V
e)	Tempest Road	1 conflict slight V/V
f)	Parkside Road/Garnet Road	2 RLV outbound
g)	Stratford Street Pelican	
i)	Tunstall Road	1 conflict slight P/V

Tempest Road junction was observed even though it is not a signalised intersection. Conflicts more likely to be veh/veh. Stratford Street Pelican included because it had a high pedestrian flow.

A6.4 Conflict survey estimates

A6.4.1 To ensure the number of conflict observers required I have concentrated on whether the whole junction can be observed. In most cases the junction can be observed and 10-15m along two arms of the junction. There are only 2 instances where two observation points are required to observe the whole junction. This can be done by one observer at two points sampling at similar times or two observers sampling simultaneously.

A6.4.2 Junctions should either be selected randomly or on a purposive basis using 3-5 years of accident data and other behavioural data.

A6.4.3 it has been estimated for a different project that 82 conflicts are required to see a 30% effect at the 90% level of significance. Alternatively each relevant junctions could be observed for one week. On a basis of three observed junctions this would take 6 weeks of one persons time for each before and after surveys. Obviously the amount of observation time increases if the junction requires 2 observation points.

A6.4.4 Links can be observed at random if they have the same characteristics. Conflicts on links may be different to junctions, in particular there may be more conflicts between vehicles.

A6.5 Conclusions

A6.5.1 Accident data showing the location of accidents is required to establish the junctions which should be sampled. In addition other behavioural data could be collected.

A6.5.2 Small scale studies should then be done to establish the rate of conflicts per hour in order to estimate the sample times.

A6.5.3 Both inbound and outbound peak times should be surveyed.

It should be remembered that the observations occurred over a very short space of time and further data should be obtained in order to make any decisions and estimates about the sampling procedures.

APPENDIX A7 : Data collection by NEMIS: Output files

A7.1 Introduction

This note describes the standard output files for NEMIS after the modifications required for the evaluation process of PRIMAVERA.
Some of the described files are updated by DIGIT every time a simulation stops while others are results of acyclic or user-defined activities.
All the output files are produced in the working directory defined in the first row of the DIGIT input file.
If the simulation is interrupted before the scheduled stop it is possible that files updated at the end of the simulation are not empty. In this case data are related to the last completed simulation.
If not differently specified files are written in ASCII format.

A7.2 FLUSSI.DAT

The FLUSSI.DAT file is updated by DIGIT at the end of the simulation.
The file reports statistics about the private and the "routing" vehicles on the network.
Routing vehicles are a sub-set of the private vehicles that are able to follow suggestions received by a route guidance algorithm. The user can set the percentage of routing vehicles and decide whether to use the route guidance algorithm or not.
FLUSSI.DAT is made of two set of rows:

- six rows reporting global statistics

- a row for each link reporting the detailed data for the link

A7.2.1 Global statistics

In these rows statistics of the whole network are reported. Exit links are not considered as they have not correspondence in the real network.
Data reported are:

1) global travel time
2) same as 1 but only for routing vehicles
3) distance covered by the vehicles from the beginning of the simulation
4) same as 3 but only for routing vehicles
5) global average speed
6) same as 5 but only for routing vehicles

A7.2.2 Link data

For each link is reported a row containing 21 elements.
Following table explains the meaning of each element. See also Section 7.10 for an explanation of the internal variables.

El.	Description	Internal variables
1	Link number	---
2	Link type (0:internal, 1:entry, 2:exit)	---
3	Vehicles present on the link at the start of the simulation	NVPS(link)
4	Number of entered vehicles	CIS(link)
5	Number of exited vehicles	ND1S(link)
6	Average travel time for exited vehicles [s]	TS(link)/ND1S(link)
7	Travel time standard deviation [s]	SQRT(VAR_TT(link))
8	Average delay [s]	TEMPC(link)/(CIS(link)+NVPS(link))
9	Number of stopped vehicles [veh]	NSTOP(link)
10	Average speed for exited vehicles [m/s]	LUNGS(link)/TS(link)*ND1S(link)
11	Average occupancy	TEMPT(link)/ (CLOCK-ISACLK)/NVMXS(link)
12	Total time spent by the vehicles on the link [s]	TEMPT(link)
13	Same as 11 but for routing	TEMPTR(link)
14	Length of the link [m]	LUNGS(link)
15	Same as 3 but for routing	NVPSR(link)
16	Same as 4 but for routing	CISR(link)
17	Same as 5 but for routing	ND1SR(link)
18	Same as 6 but for routing	TSR(link)/ND1SR(link)
19	Same as 7 but for routing	TEMPCR(link)/(CISR(link)+NVPSR(link))
20	Same as 8 but for routing	NSTOPR(link)
21	Same as 9 but for routing	LUNGS(link)/TSR(link)*ND1SR(link)

Example: FLUSSI.DAT

```
 +++++++++++++++++++++++++++++++++++++

GLOBAL TRAVEL TIME    317637.0
GLOBAL TRAVEL TIME FOR ROUTING VEHICLES   317637.0
GLOBAL TRAVELLED DISTANCE   2297.022
GLOBAL TRAVELLED DISTANCE FOR ROUTING VEHICLES   2297.022
GLOBAL AVERAGE SPEED      7.970
GLOBAL AVERAGE SPEED FOR ROUTING VEHICLES      7.970

 +++++++++++++++++++
 DETAILED LINK DATA

 LINK TYPE PRES F.IN F.OU TRA_T  s.d.  DEL.  STOP  AV.S  OCCU    INT.T. INT.T.R   LEN.  P.R IN.R OU.R  T.R  DEL.R STO.R A.S.R
    1    0    0   59   57  27.4   2.6    .2   5.0  14.8   .03    1600.0    1600.0  406    0   59   57  27.4    .2   5.0  14.8
    2    0    0   85   82  27.6   1.4    .0    .0  14.7   .04    2301.0    2301.0  406    0   85   82  27.6    .0    .0  14.7
    3    0    0  112  111   7.1   2.1    .0   5.0  12.7   .06     790.0     790.0   90    0  112  111   7.1    .0   5.0  12.7
    4    0    0   69   68   9.8    .5    .0    .0  15.3   .03     673.0     673.0  150    0   69   68   9.8    .0    .0  15.3
    5    0    0   64   63   9.9    .9    .0    .0  15.1   .03     632.0     632.0  150    0   64   63   9.9    .0    .0  15.1
    6    0    0   73   73   7.0   3.0    .0   2.0  12.9   .04     509.0     509.0   90    0   73   73   7.0    .0   2.0  12.9
    7    1    0  196  189  33.1   2.6    .0   6.0  14.3   .09    6381.0    6381.0  475    0  196  189  33.1    .0   6.0  14.3
    8    0    0  272  264  22.9  10.6   2.1  88.0   8.1   .11    6132.0    6132.0  185    0  272  264  22.9   2.1  87.0   8.1
    9    0    0  264  257  16.7  18.1  12.0 114.0   2.3   .41    4416.0    4416.0   38    0  264  257  16.7  11.7 112.0   2.3
   10    0    0  272  269  28.5   2.4    .0    .0  14.1   .06    7746.0    7746.0  403    0  272  269  28.5    .0    .0  14.1
   11    0    0   87   78  46.7  19.0  14.2  43.0   8.6   .03    4008.0    4008.0  403    0   87   78  46.7  14.0  42.0   8.6
   12    0    0   73   73   3.7   1.1    .0    .0  10.3   .02     269.0     269.0   38    0   73   73   3.7    .0    .0  10.3
   13    0    0  120  120  13.6   1.9    .1   6.0  13.6   .03    1628.0    1628.0  185    0  120  120  13.6    .1   6.0  13.6
   14    2    0   63   60  30.0   1.7    .0    .0  15.8   .03    1864.0    1864.0  475    0   63   60  30.0    .0    .0  15.8
   15    0    0  261  260   5.1   2.2    .3  14.0   7.4   .12    1336.0    1336.0   38    0  261  260   5.1    .3  14.0   7.4
   16    0    0  314  312   7.0   2.3    .0  26.0  11.4   .09    2200.0    2200.0   80    0  314  312   7.0    .0  26.0  11.4
   17    0    0  327  315  24.3   8.4   2.8  73.0  11.0   .10    7979.0    7979.0  268    0  327  315  24.3   2.7  70.0  11.0
   18    0    0  314  293  12.6  10.7   2.9  70.0   7.8   .15    4411.0    4411.0   98    0  314  293  12.6   2.9  70.0   7.8
   19    0    0  303  226 107.2  51.1  87.0 285.0   2.3   .45   33432.0   33432.0  250    0  303  226 107.2  86.0 284.0   2.3
   20    0    0  226  223  14.5  12.9   6.6  72.0   3.4   .23    3254.0    3254.0   50    0  226  223  14.5   6.6  72.0   3.4
  ...
```

It is useful to specify some detail on how delay is evaluated in NEMIS.
The value reported in the file represents the average time spent in queue by each vehicle that travelled on the link. It is clear that this variable is affected by the definition of queue that is used. For this purpose NEMIS defines a vehicle queuing when:

- the distance between the object vehicle and the one in front (or the stop line for the leading vehicle of a lane) is less than or equal to 12m **and**
- the speed of the vehicle is less than 5m/s

This logic is also used at every step of the simulation to declare a link or a lane blocked and set the corresponding flags.
The reported number of stopped vehicles is the number of vehicles that stopped at least once while travelling on the link. The used logic does not allow more than one stop per vehicle to be counted. This means that in over-saturated conditions the number of stops on the link could be greater than the value reported.
However using the information reported by the speed distribution (see next section) it is possible to evaluate the average stop time for each stopped vehicle.

A7.3 VELDIS.DAT

The VELDIS.DAT file is updated by DIGIT at the end of the simulation.
This file reports for each link the speed distribution during the simulation.
For each possible speed on the link a value between zero and one is produced. This indicates the proportion of travel time spent by all vehicles travelling at that speed on each link:

$$F^{i}(v) = \frac{\sum_{t=0}^{T} N_t^{\,i}(v)}{\sum_{v=0}^{v_{\max}} \sum_{t=0}^{T} N_t^{\,i}(v)}$$

where

$N_t^i(v)$ is the number of vehicles on link i at time t travelling at speed v

T is the simulation period

v_{max} is the maximum speed in the network

$F^i(v)$ is the frequency of speed v: the proportion of the total travel time spent at speed v on link i

A 23 elements row is reported for each link of the network. The following table reports the meaning of each element.

Element	Description
1	Link number
2..22	Frequency of speed from 0 to 20m/s
23	Frequency of speed greater than 20m/s

Knowing the speed distribution on the link it is possible to evaluate some other values like the mean speed, the travel time, the average stop time for each vehicle that travelled on the link and, using some of the information reported in FLUSSI.DAT, the average stop time for the stopped vehicles only. So for link i:
mean speed :

$$\overline{v^i} = \sum_{v=0}^{v_{max}} v * F^i(v)$$

travel time:

$$\overline{t^i} = \frac{l^i}{\overline{v^i}}$$

where

l^i is the length of link i

average stop time for all vehicles:

$$\overline{t_s^i} = \overline{t^i} * F^i(0)$$

average stop time for stopped vehicles:

$$\overline{t_{ss}^i} = \overline{t_s^i} * \frac{f^i}{s^i}$$

where

f^i is the flow on the link (reported in FLUSSI.DAT)

s^i is the number of stopped vehicles (reported in FLUSSI.DAT)

The variance of the speed distribution can be evaluated as:

$$\sigma^2_{v,i} = \sum_{v=0}^{v_{max}} (v - \overline{v^i})^2 * F^i(v)$$

Example: VELDIS.DAT

```
 1  .00 .00 .00 .00 .01 .01 .02 .00 .01 .01 .02 .01 .02 .04 .03 .44 .26 .06 .07 .00 .00 .00
 2  .00 .00 .00 .00 .00 .00 .00 .01 .01 .01 .02 .01 .02 .02 .05 .42 .27 .13 .01 .00 .00 .00
 3  .01 .00 .03 .02 .01 .01 .01 .01 .01 .01 .06 .10 .08 .10 .13 .30 .09 .00 .01 .00 .00 .00
 4  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .02 .09 .51 .22 .14 .01 .00 .00 .00
 5  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .01 .00 .01 .02 .09 .46 .24 .10 .04 .00 .00 .00
 6  .06 .00 .05 .03 .02 .01 .01 .01 .02 .01 .03 .06 .06 .07 .09 .32 .12 .02 .03 .00 .00 .00
 7  .01 .00 .00 .00 .00 .00 .01 .01 .01 .01 .01 .01 .04 .06 .15 .48 .11 .05 .02 .00 .00 .00
 8  .07 .01 .10 .05 .05 .05 .05 .06 .06 .05 .06 .06 .05 .05 .06 .12 .03 .01 .00 .00 .00 .00
 9  .59 .01 .11 .04 .03 .03 .04 .03 .02 .02 .02 .02 .01 .01 .01 .01 .00 .00 .00 .00 .00 .00
10  .02 .00 .00 .00 .00 .00 .00 .01 .02 .02 .02 .02 .04 .08 .16 .41 .15 .03 .01 .00 .00 .00
11  .25 .01 .06 .04 .03 .02 .02 .01 .01 .01 .02 .03 .03 .05 .07 .17 .09 .06 .03 .00 .00 .00
12  .01 .00 .00 .01 .00 .01 .04 .07 .10 .09 .13 .13 .06 .10 .15 .09 .01 .00 .00 .00 .00 .00
13  .00 .00 .01 .01 .01 .01 .02 .02 .03 .02 .03 .04 .05 .05 .11 .32 .17 .09 .04 .00 .00 .00
14  .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .00 .03 .45 .33 .14 .04 .00 .00 .00
15  .01 .00 .05 .04 .03 .07 .11 .12 .14 .12 .13 .10 .05 .03 .02 .00 .00 .00 .00 .00 .00 .00
16  .03 .00 .05 .02 .02 .01 .02 .02 .03 .04 .05 .09 .11 .13 .17 .19 .01 .00 .00 .00 .00 .00
17  .07 .00 .04 .03 .02 .02 .02 .02 .03 .03 .04 .05 .07 .10 .18 .22 .05 .01 .00 .00 .00 .00
18  .10 .01 .19 .10 .08 .05 .04 .02 .02 .03 .02 .03 .05 .06 .07 .09 .02 .01 .01 .00 .00 .00
19  .31 .02 .47 .05 .03 .02 .02 .02 .01 .01 .01 .01 .01 .00 .00 .00 .00 .00 .00 .00 .00 .00
20  .33 .01 .13 .07 .07 .09 .09 .09 .05 .03 .01 .02 .01 .01 .00 .00 .00 .00 .00 .00 .00 .00
21  .02 .00 .02 .02 .02 .02 .02 .03 .03 .03 .04 .06 .07 .09 .14 .27 .09 .03 .01 .00 .00 .00
22  .12 .00 .02 .03 .02 .02 .03 .02 .05 .06 .09 .09 .10 .10 .13 .11 .01 .00 .00 .00 .00 .00
23  .12 .01 .10 .07 .06 .07 .07 .06 .07 .06 .05 .04 .03 .03 .04 .09 .03 .01 .01 .00 .00 .00
24  .00 .00 .00 .00 .00 .00 .01 .02 .04 .09 .10 .14 .15 .17 .11 .15 .02 .00 .00 .00 .00 .00
25  .06 .00 .03 .02 .01 .01 .02 .01 .02 .02 .02 .03 .04 .08 .16 .32 .10 .04 .03 .00 .00 .00
26  .10 .00 .04 .02 .03 .03 .05 .05 .06 .07 .06 .07 .07 .06 .08 .14 .03 .00 .02 .00 .00 .00
...
```

A7.4 STMP.DAT

In the STMP.DAT file data about public vehicles are reported.
The file is updated by DIGIT during the simulation every time a public transport vehicle exits from a link.
Each record contains information about the entry time, exit time and stop time of the vehicle on each link of the network where the vehicle travelled.
For each link a row of 17 elements is reported. The following table explains the meaning of each element.

Element	Description
1	Vehicle number
2	Service number
3	Length of the link to which data are related
4	Link number
5	Entry lane
6	Entry clock
7	Exit clock (negative if the vehicle has reached a terminus or an exit node)
8	Clock when the vehicle stopped near the intersection or terminus (if no stop has been made the same as element 7)
9,12,15	Position of the stop on the link
10,13,16	Clock when the vehicle stopped
11,14,17	Clock when the vehicle restarted

Example: STMP.DAT

```
117    9   33  132    1    1    5    5    0    0    0    0    0    0    0    0    0
113   19  140   28    1    1   12   12    0    0    0    0    0    0    0    0    0
118    6  150  123    1    1   13   13    0    0    0    0    0    0    0    0    0
115   17  188  113    1    1   15   15    0    0    0    0    0    0    0    0    0
119    2  215  127    1    1   17   17    0    0    0    0    0    0    0    0    0
118    6   38  124    1   13   21   16    0    0    0    0    0    0    0    0    0
112   20  313   58    1    1   23   23    0    0    0    0    0    0    0    0    0
114   18  313   58    1    1   26   26    0    0    0    0    0    0    0    0    0
117    9  385  133    1    5   44   44  350   36   37    0    0    0    0    0    0
113   19  343   61    1   12   45   45  138   28   30    0    0    0    0    0    0
119    2  185    8    2   17   46   46   38   29   34    0    0    0    0    0    0
...
```

A7.5 STPF.DAT

In the STPF.DAT file data about fixed route vehicles are reported.
The file is updated by DIGIT during the simulation every time a fixed route vehicle exits from a link.
Each record contains information about the entry time, exit time and stop time of the vehicle on each link of the network where the vehicle travelled.
For each link a row of 8 elements is reported. The following table explains the meaning of each element.

Element	Description
1	Vehicle number
2	Fixed route number
3	Length of the link to which data are related
4	Link number
5	Entry lane
6	Entry clock
7	Exit clock (negative if the vehicle has reached a terminus or an exit node)
8	Clock when the vehicle stopped near the intersection (if no stop has been made the same as element 7)

A7.6 STATSEN.LOG

The STATSEN.LOG file is the output of acyclic activity number 8.
At the clock when activity is scheduled a report of the current statistics on all the links of network (except the exit links and links where the exit flow is zero) is written in the file.
The first row reports the clock to which data are related.
Then, after a comment row, one row for each link follows. After each "link" row another row for each lane of the link is reported.
At the end of this set of rows a last line reports two global speeds: the average value of the links' speed and the average value of speed for vehicle. Both are expressed in km/h.
The "link" row is made of six elements. The following table explains the meaning of each element. See also Appendix A1 for an explanation of the internal variables.

El.	Description	Internal variables
1	Link number	---
2	Number of lanes of the link	NCORS(link)
3	Number of vehicles present on the link [veh]	NVPS(link) + CIS(link) - ND1S(link)
4	Number of vehicles exited from the link [veh]	ND1S(link)
5	Average travel time [s]	TS(link)/ND1S(link)
6	Average speed [km/h]	3.6*LUNGS(link)/(Av. travel time)

A "lane" row is made of 7 elements. The following table explains the meaning of each element.

El.	Description	Internal variables
1	Lane number	---
2	Maximum number of vehicles queuing on the lane from the beginning of the simulation [veh]	MAXCO(lane,1)
3	Clock of the maximum queue	MAXCO(lane,2)
4	Average queue length [veh]	JRITS(lane)/(CLOCK-ISACLK)
5	Maximum number of stops on the lane during a simulation step [veh]	MAXST(lane,1)
6	Clock of the maximum number of stops	MAXST(lane,2)
7	Average number of stops per second	JSTOPS(lane)/(CLOCK-ISACLK)

Example: STATSEN.LOG

```
CLOCK   1800
SENSO N.CORS. PRES.  USC. T.MED. V.MED.  CORS.     STAT.CODE        STAT.TEMPI

  ...

  6      1      0    87      7   46.29
                                           4      1 1260   .00    1 1170   .00
  7      1     76   142    180    9.50
                                           7     74 1764 31.59    4 1746   .23
  8      2     51   232    211    3.16
                                           9     30 1397 26.00    1  919   .12
                                          10     29 1566 23.03    2  915   .14
  9      2     10   227     26    5.26
                                          13      5  900  2.85    1  976   .02
                                          14      5 1079  2.67    1  977   .02
 10      2      9   290     28   51.81
                                          17      0    0   .00    0    0   .00
                                          18      0    0   .00    1 1422   .00
 11      2     11   113    107   13.56
                                          19      9  971  4.11    3  969   .06
                                          20      9 1559  4.37    2 1243   .06
 12      2      0   115      4   34.20
                                          15      0    0   .00    0    0   .00
                                          16      0    0   .00    1  959   .00
 13      2      2   170     18   37.00
                                          11      4 1777   .28    2 1246   .05
                                          12      0    0   .00    0    0   .00
  ...
```

A7.7 LINKS.LOG

In this file data are recorded by DIGIT for each link every 100 exited vehicles.
For each link a row of 8 elements is produced reporting the main data that is also given at the end of the simulation in the FLUSSI.DAT file.
The definition of delay and occupancy is the same than the one used for the statistics at the end of the simulation.
The following table explains the meaning of each element.

Element	Description
1	Clock
2	Link number
3	Total number of exited vehicles
4	Average travel time for last 100 exited vehicles [s]
5	Average delay since the last record [s]
6	Average occupancy of the link since the last record
7	Number of stopped vehicles since the last record [veh]

Example: LINKS.LOG

```
396    16   100    6.43      .00      .06     1
411    17   100   20.39     1.20      .06    10
414     8   100   19.60     1.91      .09    35
417    18   100    7.51      .00      .06     0
419     9   100   17.07    11.96      .34    47
429    43   100    6.89      .55      .06     8
453    15   100    4.53      .01      .08     1
466    22   100    3.39      .13      .06     2
468    44   100   34.22     7.54      .13    83
475   132   100    4.17      .00      .18     7
486    19   100   61.83    25.67      .19   110
492    23   100   18.34     3.47      .09    39
494    31   100   16.40     3.96      .15    55
507    32   100   10.84      .00      .10     0
512     7   100   32.82      .00      .09     4
514    24   100    5.96      .00      .11     0
514    33   100    4.28      .43      .14    10
518   107   100   92.57    25.25      .38   137
523    20   100   12.44     5.12      .15    25
...
```

A7.8 CODE.BIN

This file reports the queue evolution on some selected links of the network.
The file is written in binary format but a utility program is available to translate it to an ASCII format.
It is possible to monitor up to ten links during a simulation.
The number of links to be monitored and the links' numbers are read by DIGIT in a file named CODE.DAT.
CODE.DAT is an ASCII format file made of two rows:

Row	Contents
1	Number of links to be monitored (0-10)
2	The links' list. The list of the links' numbers must be given separating the numbers by commas

At the start of the simulation DIGIT looks for CODE.DAT in the working directory and reads it. If the file is not found the CODE.BIN file is not produced.

If the output file has to be produced records are written every three step of simulation.

A7.9 Analysis tools

A set of programs is available to perform an analysis of some output files in a graphic form.
They also allow a comparison between results of different simulation to be performed.
The graphic programs run under MS-DOS operating system and require at least a VGA video adapter.
A menu presents the option to visualize the information contained in files having the format of FLUSSI.DAT, VELDIS.DAT and CODE.BIN.
As the first graphic is visualized an on-line Help of Commands is available pressing the key 'H'.

A7.10 Internal variables

ISACLK starting clock of the simulation

JRITS(lane) queue integral from the beginning of the simulation

$$JRITS(lane) = \sum_{t=0}^{T} N_{qq}(t)$$

where
$N_{qq}(t)$ is the number of queuing vehicles on the lane at step t
T is the simulation period

JSTOPS(lane) total stopped vehicles on the lane

$$JSTOPS(lane) = \sum_{t=0}^{T} N_{s}(t)$$

where
$N_{s}(t)$ is the number of vehicles that stop for the first time on the lane at step t
T is the simulation period

LUNGS(link) length of the link

NVMXS(link) storage capacity of the link

TEMPC(link) total queuing time o the link

$$TEMPC(link) = \sum_{t=0}^{T} N_{q}(t)$$

where
$N_{q}(t)$ is the number of queuing vehicles on the link at step t
T is the simulation period

TEMPT(link) total travel time on the link

$$TEMPT(link) = \sum_{t=0}^{T} N_p(t)$$

where

$N_p(t)$ is the number of vehicles present on the link at step *t*

T is the simulation period

TS(link) total travel time for exited vehicles

$$TS(link) = \sum_{veh=1}^{N_{out}} t_{tr}(veh)$$

where

$t_{tr}(veh)$ is the travel time of vehicle *veh* on the link

N_{out} is the number of vehicles exited from the link

APPENDIX A8 : STRATEGY COMBINATIONS

A8.1 List of Likely Individual Strategy Combinations:

AREA	STRATEGIES	ENVIRONMENTS	CONDITIONS	TOTAL
BASE	1	4	3	12
QM	8	4	3	96
PT	2	4	3	24
TC	2	4	3	24
TOTAL	13	4	3	156

Environments: EXISTING
PT
TC
PT & TC

Conditions: AM PEAK
INTER-PEAK
PM PEAK

As time and other practical constraints will not allow all possible combinations to be simulated the following plan is proposed.

In order to simulate the highest possible proportion of cases.

Prioritise Simulations **1 DO** (bold & underline)
2 - DO if time (underline)
3 - Maybe (depends on other results)

A8.2 Base case

All combinations should be simulated for the BASE case (ie NO ATT STRATEGIES). The PT environment should be AM PEAK (Inbound only), PM PEAK (Outbound only), INTER-PEAK (Inbound only). The TC environment should be in place and the same throughout the day.

BASE

- EXISTING **AM, INTER** & PM PEAK
- PT **AM, INTER** & PM PEAK
- TC **AM, INTER** & PM PEAK
- PT & TC **AM, INTER** & PM PEAK

A8.3 QM techniques

Basically ATT QM techniques are only appropriate in cases where there are queues to handle (ie the PEAKs, especially AM PEAK). If there is a PT environment then intuitively we also need a TC environment.

Autogating (x 4 types)

- EXISTING **AM** & PM PEAK
- TC **AM** & PM PEAK
- PT & TC **AM** & PM PEAK

Starting & Stopping waves

- EXISTING **AM** & PM PEAK
- TC **AM** & PM PEAK
- PT & TC **AM** & PM PEAK

External metering

- EXISTING **AM** & PM PEAK
- TC **AM** & PM PEAK
- PT & TC **AM** & PM PEAK

Variable message signs

- EXISTING **AM** & PM PEAK
- TC **AM** & PM PEAK
- PT & TC **AM** & PM PEAK

Total = **24** (48)m **25**% (50%) of possible 96 combinations

A8.4 PT priority

ATT PT priority is of use in both the AM PEAK, the PM PEAK and also in the INTER-PEAK. If we have BUS detection then we also need zero setback for bus lanes at signalised junctions.

Co-ordinate signals for BUS progression

- EXISTING **AM, INTER** & PM PEAK
- PT **AM, INTER** & PM PEAK
- TC **AM, INTER** & PM PEAK
- PT & TC **AM, INTER** & PM PEAK

Priority to BUSES at signals

- PT **AM, INTER** & PM PEAK
- PT & TC **AM, INTER** & PM PEAK

Total = **12** (18), **50**% (75%) of possible 24 combinations

A8.5 TC Strategies

ATT TC strategies will be easiest to implement during the INTER-PEAK period.

Linked traffic signals

EXISTING	**INTER-PEAK**
PT	**INTER-PEAK**
TC	**INTER-PEAK**
PT & TC	**INTER-PEAK**

Signalised pedestrian crossings

EXISTING	**INTER-PEAK**
PT	INTER-PEAK
TC	INTER-PEAK
PT & TC	INTER-PEAK

Total = **5** (8), **21**% (33%) of possible 24 combinations

A8.6 Overall proportion of total possible SCOOT simulations expected

The overall percentage of runs expected together with a likely time schedule is given below. Those with a high priority (ie priority 1) constitute 31% of the total possible and can be realistically achieved in 5 weeks. If resources permit we may wish to simulate up to 44% of the total combinations and at worst we expect this could take 13 weeks.

	Runs	Optimistic (3 per day)	Realistic (2 per day)	Pessimistic (1 per day)
PRIORITY 1	49 (31%)	4 weeks	5 weeks	10 weeks
PRIORITY 2	66 (42%)	5 weeks	7 weeks	13 weeks
PRIORITY 3	69 (44%)	5 weeks	7 weeks	13 weeks

A8.7 Strategy combinations for the SPOT system

A8.7.1 Test site: Turin - Gran Madre

Here two environments are considered, the base case and the addition of a reserved bus lane as a PT measure.

INDIVIDUAL STRATEGIES

	QUEUE MANAGEMENT STRATEGY	Env	Time	No.(*)
A	SPOT Management of saturated conditions (H.Q. estimation, downstream propagation of queue estimation, gating)	Basic Modif	TYP	7, 8
B	Auto-gating	Basic Modif	TYP	1, 2, 3, 4

	BUS PRIORITY STRATEGY	Env	Time	No.
C	Bus stop protection	Basic Modif	TYP	1

INTEGRATION OF STRATEGIES

STRATEGIES	Env	Time
A + C	Basic Modif	TYP
B + C	Basic Modif	TYP

TIME OF THE DAY: TYP refers to normal, nearly steady conditions; all day long measurements available for further simulations planning (suggested: AM, PM)
ENVIRONMENT: Modified refers to the addition of a short reserved lane before the bus stop

All strategies suitable for field trial implementation

(*) No. refers to the number initially allocated to each strategy see Internal Audit Report 24/11/92, Table 1

A8.7.2 Test site: Turin - Corso Grosseto

The Corso Grosseto site will be subjected to more thorough evaluation than Gran Madre and consists of a single environment. The bus priority strategy (C) will only be tested under simulated conditions. The traffic calming strategy D may be additionally tested in the interpeak period and strategy E (speed control) will be implemented using VMS.

INDIVIDUAL STRATEGIES

	QUEUE MANAGEMENT STRATEGY	Env	Time	No(*)
A	SPOT Management of saturated conditions (H.Q. estimation, downstream propagation of queue estimation, gating)	Basic	AM	31
B	Auto-gating	Basic	AM	32

	BUS PRIORITY STRATEGY	Env	Time	No(*)
C	Bus stop protection	Basic	AM	33

	TRAFFIC CALMING STRATEGY	Env	Time	No(*)
D	Speed limitation	Basic	AM	34
E	Speed control	Basic	AM	35

(*) No. refers to the strategy numbers allocated to revised strategies developed for the Corso Grosseto site.

INTEGRATION OF STRATEGIES

STRATEGIES	Env	Time
A + C, B + C	Basic	AM
A + D, A + E	Basic	AM
A + C + E	Basic	AM

TIME OF THE DAY: AM peak (7:30-8:30) is typical, other simulation conditions not planned yet
ENVIRONMENTAL: No structural modifications planned

All strategies suitable for field trial implementation

A8.7.3 Test site: Leeds - Dewsbury Road

INDIVIDUAL STRATEGIES

	QUEUE MANAGEMENT STRATEGY	Env	Time	No.(*)
A	SPOT Management of saturated conditions (H.Q. estimation, downstream propagation of queue estimation, gating)	Basic	AM, PM, IP	7, 8
B	Auto-gating	Basic	AM, PM, IP	1, 2, 3, 4

	BUS PRIORITY STRATEGY	Env	Time	No.
C	Selective vehicle detection	Basic BL	AM	1

	TRAFFIC CALMING STRATEGY	Env	Time	No.
D	Signalised pedestrian crossings	Basic TC	AM	3

INTEGRATION OF STRATEGIES

STRATEGIES	Env	Time
A + C	Basic, BL	AM
B + C	Basic, BL	AM
A + C + D	Basic, BL, TC, BL + TC	AM, PM, IP
B + C + D	Basic, BL, TC, BL + TC	AM, PM, IP

TIME OF DAY: PM and interpeak (IP) conditions should be considered only for the best individual strategies

ENVIRONMENT: BL refers to the addition of a bus lane, TC to traffic calming modifications

APPENDIX A9 : Draft MCA Tables for Simulations and Field Trials

Overall Performance Indicator	Safety %	Mean Speed(-) without delay	Link weights Network
		Proportion at high speed - need to define high speed and speeders via classes	Link weights Network Detectors for spot speeds mid-link
		Blocking Back	Link weights
	Efficiency %	Vehicle operating cost (distance)	Private Public (Veh.Km)
		Fuel consumption	Link weights Network
		Average stop time	Link weights Network
		Mean speed (+) with delay	Link weights Network
		Variance in speed	Link only
		Mean journey time	Link (+s.d.) Network OD Pair
		Delay	Link weights Network
		Mean flows	Link weights
		Mean traffic density (Occupancy)	Link weights
		Mean Bus travel times	route, link, Bus
		Blocking back	Link weights
	Environment %	Emissions (NO_x HC CO)	Link weights Network
		Visual intrusion (Delay)	Link weights Network
		Fuel consumption	Link weights Network

Table 6: Draft MCA table for computer simulations

Scheme Performance	DRIVE Goal	Criteria of Response	
	Safety %	Slight Conflicts	%
		Serious Conflicts	%
		Mean Speed	%
		"Speeding Vehicles"	%
		Vehicle Operating Costs	%
		Fuel Consumption	%
		No of Stops (Comfort)	%
		Mean Speed	%
Overall Performance Indicator		Variance Speed	%
	Efficiency %	Mean Journey Time	%
		Mean Queue Length	%
		Mean Traffic Flow	%
		Mean Traffic Density	%
		Mean Bus Occupancy	%
		Bus Journey Time Variance	%
	Environment %	Estimated Air Pollution	%
		Fuel Consumption	%

Table 7: Draft MCA table for field trials