Monograph:
Institute of Transport Studies, The (1995) VRU-TOO: variable road user traffic observation and optimisation, Drive II Project V2005. Working Paper. Institute of Transport Studies, University of Leeds , Leeds, UK.

Working Paper 439

Published paper
Institute of Transport Studies (1995) *VRU-TOO: Variable Road User Traffic Observation and Optimisation, Drive II Project V2005.* Final Report. University of Leeds, Working Paper 439

VRU-TOO

Vulnerable Road User Traffic Observation and Optimization

DRIVE II Project V2005

Final Report

Institute for Transport Studies, University of Leeds

Deliverable type:	P
Contract date:	February 1995
Submission date:	August 1995
ITS Working Paper:	439

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

The research reported herein was conducted under the European Community DRIVE II Programme. The project is being carried out by a consortium comprising: Institute for Transport Studies, University of Leeds; West Yorkshire Highways Engineering and Technical Services; Traffic Research Centre, University of Groningen; Department of Traffic Planning and Engineering, Lund Institute of Technology; FCTUC, University of Coimbra; FEUP-DEC, University of Porto; and TRENDS (Transport Environment Development Systems). The opinions, findings and conclusions expressed in this report are those of the authors alone and do not necessarily reflect those of the EC or of any organization involved in the project.

TABLE OF CONTENTS

1 EXECUTIVE SUMMARY

The VRU-TOO project has been unique in DRIVE II in that it has been the only project applying transport telematics specifically to reducing risk and minimizing delay to vulnerable road users. To achieve this the project has carried out further development of the signal systems that had been tested in DRIVE I by V1031, An Intelligent Traffic System for Vulnerable Road Users. These signals are able to register pedestrian demand automatically and to use that registration to provide pedestrians with signal timings that are better adapted to their actual needs. Alterations in signal timing have included both pre-arrival detection to provide instantaneous green on arrival at the kerb and green extension when demand is large. The signal systems have been implemented in varied traffic environments in the UK, Portugal and Greece.

In addition to this development and implementation work, the project has continued work on the pedestrian route choice simulation model VULCAN and has carried out detailed studies of pedestrian behaviour and risk in four European countries at two types of location, signalized and unsignalized junctions.

This report summarizes the three years of work in all the project work areas. The report indicates that telematics systems of the type implemented have great potential for improving conditions for vulnerable road users. Further extensions of the technology, particularly when informed and guided by the behavioural knowledge obtained, could save large numbers of casualties to pedestrians on major urban roads.

2 OBJECTIVES

The work in VRU-TOO has been targeted specifically at the reduction of risk and minimization of delay to vulnerable road users, namely pedestrians with as little inconvenience to motorised traffic as possible. To achieve this, the project has linked practical implementations in three countries with behavioural studies of the micro-level interaction of pedestrians and vehicles and the development of computer simulation models.

The implementations have taken the form of pilot projects in cities in both northern and southern Europe. Work in DRIVE I confirmed that, by incorporating passive detection of pedestrians in signalized crossings, pedestrian comfort and safety could be improved. The new schemes applied advanced detector systems to improve conditions for pedestrians, at signalized junctions and crossings on main roads. The UK implementation, in Leeds, involved the application of these techniques to a large city-centre scheme, where pedestrian needs can conflict with those of vehicle traffic. The systems have been being designed in such a way as to improve safety for VRUs, with as little inconvenience to motorized traffic as possible. This implementation was linked to an Urban Traffic Control (UTC) system.

Two smaller implementations have been made at urban locations in Portugal (Porto) and Greece (Elefsina), where once again it is difficult to satisfy both the needs of pedestrians and those of vehicles. This work is verifying the applicability of the same detection techniques in different environments.

At the same time, the project has carried out the necessary behavioural work to create detailed rules for the normal (safe) and abnormal (unsafe) interaction of pedestrians and vehicles. These rules have been developed independently of the pilot project locations, but the rules were applied in the behavioural evaluation of the pilot projects. This was intended to make it possible to go beyond the normal assessment of such schemes in terms of success or failure, by obtaining an understanding of how the behaviour of pedestrians and vehicle drivers was affected by the schemes and therefore of what the requirements for success are. This work was intended to permit the generalization of project results to other locations and the future implementation of new schemes that are even better tuned to the needs of pedestrians.

The computer modelling work has been aimed at the further development of the VULCAN1 (Vulnerable Road Users Can be Assigned to Networks) model developed by DRIVE I project V1031. This model takes as input a pedestrian origin-destination matrix for a small road network, and predicts pedestrian crossing flows at different locations. The flows are affected by the nature of the facilities provided and the consequent delay to pedestrians. Based on the flows, a safety prediction can be made for the network. The further development has aimed to improve the route choice model in VULCAN with the effect of improving the accuracy of its predictions. Furthermore, the VULCAN2 model has been applied in Portugal, to test its transferability from northern to southern Europe.

3 TECHNICAL DESCRIPTION OF THE PROJECT

3.1 PILOT PROJECT WORK AREA

3.1.1 Background

The principal objective of the work in this work area was to formulate ways to reduce the risk to vulnerable road users, namely pedestrians, in urban situations. The work would follow on from that commenced in DRIVE I, where different types of pedestrian facilities at signalised locations were introduced at different locations within northern Europe. These trials showed that it was possible to make the signals more responsive to the needs of pedestrians and that by the intelligent implementation of such systems there would be an improvement in safety and a reduction in delay for pedestrians.

In DRIVE I there were two projects (V1031-An Intelligent Traffic System for Vulnerable Road Users and V1061-PUSSYCATS) in which different techniques for the detection of pedestrians who wanted to cross the road were used. The results from this DRIVE I work showed clearly that by using technological advances it was possible to make alterations to the response of the signals to the needs of pedestrians and thus improve their safety and mobility. Hence the first part of the work within this work area was to carry out an extensive examination of all the existing techniques available for detecting pedestrians wishing to cross a road at a signalised location and then determine what techniques would be most suitable for use at the particular locations to be used in the planned pilot trials.

3.1.2 Detection Technology

As a result of these examinations it was decided by the project that it would be most appropriate, in all three cases, to use microwave detectors. The advantages of using such detectors are that they can be easily attached to signal poles and that the signal from the detectors can be transmitted through the signal controller to amend the timings of the signals in an intelligent manner. As implemented, the VRU-TOO system applied detection of pedestrians approaching a signalized crossing so that, when possible, they could be given a green at the moment of reaching the kerb. The concept is illustrated in Figure 1. The technology is based upon well tried and tested systems which have

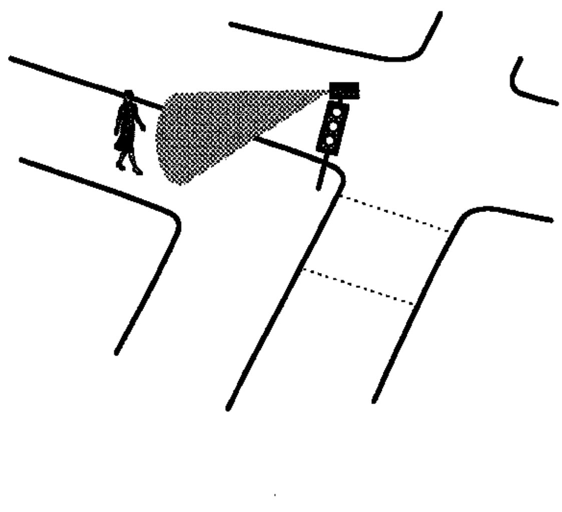

Figure 1: The VRU-TOO "system"

already been used for the detection of motor vehicles in urban areas; the only major alteration that was required was that the sensitivity of the instruments had to be adjusted so that slower moving objects (i.e. pedestrians) would be detected. The "system" is described in more detail in Appendix 2.

Figure 2 shows how the microwave detectors were affixed to the signal poles in one particular location.

3.1.3 Pilot Trials

The major task of the work area was to carry out trials in three different locations through Europe (Greece, Portugal and United Kingdom) to show that by the installation of microwave detectors at appropriate locations the mobility and safety of pedestrians at signalised crossings in urban situations could be improved. In all three cases the sites identified were in situations where there was a significant flow of pedestrians wishing to cross the road and that the requirement to provide time for pedestrians to cross the road was in conflict with the need to maintain the flow of vehicular traffic. In this set of trials there was a requirement to try and improve the conditions for pedestrians without making the situation significantly worse for the vehicular traffic.

Figure 2: Microwave detectors mounted on traffic signal

In all the three sites the crossing points were already fitted with push-buttons which would signify to the signal control system that there was a demand, the programme within the controller would then process this demand and then allocate a fixed amount of time for the pedestrian to cross the road. In the feasibility stage the project examined many of the simple alternatives that could be used to make this operation more responsive to the needs of the pedestrians and to the requirements of any given situation. The advantage of using the concept of detecting pedestrians as they approached a particular crossing point was that even within this very simple sounding concept there are very many alternatives that can be used to make the system more responsive. Thus the system, whilst being a "standard system", would also have the in-built flexibility to accommodate both national rules and local conditions. Therefore within the confines of the three trials the project has been able to combine the options and tailor them to the precise needs of the particular locations.

Examples of the actual manipulations that have been carried out within one or more of the trials are:

1. Triggering of the pedestrian demand to cross, before the pedestrian actually reaches the crossing point.

2. Extending the length of the pedestrian green time if pedestrians are still approaching the crossing point

3. Extending the length of the crossing time if the occupancy of the crossing is above a specified level.

4. Extending the length of the crossing time if any pedestrians are still on the crossing.

5. Bringing the pedestrian green time forward when pedestrian demand is above a certain level.

6. Reducing the pedestrian green time if no crossing pedestrians are detected.

It should also be noted that there was also a need to show that using such a pedestrian detection system could be incorporated within the existing situation in different countries within Europe. This requirement had two distinct phases: first of all it meant that the manipulations and alterations that were to be made to the signal timings should not conflict with the national signal regulations of the country within which the trial was being carried out. Secondly the response from the detector should be accepted and be in a form which can be used by the existing signal and signal control systems which are common in the country of the trial. In the case of VRU-TOO the trials were carried out in Greece, Portugal and United Kingdom and there was absolutely no problem in being able to meet these requirements.

Evaluation

In order to ensure that the work carried out on the three trials could be compared not only on a before and after basis on the same site but also between sites it was important that the evaluation be done on a similar basis. As far as possible the before and after periods for each site were chosen so as to be as similar as possible with regards to conditions, time, etc. The number of data values recorded at each site were related to that number need to obtain a valid result. Consequently the type of data and the means by which it was collected was specified so that it was as similar as could be arranged and that the definitions of the variables were consistent.

Examples of the data fields that were collected during the three trials so as to evaluate whether the specific objectives of the trials had been achieved include:

1. The number of pedestrians who crossed the road at all light settings were recorded from video records for specified periods of time.

2. The number of vehicles that passed the different crossing facilities at all signal settings were recorded from a video recording.

3. A manual observation of each of the sites for specified periods was used to quantify the number of serious conflicts and this was used to assess changes in safety

4. In one site, a manual record of the time taken for a sample of vehicles to pass through the full length of the section was collected at different times of the day using registration plate matching. In another site, the moving observer method was used to collect this type of information.

5. Queue lengths for the various streams of motorised traffic passing through the pedestrian facilities were obtained from video.

6. A manual record of the number of vehicles that violated the red lights was made throughout different periods of the trials.

The above data collection exercises were undertaken solely to address the question as to whether the specific objectives of the trial have been achieved. However, in addition, other data collection exercises were undertaken by the behavioural work area team to build up knowledge on pedestrian behaviour and to examine the differences/similarities between the trials.

The data collection was carried out in an identical manner (as far as was practical) on a before and after basis. Also every attempt was made to ensure that all other conditions remained the same in the before and after period. A period of at least three weeks was allowed after implementation, but before data collection, to allow the situation to settle down; during this time some ad-hoc measurements were taken to check what was happening, but this was not part of the formal evaluation process.

The number of pedestrians crossing the road was counted for at least a total of twenty-four hours. This time covered both peak and off-peak weekday periods and all of the signalised crossing points. For each of these periods the actions of the pedestrians were recorded together with the signal settings at the salient times during their movement. This recording was be carried out by video wherever possible and the settings of the signals were transmitted directly to the input channel in the recorder using a specially made piece of equipment involving sensors on the signal lights. One of the crossing points had to be covered by manual counts. The signal settings over an extended period were recorded, this allowed for reference to be made with regards to the proportion of time allowed to pedestrians and main road traffic.

The number of vehicles going through the signals was recorded from the video together with their movement and the setting of the signals at that time. A vehicle registration plate check was carried out at both ends of the length under consideration in Leeds to check the time taken to travel along the length. This work was done for 10 minute intervals in each hour covering the full working day. At least four such records were collected. In Porto, the moving observer method was used to obtain travel times.

A comprehensive conflict study was carried out at each site using the Swedish Conflict Technique and properly qualified conflict analysis personnel. A minimum of twenty-four hours of observation was taken.

The Sites

GREECE

Location

The site is at a recently installed signalised junction with standard pedestrian facilities (i.e. push button calling the pedestrian phase). This junction is on the main road which runs directly through the city of Elefsina, across which there is an established pedestrian route for workers and shoppers. Since there is also a by-pass around the city, queues of motorised traffic on the road are not considered to be a major problem, and in fact there is a desire to encourage more through traffic to use the by-pass route. The signals were installed in November 1993. Following this, the junction was allowed to settle down and the timings of the signals were adjusted to reflect local best practise. Then all the before data was collected and the microwave detection devices were installed on the existing signal poles. The enhanced system became operational in March 1994.

Response from detectors

At this location the detectors on either side of the minor junction were used in a different fashion. On the western side of the junction, the detectors detected pedestrians as they approached the crossing point, whereas on the eastern side of the junction the Greek Ministry of Transport had requested that the detectors be used to identify pedestrians who were on the crossing. The response from the microwave detection devices was then used to amend the signal timings. In this particular case this means that there was a dual response from the detectors: on the western side of the junction, when pedestrians were detected approaching the crossing then the procedure for changing the lights to give a green light for pedestrians was immediately started, thus advancing the change to and reducing pedestrian waiting time green by up to 4 seconds. On the eastern side the detectors were used to detect pedestrians while crossing and to extend the green time for pedestrians to allow the pedestrians to complete their crossing (although this is not strictly part of the VRU-TOO implementation).

PORTUGAL

Location

The site is a signalised intersection on a major dual carriageway acting as radial route to and from Porto. The signals are situated outside a school, which means that there is a constant flow of pedestrians throughout the day, with heavy concentrations of pedestrians for short periods during the day. There was an existing safety problem relating to children travelling to and from the school. (For more details see Deliverable 1).

Response from detection

Microwave detection devices were installed on the newly altered signal poles so as to detect pedestrians as they approached their crossing point. The locations of the devices are such that the majority of pedestrians detected will be intending to cross the road. When pedestrians are detected approaching the crossing then the change in the signals to give a green light for pedestrians is advanced by five seconds, thus reducing their waiting time. In addition if pedestrians are detected approaching the crossing when the lights are at green for pedestrians this phase is extended, up to a possible specified maximum of two seconds. Finally, if no pedestrian is detected starting to cross at the beginning of the pedestrian green time, this period is reduced by four seconds.

UNITED KINGDOM

Location

Leeds City Council are installing a one-way city centre loop (CCL) around the central shopping area as part of their strategy for controlling vehicles within the city centre. One feature of the CCL is that, although it has been designed so as to allow cars to travel around the central area, there is still the need for pedestrians to cross this road at street level. Therefore it has been accepted that the pedestrian facilities provided should be efficient as possible so as to allow the signal settings to be responsive to the needs of *all* road users. The CCL is being installed in four phases so as to minimise the overall disruption to the city centre. The work of the pilot trial is involved in Phase 2. This stretch goes essentially along one main street of length 0.6km. This stretch includes two signal controlled junctions and three other signalled controlled pedestrian crossing facilities. There is strong pedestrian demand to cross this road, but this is mainly in a direction perpendicular to the CCL and is thus very localised. The signalization of the CCL is run under a series of fixed time plans with various cycle times. The ATT measures have been attached to three of the signalised crossings.

Response from detection

The effect of the detection at the signalised locations was three-fold:

1. It triggered the pedestrian demand irrespective of whether the pedestrian button is pressed (with the exception of the peak periods at Merrion Street, when there was a permanent demand).

2. It prevented the situation of a pedestrian just missing the time window when approaching the crossing.

3. If a pedestrian approached the crossing at the end of the green man period, this period can be extended.

3.2 COMPUTER MODELLING WORK AREA

Computer modelling in VRU-TOO has focused upon two issues:

- Further development of the VULCAN pedestrian assignment model
- The transferability of Northern European modelling work to Portugal

3.2.1 Overview of VULCAN

VULCAN is a flow-based simulation of pedestrian movement on an urban street, concerned primarily with estimating where pedestrians will cross the street. It is described fully in VRU-TOO Deliverable 7 "Final Version of Pedestrian Meso Model" (Brundell-Freij and Timms, 1993).

VULCAN is typically to be used for a length of street with about three road junctions on it, and is intended to help the engineer plan crossing facilities for pedestrians. It requires as input:

- An origin-destination matrix of pedestrian flows (restricted to the street)

- A description of the network in terms of types of crossing facility and signal timings
- Counts of car flows through the network
- Parameters for route choice and accident models, although default values are given which are taken from empirical results in the UK

It outputs estimates on pedestrian flow and pedestrian accidents at crossing points. Such estimates are useful for the following situations:

1. Deciding on the benefit to be obtained by installing a pedestrian facility, such as a pelican crossing. The model will estimate both the number of pedestrians who will use such a facility and the aggregate safety benefit (over the whole network) that might be obtained.
2. Predicting the effect of changes in signal timing (such as those obtained with pedestrian detection systems) on pedestrian movement and safety. New signal timings will alter car flow and thus affect both pedestrian delay (and hence route choice) and pedestrian safety.

At the heart of VULCAN is a pedestrian route choice model described in 3.2.2 below. Delay is clearly an important factor in pedestrian route choice, and is calculated by a formula dependent on car flow. This is discussed in 3.2.3 below.

3.2.2 Pedestrian Route Choice

The VULCAN nested logit route choice model has been fully documented by Brundell-Freij and Timms (1993). The default hierarchical choice structure is shown in Figure 3.

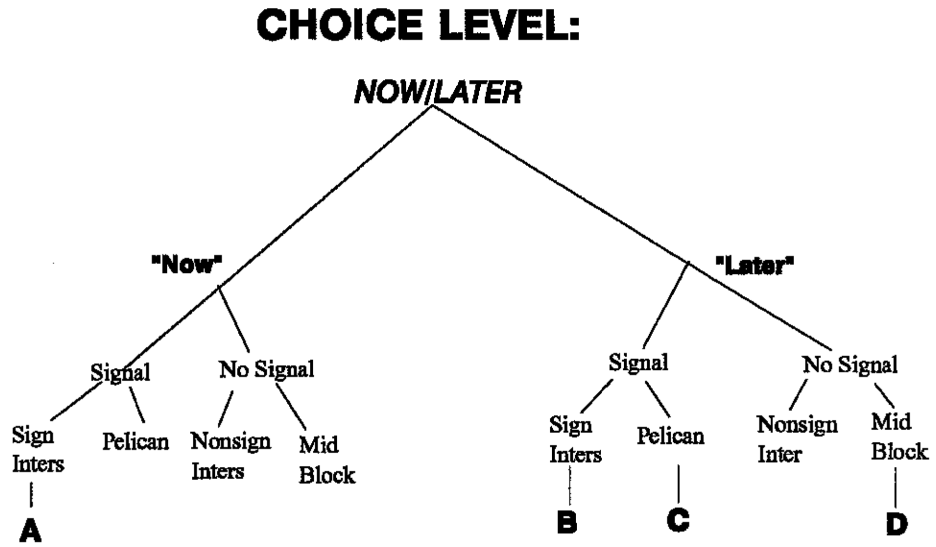

Figure 3: Default nested structure for VULCAN2

Each crossing alternative has a "generalised delay" term given by:

$$\alpha_{delay} * D_i + \sum_{J=\{j\}} \alpha_j * Z_{ij} \qquad (2.3)$$

where:

D_i is the expected delay in seconds (for the complete route through the network) associated with crossing opportunity i

Z_{ij}'s are dummy variables (taking the values 0 or 1) dependent upon attributes of the crossing alternative i (such as whether it is signalised etc)

α's are parameters giving the relative weights between delay and dummy variables (so that we can make statements such as "a pedestrian will accept up to five seconds delay in order to use a pelican")

At any decision point (as to whether or not to cross), the decision is based upon the generalised delays of the different available routes (i.e. the generalised delay is summed over all the places that a route crosses either the main road or a "side-street").

It was considered important in VRU-TOO to compare parameter values derived in Portugal with those derived in England. Hence, on a site in Coimbra (Portugal) the crossing behaviour of 277 pedestrians was observed over three days within the period 8.45 to 17.15. Part of the data was observed directly: namely the routes chosen by pedestrians, the signal stage at their arrival at a crossing, pedestrian classification and the time of observation. Recordings made by two video cameras (which covered the site) enabled the remaining data, namely pedestrian delay and vehicle flows, to be transcribed later in the laboratory. This data was used to calibrate a new pedestrian route choice model.

3.2.3 Pedestrian Delay / Car Flow Relationships

As stated above, estimates of delay are central to the VULCAN route choice model. In VRU-TOO Deliverable 7 (Brundell-Freij and Timms, 1993), it is explained why modelled estimates of delay are used rather than observed estimates.

The models of midblock and zebra crossing delay assume that a pedestrian arrives at the kerbside and expects to be delayed for time D. D is assumed to have an exponential distribution with mean E(D) given by:

$$E(D) = \beta + \psi * Q^{\omega} \qquad (2.1)$$

where β, ψ and ω are parameters calculated from empirical results
Q is the car flow conflicting with the pedestrian crossing movement[1]

[1] If there is no pedestrian waiting area in the middle of the road, then Q on a two-way road is taken as the sum of flows in both directions. If there is a pedestrian waiting area, however, then delay is worked out separately for both sides of the road.

The transferability of this type of relationship (and in particular the parameter values) was checked in VRU-TOO. To do so, data was collected data from four crossings in Coimbra, two of the "mid-block" type and two at "zebras".

Work in VRU-TOO developed formulae for the (truncated) expected delays of pedestrians arriving at a signalised crossing during a particular stage of the cycle, so that the overall expected delay is given by:

$$E(D) = \sum_i E(D_i) \frac{s_i}{c} \qquad (2.6)$$

where D_i is the (truncated) expected delay if arriving during stage i
s_i is the length of stage i
c is the signal cycle time

3.2.4 Use of SATURN

The main emphasis of modelling work in VRU-TOO has been on pedestrians. However, it is recognised that it is important to try to predict the effect on cars of pedestrian-oriented policies. With this objective, an exercise was carried out in V1031 to assess the effects on road traffic of pedestrian-friendly policies in Leeds, England, using the motorised vehicle model SATURN (Van Vliet, 1982). The results of this exercise were reported by Timms and Carvalho (1991). It was decided that a similar exercise should be carried out in VRU-TOO, this time testing the effects of pedestrian-friendly policies in Coimbra in order to examine whether there were any significant problems of technology transfer from UK to Portugal.

3.3 BEHAVIOURAL STUDIES WORK AREA

The behavioural studies have focused on three major objectives. The first was to identify relevant behavioural indicators of pedestrian safety and comfort at crossings. The second was to provide rule specifications for pedestrian interactions and conflicts. The behaviour-safety relations serve as a basis for the development of a safety model. On the basis of these preliminary activities, a framework for behavioural and safety evaluation of pedestrian detection systems was devised and applied in the pilot implementations that were realised in Leeds (UK), Elefsina (GR) and Porto (P).

3.3.1 Behavioural data collection protocol

The general aim of the activity was to define and quantify behavioural variables related to the safety and comfort of pedestrians.

A first global selection of variables supposedly related to the safety of pedestrians took place on the basis of a literature study including English, French, German, Dutch and Scandinavian publications. The available literature appeared to focus either on pedestrian conflicts or on pedestrian behaviour. In those cases, situational characteristics (e.g. presence of pedestrian facilities, traffic intensities) were considered as independent variables. However, the behaviour preceding interactions leading to a conflict could not be deduced. Consequently, relationships between pedestrian behaviour and safety could not be quantified. Nonetheless, a preliminary list of relevant behavioural variables could be construed. Furthermore, a data collection protocol was formulated that could be used for further work.

This protocol can be summarised as describing crossing behaviour in three stages:
1. approach phase: starting at a distance of about 3 meters away from the point where the pedestrian leaves the kerb and ending at the kerb.
2. first half crossing phase: starting at the point where the pedestrian leaves the kerb and ending at the middle of the road.
3. second half crossing phase: starting at the middle of the road and ending at the point where the pedestrian reaches the opposite kerb.

Within these three phases the following independent variables were scored:
- Course
- Visual orientation

In addition to these variables, the following characteristics of the pedestrian and the traffic situation were scored:
- Personal variables
- Social/situational variables
- Traffic variables

Conflicts between pedestrians and motorised traffic were scored in accord with the Swedish Traffic Conflicts Technique developed by the University of Lund (Hydén, 1987). The Traffic Conflicts Technique is a complementary technique to accident analysis for safety assessment. The basic concept is that there is a relationship between serious conflicts and injury accidents. These accident comparable events called serious conflicts, are recorded by human observers. A serious conflict is a conflict with a small margin. The margin is set by the TA-value (time to accident value) and the initial speed. The TA-value is the time from the moment when one road user starts an avoidance action to the moment a collision would have occurred if no evasive action had been undertaken. The border line which distinguishes serious conflicts from non-serious conflicts represents the time margin necessary for braking plus 0.5 seconds.

To validate the preliminary selection of critical variables and to quantify behaviour-safety relationships empirically, an observation study was carried out. Two different types of intersections were identified: signalised and non-signalised intersections. One intersection of each type was selected in the UK, NL, P, and S. To increase comparability of the intersections, several criteria with regard to situational characteristics such as road lay-out and traffic flows were applied.

The objective of the study was to investigate which crossing behaviour could explain conflict occurrence. Therefore, a novel approach had to be adopted involving simultaneous behaviour observation, recorded on videotape, and conflict observation on the spot, thus allowing comparison of behaviour that was conflict-related with behaviour in similar situations that did not lead to a conflict. For this purpose "encounters" were defined as interactions between pedestrians and vehicular traffic that did not lead to conflicts. Four types of encounter were identified:

type A: The pedestrian stops or slows down at the kerb to allow a vehicle driving on the near-side lane to pass and crosses behind that vehicle.

type B: The pedestrian stops or slows down at the kerb to allow a vehicle driving on the far-side lane to pass and crosses behind that vehicle.

type C: The pedestrian meets a vehicle driving on the near-side lane and crosses in front of that vehicle

type D: The pedestrian, while crossing the first half, meets a vehicle on the far-side lane and crossing behind that vehicle.

type E: The pedestrian, while crossing the first half, meets a vehicle driving on the far-side lane and crosses in front of that vehicle.

Observations were carried out for 50 hours at each location. Conflicts scored during the observations were identified on videotape and the behaviour preceding the conflict was analyzed. In addition, samples of videotape recording were used to analyse non-conflictuous behaviour. Thus, behaviour of pedestrians preceding conflictuous and non-conflictuous interactions could be identified.

3.3.2 Rule specifications for pedestrian interactions and conflicts

The objectives of the work were to quantify and formulate logical rules to describe the empirically found relationships between situational characteristics, the behaviour of the pedestrians, and road user interactions and conflicts. For this purpose, a reliability check of the conflict data, a decision tree analysis, and a reanalysis of the observational data was carried out that allow the calculation of conflict-encounter ratios.

The objectives of the reliability test of the conflict observations was twofold. Firstly, the test served to check the observers' judgement of the basic parameters, i.e. speed and time to accident, and secondly the test served to check whether the database included events other than serious conflicts. The objective of the decision tree analysis was to provide a quantitative description of the relative risk of specific pedestrian crossing behaviour strategies. The objective of the reanalysis of the observational data was to allow the description of conflict-encounter ratios in quantitative terms and to allow the testing of a number of hypotheses that were formulated on the basis of earlier stages of the work.

The analysis followed a step-wise approach. In the first step a reliability test of the conflict studies was carried out to check for errors due to observer variability. This was considered necessary, as the conflict observations in the different countries were carried out by different observers. Although all observers had followed a formal training in conflict observation, differences in the subjective judgement of the seriousness of conflict could not be ruled out. It would also be possible that the observers judgements with regard to the severity of the conflicts would drift over time, especially at locations where few conflicts would be observed. The method followed was to check the original conflict observations against the video observation material that was recorded at the time of the conflict observations.

A random selection of 20 conflicts per country (10 from the signalised and 10 from the non-signalised intersection) was made and the conflicts, 60 in total, were analyzed on video by an experienced conflict observer, who is a teacher of the Swedish Traffic Conflict Technique. The Swedish data were not considered as these were collected by the same person as the person who performed the secondary analysis. The re-evaluation of the conflicts was done prior to considering the individual observers' judgement. For each conflict, a new estimate of speed and time to accident (TA) was carried out as well as a general judgement whether the event was a conflict or not.

In the second step a decision tree analysis of crossing behaviour was made. For this purpose the database produced in an earlier stage of the project was used. This database contains a very detailed description of the pedestrian behaviour in relation to approaching traffic. Earlier analyses had considered the behaviour elements separately. This allowed the formulation of behavioural strategies for which a conflict-encounter ratio could be calculated. These conflict-encounter ratios are used as an indication of the relative dangerousness of the different strategies used by pedestrians.

In the third step the original data were reanalysed to allow calculation of the conflict-encounter ratios in absolute terms. For this purpose, 5 minute periods of videotape were scored on the number and type of encounters occurring. Subsequently, a number of hypotheses were formulated and tested. Further data analysis included logistic regression analyses for modelling pedestrian behaviour in encounters.

3.3.3 Behavioural and conflict evaluation of pilot project implementations

The objective of the study is to assess the effects of the pilot project implementations on the micro-level behaviour of pedestrians and to assess the effects of these implementations on the occurrence of conflicts between pedestrians and motorised traffic. The implementations involve the application of advanced pedestrian detector systems at signalised crossings in Elefsina (Greece), Porto (Portugal) and Leeds (UK). The technical description of these applications and the description of the implementation sites is provided in section 3.1.3 of this report.

The assessment indicators were selected on the basis of the results of the work described in the preceding paragraphs. Specifically, the study focused on the behavioural parameters shown in Table 1.

Table 1: Behavioural Criteria and Indicators

Behavioural Criteria	Indicators
safety	red light violations
	number of pedestrian/vehicle encounters
	pedestrians' normative behaviour
comfort	waiting time before crossing
	pedestrians' arrival at green light phase

The behaviour of the pedestrians was recorded both before and after the pilot implementations for a period of at least five working days. At least two weeks elapsed after implementation before "after" recordings were made. Recording hours were chosen such that both peak and off-peak period were included. Recordings were made on videotape which also registered a time-frame and the pedestrian and main vehicle stream traffic light signal stages. Pedestrian behaviour was scored from these videotape recordings using the parameters defined in the earlier stages of the project. Variables that were scored included: 1) general information; 2) pedestrian characteristics; 3) situational characteristics; 4) traffic light stages; 5) pedestrian's course of crossing; 6) timing of crossing; 7) head movements; 8) presence of other pedestrians and 9) description of encounters that occurred.

Conflict studies were carried out at all sites including three crossing sites in Leeds. In the Elefsina sites 45 hours of conflict observation was done both before and after the implementation. In Porto 15 observation days were realised. In Leeds all sites were observed 25 hours before and 25 hours after the implementations. Only serious pedestrian/vehicle conflicts were recorded. Conflicts were only recorded under dry weather conditions. The conflict observation technique used was the Swedish Traffic Conflict Technique as described above.

4 ACHIEVEMENTS

4.1 PILOT PROJECT WORK AREA

The primary objective of this work area was to carry out three major pilot trials at sites in urban areas where there was an existing problem relating to the needs of pedestrians wishing to cross a major trafficked route. In the three cases selected there were existing safety and mobility problems that could not be solved by the usual radical solution of complete segregation (either by banning vehicles or by diverting pedestrians over or under the road). Thus the introduction of intelligent crossings was seen as providing one more tool for highway engineers to improve conditions for pedestrians in urban areas. At the feasibility stage of the project it was discovered that at one of the sites the setting of the signals was not at its optimum positions, and therefore it was still possible that further improvements could be achieved with existing technology. Therefore the workings of that location were improved to the level of best practise before the actual trial began. This process was followed at the two other sites where no signal settings were introduced prior to the trial. Thus the data collected during the before period at each site was as for best practise for existing technologies. During the life of the project much of the effort within this work area was concentrated upon the designing and implementation of the pilot trials in the three countries and the organisation and collection of all the relevant data so that the results from the trials can be accurately evaluated. Time and effort was also spent in ensuring that the coordination and cooperation with the relevant national and local highway agencies was maintained so that the trials could be implemented. In addition this meant discussions with various commercial firms regarding the supply and modification of equipment needed to carry out the trials. At the times of the trials press releases and other publicity attractions were devised so as to widen the press exposure to the innovative nature of the new measures that were to be installed. All of the trials and the associated data collection exercises were completed, as per programme.

In order to assess whether the trials had been successful the project, at its very beginning specified at set of overall objectives that it wished to see achieved and a set of specific objectives for each trail site. It would be against these pre-determined objectives that the success or failure of the trials would be determined.

The overall objectives of the project that were used in the design of the trial were:

a) To improve the safety and mobility of pedestrians, especially children, without significantly worsening conditions for motorists.

b) To show that the results obtained from the trial are consistent with those obtained in Northern Europe, especially from DRIVE I project V1031.

c) To show that the results obtained a previous pilot trial can be reproduced when the system is integrated within a city traffic management system.

Each of the sites is discussed separately below. The behavioural evaluations of the implementations, including the conflict studies, are presented in greater detail in section 4.3.3.

4.1.1 Elefsina, Greece

In the case of Elefsina the overall objectives were translated into the following specific objectives:

a) There should be a significant reduction in the number of pedestrians who have to wait for more than 10 seconds before crossing the main road.

b) There should be a reduction in the number of serious conflicts between main road traffic and pedestrians.

An analysis of the results shows that:

- There has been a 22% overall reduction in the number of serious conflicts (a 51% reduction on the "VRU-TOO" side with pre-arrival detection, a 10% increase on the "Ministry" side with green extension).

- There has been a small reduction in the overall pedestrian delay, from a mean of 18.5 secs to 17 secs. This has been most marked in the proportion of pedestrians who wait for more than 30 seconds, where there has been a decrease from 28 percent to 18 percent.

- There has been an increase in the proportion of pedestrians who arrive at the crossing on a green signal from 5 percent to 9 percent.

- There was a slight reduction in the number of vehicles who violated the red light on the main road from 7 to 5 vehicles per hour.

- There was no increase in the length of the vehicle queues (a slight reduction was observed, but it was not statistically significant).

In addition to the above main trial specified above, additional work was carried out in Elefsina to apply microwave detection to build up a long-term pedestrian movement profile. This test was intended to confirm that the information from the detector could be extended to indicate quantity of flows. In the Greek situation, such information on flow could assist in setting up and implementing signal plans in a fixed-plan type UTC. In order to assist with this work, a small additional test was set up at a site with a particular pedestrian demand so that the pedestrian demand profile over a long time period (at least one month) could be monitored and evaluated.

Conclusions

Although the results from the trial have been comparatively small, the trial has been completed successfully and all the results have shown some benefits to pedestrians. The trial has been followed closely by the Greek Ministry who, as mentioned earlier, have made some suggestions as to how they see future installations being used.

4.1.2 Porto, Portugal

In the case of Porto the overall objectives were translated into the following specific objectives:

a) There should be a reduction of at least 10% in the number of children who cross the road against a red light.

b) There should be a significant reduction in the number of serious conflicts between main road traffic and child pedestrians.

c) There should be no increase in the number of vehicles going through red lights.

d) There should be no significant increase in the maximum queue lengths for vehicles on the main road.

The results were as follows:

- There was a reduction in the number of pedestrians who waited longer than 20 seconds. There was also a reduction in the number of children who waited for this time but the difference was not significant.
- There was no significant change in the number of pedestrian red light violations by adults or children, although there were variations in the effects on different sides of the dual carriageway.
- There was a slight overall reduction of 2% in the number of serious conflicts but this was not statistically significant.
- There has been no increase in the observed traffic queue lengths and also no significant increase in the length of the stated vehicular journey times.

These results have been slightly complicated by the fact that there was a 6% reduction in the total traffic flows across the pedestrian crossing, between the before and after data collection phases, probably due to other temporary road works which took place on another section of the main radial route. There was no overall change in the number of pedestrians crossing the road.

Conclusions

The trial showed that it was feasible to use pedestrian detectors in such a situation and that their use could be integrated within existing signal installations. However in the case used with the limitations on the scale of the changes in signal timings the present analysis shows that although the changes are consistent with those found in earlier studies the degree of change is low. It may also highlight some of the additional problems in using formal facilities in situations where the majority of pedestrians are schoolchildren.

4.1.3 Leeds, United Kingdom

In the case of Leeds, the overall objectives were translated into the following specific objectives:

a) There should be a reduction in the number of pedestrians who cross the road against a red light.

b) There should be a reduction in the number of pedestrians who wait for longer than 20 seconds.

c) There should be a reduction in the number of serious conflicts between main road traffic and pedestrians. (Due to the restricted time for evaluation, direct comparisons of injury accidents is not possible)

d) There should be no increase in the number of vehicles going through red lights.

e) There should be no significant increase in the total time for vehicles to travel through the length of the main road under consideration.

The specific objectives recorded above relate to the whole length of the CCL under consideration. The data collected was aggregated so as to assess whether each objective has been obtained; however obviously note has been taken of the results at each individual location. In theory objectives (a) through (d) could have been achieved at each of the locations individually, but because of the limitations on the amount of data that can be collected and the timescale which has been involved in this effort, it was not possible to statistically confirm the results at each individual location. Therefore in some instances the data will be aggregated.

The results from this trial show the following:

- There has been a reduction in the number of pedestrians who crossed the road whilst the signals were green for vehicles.

- There was a 17% reduction in the number of serious conflicts at the major crossing point along the length, but this was not statistically significant. At the other two crossing points, the original level of conflicts was much lower. At one there was a significant (p=.09) reduction from 4 to 1, and at the other there was no change from the initial 10 conflicts. The overall reduction in conflicts was 18%, which is significant at the .10 level.

- There was a slight reduction in the number of pedestrians who waited for more than 20 seconds.

- There was no increase in the number of vehicle red light violations.

- There was no increase in any of the queue lengths but the survey has shown some increase in total journey times.

Conclusions

The results of this trial showed that it was possible to incorporate such intelligent pedestrian facilities into a City Centre traffic management scheme and obtain benefits for pedestrians without undue problems for vehicles.

4.1.4 Overall Conclusions

In the cases of each of the trials the higher level overall objectives were translated into more specific aims which could be accurately judged by means of analysing the data that had been collected. Although these specific aims varied in degree from site to site, their underlying themes were common and thus the results can be summarised under the following headings.

Pedestrian Safety

In all three locations there was an overall reduction in the number of serious conflicts between pedestrians and other vehicles. There were however considerable variations between the sites and even between different carriageways on the same site.

There were no increases in the number of vehicles going through red lights.

Pedestrian Mobility

There was a reduction in the average length of time pedestrians had to wait at the kerb edge.

There was an overall increase in the number of pedestrians who arrived at their crossing point to a green signal; this increase was greater than would have been expected from the actual increase in pedestrian green time on the signals.

Traffic Flows

There was no significant increase in vehicle queue length at the individual sites although there was a slight increase in overall journey time over the length in Leeds (UK).

In addition to the factors above which showed that the objectives of the trials were achieved it should also be noted that the equipment proved itself to be reliable throughout all the trials with very little need for adjustment. In addition an extra check was carried out in Leeds to confirm that all pedestrians were detected and that there were no spurious detections that would cause false green time. This check confirmed the efficiency and reliability of the equipment.

4.2 COMPUTER MODELLING WORK AREA

4.2.1 Pedestrian Delay / Car Flow Relationships

The pedestrian delay / car flow relationship for midblocks in Coimbra is shown in Figure 4 (as "Reg_equation"), and is compared with results found by Goldschmidt (1977) in London. It can

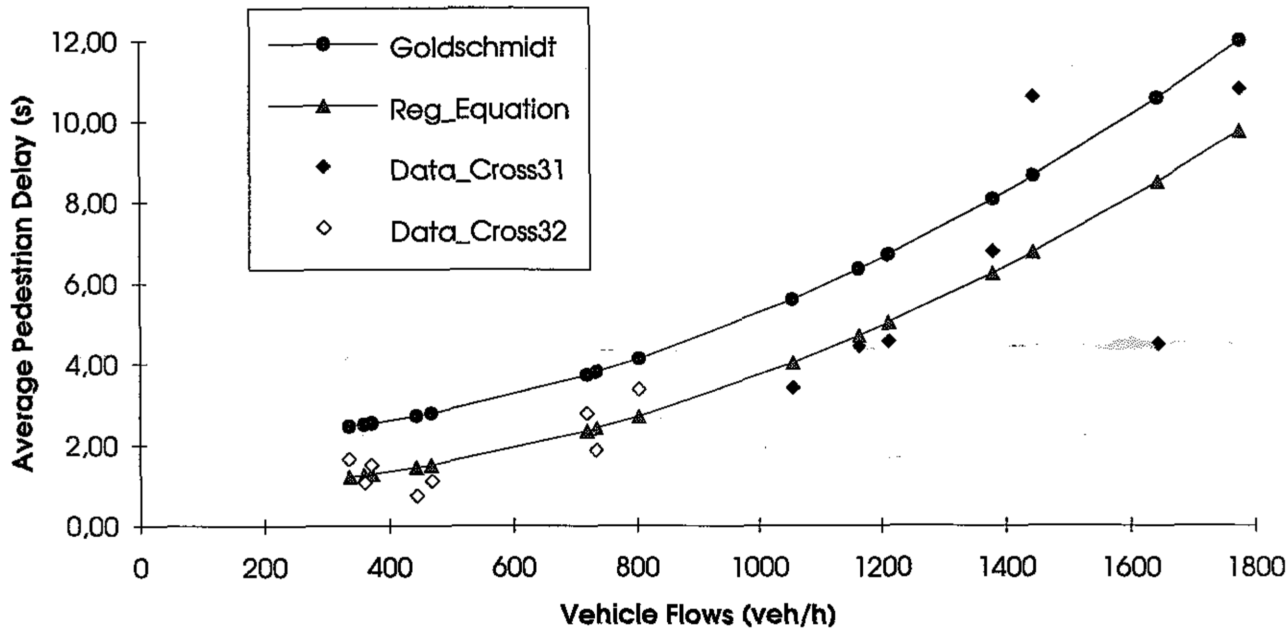

Figure 4: Pedestrian delay / car flow relationships at midblock crossings

be seen that there is a great similarity between the two regression equations, with an almost constant shift towards reduction of delay (whatever the flow level) in the Portuguese situation. This could suggest either that there is a higher level of risk-taking in the Portuguese pedestrian population or that there is a greater level of courtesy from Portuguese drivers.

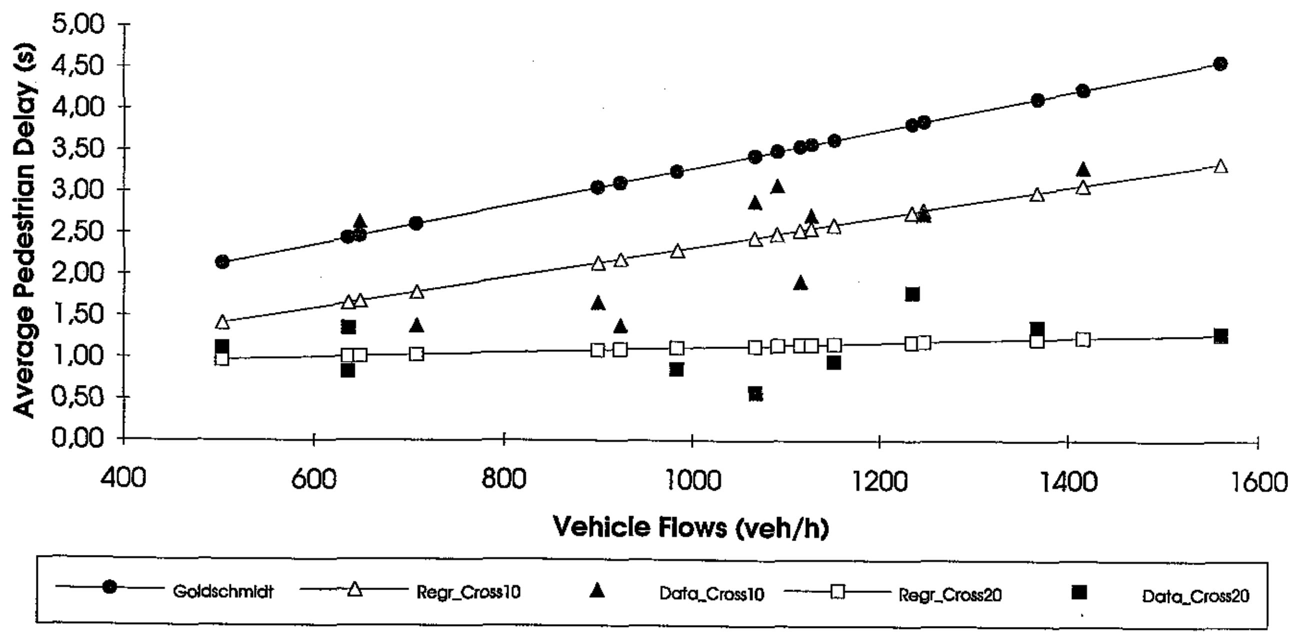

Figure 5: Pedestrian delay / car flow relationships at zebras

Figure 5 shows the relationship between car flows and pedestrian delay at zebra crossings. Unfortunately (from a modelling point of view), the relationship was found to be quite different at the two sites sampled in Coimbra ("Site 10" and "Site 20"). At Site 20, pedestrian delay was found to be virtually insensitive to car flow. Hence Figure 5 gives two relationships: "Regr_Cross10" and "Regr_Cross20", corresponding to these two sites. As with the midblock results, both relationships are compared with the London results obtained by Goldschmidt. Two comments can be made about these results:

(i) The Coimbra relationships give smaller values of delay than the Goldschmidt relationship at all levels of car flow. This result is similar to the midblock case and similar possible conclusions can be drawn.

(ii) Differing pedestrian behaviour at zebras was not discussed in Goldschmidt's work. It is thought that it can be explained by two factors: differences in pedestrian flow (much higher at Site 20) and in vehicle speed (higher at Site 10).

4.2.2 Pedestrian Route Choice

The nested logit model structure, used to describe route choice in VULCAN, is very flexible. Given a network of the VULCAN-type the model contains enough parameters to adapt to very large variations in observed route choice, which implies a good transferability.

However, there was a difficulty in testing the transferability of model formulation because of the impossibility of finding a "similar" site to the Bradford site where the original nested logit model was calibrated: sites in Coimbra that were similar for most purposes all had "middle islands" in the road. This leads to increased complexity of the network (and hence sets of crossing choices). It followed that the amount of data that was collected in Bradford (and which was sufficient to create a statistically good nested logit structure) was not sufficient to create stable and statistically significant results in Coimbra.

In order to apply transferability tests of parameter estimates a non-nested multinominal model was constructed. In spite of the disappointment about not being to test model formulation directly, it should be pointed out that this multinomial model was far superior in terms of behavioural sophistication to the simple binomial model produced in DRIVE I (see Brundell-Freij and Timms (1993) for details of the latter).

Table 2 summarizes estimates of α values for five sets of variables ("Coimbra 1" to "Coimbra 5") for the non-nested multinomial model for Coimbra, together with the corresponding Bradford ("Default") values. The data set that is most comparable with the default values is "Coimbra 5": the only different variable between the two models is "Walking middle island". The comparisons given below thus concentrate on these two sets of estimates.

Looking at α values for delay, it can be seen that men and women have very similar values of time in Coimbra, while in Bradford men seemed to have lesser values of time than women (contrary to what is normally found in modal split studies). This might be explained , though, by the fact that the Coimbra site was in the city centre and was filled with "busy" people. On the other hand, the Bradford site was in a residential area with high unemployment and traditional gender roles, so that women would tend to be more busy than men.

It can be seen that pelicans are attractive in both locations, scoring relatively high positive values. Comparing the attractiveness of both pelicans and signals between Bradford and Coimbra, we find surprisingly similar results for people under the age of 65. For the elderly, however, there is a striking difference between the two locations. For example, men over 65 in Bradford would accept a delay of up to 38 seconds ((3.12+2.26)/0.14) at a pelican to avoid an unsignalized crossing place, whilst the equivalent group in Bradford would only accept a delay of up to 4 seconds ((1.38-0.40)/0.23). In fact, the estimates show that the Coimbra pelican is less attractive to older people than to younger people. As above, a possible explanation for the difference between Bradford and Coimbra is to do with the difference between city centre and residential area: the over 65's in a residential area would be likely to be older, and hence more cautious, than those found in a city centre area.

In general, Table 2 indicates many similarities and a few dissimilarities. Since there is the possibility that dissimilarities could be explained by the difference between residential and city centre locations, it would appear that the transfer of parameter values was a far smaller problem than might have been expected.

Table 2: Parameter Estimates for Five Coimbra Models, with Default Bradford Values

	Coimbra 1	Coimbra 2	Coimbra 3	Coimbra 4	Coimbra 5	Default
DELAY:						
men	-1.003	-1.086	-0.85	-0.42	-0.23	-0.14
women	-0.863	-0.98	-0.70	-0.34	-0.17	-0.45
DUMMIES:						
signalised < 65 years			0.649	-0.79	-0.41	-0.47
signalised > 65 years			0.600	-0.85	-0.40	2.26
signalised common		0.51				
pelican > 65 years				1.75	1.72	1.33
pelican > 65 years				1.62	1.38	3.12
split crossing			-1.49	-1.65		
walking middle island					-3.18	
forced crossing					-0.98	0.44
Rho-2	0.11	0.13	0.23	0.31	0.34	0.19

4.2.3 Use of SATURN

The exercise using SATURN to assess the effects on cars of pedestrian-friendly policies in Coimbra has been fully documented by Godoy (1992). The main conclusions were as follows:

- The SATURN programme has a large number of options and parameters that can be set by the user. In a purely programming sense it is straightforward to transfer it from UK to Portugal and change values for parameters such as gap acceptance, give way rules, traffic signal standards, average vehicle length, saturation flows and whether there is right or left hand drive.

- However, there is a potential problem in Portugal of lack of availability of "standard" values of many parameters. Thus, estimates of such values rely more upon the experience of the engineer using the model than would be the case in the UK. It follows that, at present, the programme needs to be run by more experienced users (in terms of traffic knowledge) in Portugal.

- There was a problem "fitting together" the car network with a pedestrian network, in view of the more complex behaviour of pedestrians. This was a result found also in the "parallel" study in Leeds (Carvalho, 1990) and so is not essentially a transferability issue.

4.3 BEHAVIOURAL STUDIES WORK AREA

4.3.1 Reliability of conflicts

The reliability check of the conflict observations produced a comparison between the selected conflicts observed and the scoring of the same events from videotape. The results were plotted in Speed - TA graphs indicating scoring differences as represented by arrows. The results indicated clearly that serious conflicts were correctly identified and that no problem with observer reliability could be found. Only four conflicts out of 60 were considered non-serious conflicts in this test. The locations were selected on the basis of *a priori* definitions of intersections in order to achieve maximal comparability, which implies that the locations cannot be considered as typical locations for the different countries. The number of conflicts observed is therefore not an indication for the number of conflicts occurring at typical intersections in the different countries. The fact that, as intended only the serious and potentially dangerous conflicts were scored, indicates that it might be difficult to compare the number of conflicts in absolute terms. However, for the purpose of the study, comparison of the conflict and encounter ratios, the conflict data collected seem well suited.

4.3.2 Decision tree analysis

The strategies used in the decision tree analysis consist of a series of sequential variables, that belong to one of the three phases of the crossing manoeuvre: approaching phase; kerb phase and, finally, crossing first lane phase. The conflict-ratio is the quotient of the number of conflicts and the total number of encounters per strategy. The strategies are ordered in descending order of the magnitude of the conflict-ratio. The list of theoretical strategies for crossing a signalised intersection is 16 strategies at a first lane encounter and 32 strategies at a second lane encounter.

For crossing a non-signalised intersection the number of possible strategies is 8 and 16 at first lane and second lane encounters, respectively.

Signalised intersections

When having an encounter on the first lane of a signalised intersection, five crossing strategies (out of the 16) were used most often. These were:

1. pedestrian makes head movements during approach; pedestrian traffic light is **red** at departure from kerb; pedestrian changes tempo (slows down or stops) at kerb; and makes head movements at kerb (% of cases: 18; conflict ratio: .04).
2. pedestrian makes head movements during approach; pedestrian traffic light is **green** at departure from kerb; pedestrian changes tempo (slows down or stops) at kerb; and makes head movements at kerb (% of cases: 18; conflict ratio: .07).
3. pedestrian makes no head movements during approach; pedestrian traffic light is **green** at departure from kerb; pedestrian does not change tempo at kerb; and makes no head movements at kerb (% of cases: 13; conflict ratio: .45).
4. pedestrian makes no head movements during approach; pedestrian traffic light is **red** at departure from kerb; pedestrian changes tempo (slows down or stops) at kerb; and makes head movements at kerb (% of cases: 13; conflict ratio: .05).
5. pedestrian makes no head movements during approach; pedestrian traffic light is **green** at departure from kerb; pedestrian changes tempo (slows down or stops) at kerb; and makes head movements at kerb (% of cases: 12; conflict ratio: .28).

Five strategies were used less often in these circumstances, but much more likely to result in conflict. WHAT WERE THEY??? These five highly dangerous strategies take 22% of all encounters giving a conflict ratio of .65.

When having an encounter on the second lane of a signalised intersection, only 13 of the theoretically possible 32 crossing strategies are used (more than 4 times in the database). Five of these are used most often, namely:

1. pedestrian makes no head movements during approach; pedestrian traffic light is **green** at departure from kerb; pedestrian does not change tempo at kerb; makes no head movements at kerb; and makes no head movements on first lane (% of cases: 18; conflict ratio: .17).
2. pedestrian makes no head movements during approach; pedestrian traffic light is **green** at departure from kerb; pedestrian changes tempo at kerb; makes no head movements at kerb; and makes no head movements on first lane (% of cases: 14; conflict ratio: .09).
3. pedestrian makes no head movements during approach; pedestrian traffic light is **green** at departure from kerb; pedestrian changes tempo at kerb; makes head movements at kerb; but makes no head movements on first lane (% of cases: 12; conflict ratio: .05).
4. pedestrian makes head movements during approach; pedestrian traffic light is **red** at departure from kerb; pedestrian does not change tempo at kerb; but makes head movements at kerb; and makes head movements on first lane (% of cases: 8; conflict ratio: .38).
5. pedestrian makes no head movements during approach; pedestrian traffic light is **red** at departure from kerb; pedestrian changes tempo at kerb; makes head movements at kerb; and makes head movements on first lane (% of cases: 8; conflict ratio: .23).

These five strategies took 61% of the cases and had a conflict ratio of .16.

Two strategies were used less often in these circumstances, but highly conflictuous. These two strategies took 12% of the cases and had a conflict ratio of .65.

Non-signalised intersections

When having an encounter on the first lane of a non-signalised intersection, six of the eight possible crossing strategies were used. Three of these six were used most often. These were:

1. pedestrian makes head movements during approach; pedestrian changes tempo at kerb; and makes head movements at kerb (% of cases: 40; conflict ratio: .14).
2. pedestrian makes no head movements during approach; pedestrian changes tempo at kerb; and makes head movements at kerb (% of cases: 28; conflict ratio: .04).
3. pedestrian makes head movements during approach; pedestrian does not change tempo at kerb; but makes head movements at kerb (% of cases: 18; conflict ratio: .51).

These three strategies alone took 86% of the cases and had a conflict ratio of .18. The other three strategies were less often used in these circumstances, but very likely to result in conflict. These relatively dangerous strategies took the other 14% of the cases and had a conflict ratio of .85.

When having an encounter on the second lane of a non-signalised intersection, only four crossing strategies were used:

1. pedestrian makes head movements during approach; pedestrian does not change tempo at kerb; but makes head movements at kerb; and makes head movements on first lane (% of cases: 43; conflict ratio: .43).
2. pedestrian makes head movements during approach; pedestrian changes tempo at kerb; makes head movements at kerb; and makes head movements on first lane (% of cases: 26; conflict ratio: .38).
3. pedestrian makes no head movements during approach; pedestrian changes tempo at kerb; makes head movements at kerb; and makes head movements on first lane (% of cases: 19; conflict ratio: .09).
4. pedestrian makes no head movements during approach; pedestrian does not change tempo at kerb; but makes head movements at kerb; and makes head movements on first lane (% of cases: 13; conflict ratio: .19).

These four strategies led to an overall conflict ratio of .32.

In considering these results, it should be realised that the calculated ratios for the different strategies are based on data that contain a fixed number of encounters. While this provides an overall idea of the relative risk of the various strategies analyzed, it does not give an indication of the absolute numbers of encounter and conflicts occurring during specified periods. This would require scoring all encounters observed. As this was impossible to do with the very detailed and extensive variable set used in the earlier analyses, this procedure was limited to a small range of variables that appeared relevant in these earlier analyses.

4.3.3 Analysis of encounter-conflict ratios

The second analysis of the video-registrations of the pedestrian behaviour resulted in estimates of the true number of encounters that occurred during the video-registrations. All encounters were collected from video for a 10% period of the total hours of observation per junction. A check was made to see whether there was any relationship between the countries and the event types using the ratio of conflicts to the overall number of events. Only the data collected in The Netherlands and United Kingdom could be used because these two data sets have been collected in a consistent manner. A chi-square test revealed no significant relationship. Thus the formulated hypotheses can be tested independent of the country in which the data have been collected.

- *conflicts are more likely with turning traffic than with traffic travelling straight ahead.* For encounter/conflicts of type A, this is the case at signalised intersections (C^2=131.0, df=3, p < .0001) but not at non-signalised intersections (C^2=3.75, df=3, NS). For encounter/conflicts of type C and those of type D no difference is found at either signalised or non-signalised intersections. For encounter/conflicts of type E, the ratio in fact appears to be *lower* for turning traffic.

- *children will be more often involved in encounters of type C than adults.* The analysis showed that when a car approaches on the first lane, 44.5% (n=81) of the children crossed in front of the vehicle, while only 22.7% (n=260) of the adults did so. This difference is highly significant (C^2 = 38.89, df=1, p < .0001).

- *higher conflict-encounter ratios occur at non-signalised junctions than at signalised intersections.* While this is indeed found for the first half of the crossing (non-signalised encounter ratio = .05; signalised ratio = .02), it is not the case for the second half of the crossing (ratios .2 and .19, respectively).

- *high approach speeds of the vehicle increase the likelihood of the pedestrian crossing behind the vehicle*, and *high approach speeds increase the conflict-encounter ratio.* These hypotheses could not be confirmed.

- *if the pedestrian does not look in the direction of the approaching vehicle it is more likely that the driver will yield.* In the first lane encounters, 47.7% (n=155) of the pedestrians who do not look for approaching traffic cross in front of approaching cars, while 25.9% (n=297) of those that do look cross in front of approaching cars. In the second lane encounters, 79.5% (n=264) of the pedestrians who do not look while crossing the first half cross in front of a vehicle approaching in the second lane, while 67.9% of those who do look cross in front of an approaching vehicle.

- *the pedestrian crossing in front of an approaching vehicle are more likely to get involved in a conflict.* Comparison of the conflict/encounter ratio for pedestrians crossing in front of approaching vehicles and those crossing behind approaching vehicles shows a marked difference in ratio's. The conflict/encounter ratio for crossing in front is .031 while it is .004 fro crossing behind an approaching vehicle.

- *the conflict-encounter ratio is lower if several pedestrians cross at the same time.* There are higher conflict ratios for pedestrians crossing alone at signalised junctions but this relationship is not so clear at non-signalised junctions.

- *at signalised junctions the conflict/encounter ratio is higher in the first lane than the second lane.* While second lane events appear to have a much higher conflict-encounter ratio (overall for first half 0.04; for second half 0.17), this difference is not significant.

- *at signalised intersections pedestrians who stop at the kerb are less likely to get involved in a conflict.* For pedestrians who stop at the kerb the conflict/encounter ratio is .023, for those who do not stop at the kerb it is .331.

- *pedestrians with an age below 17 or above 65 years of age are more likely to get involved in a conflict.* Comparison of the conflict/encounter ratio's shows that this ratio is .022 for pedestrians younger than 17 or older than 65 while it is .013 for pedestrians aged between 18 and 64.

- *adult pedestrians are more likely to make head movements on approaching the crossing while young children are more likely to make head movement at the kerb.* While approaching the kerb, 55.1% (n=867) of the adult pedestrians make head movements and 66.9% of the children do so. This difference is significant but not in the expected direction (C^2=13.47, df=1, $p < .0002$). At the kerb, 84.9% (n=1395) of the adults make head movements against 87.6% (n=248) of the children.

- *the encounter/conflict ratio is higher for pedestrians who wait a longer period of time than for those who wait a short period of time or do not wait at all.* The pedestrians who do not stop have the higher conflict ratio at signalised junctions. At non-signalised junctions there is virtually no difference in the conflict/encounter ratio.

The remainder of the conflict/encounter ratios have been tested using simple probability and logistic models. Two types of models were developed:

Model type 1 predicts the probability of **stopping** before the conflict point

Model type 2 predicts the probability of passing the conflict point **behind the car**, *given* that the pedestrian has stopped (or not)

For the different situations, the results can be summarised as follows:

in non signalised situations:
- pedestrians tend to stop in first lane encounters *(sign test, $p<0.001$)*, and not to stop in second lane encounters *(sign test, $p<0.001$)*
- if pedestrians stop, they tend to let the car pass the conflict point first *(sign test, $p<0.001$)*
- if pedestrians do not stop, they tend to pass the conflict point before the car *(sign test, $p<0.001$)*

in signalised situations with a separate pedestrian signal:

- pedestrians tend to not stop *(sign test, $p<0.001$)*, especially in second lane encounters (*Chi-2 test, $p<0.001$)*
- if pedestrians (nevertheless) stop for second lane encounters, they tend to let the car pass the conflict point first *(sign test, $p<0.05$)*
- if pedestrians do not stop, they tend to pass the conflict point before the car *(sign test, $p<0.001$)*

in signalised situations without a separate pedestrian signal:

- pedestrians tend to stop in first lane encounters *(sign test, $p<0.001$)*, and to not stop in second lane encounters *(sign test, $p<0.01$)*, i.e. stopping behaviour is similar to that in non-signalised situations
- pedestrians tend to let the car pass the conflict point first *(sign test, $p<0.001$)*, especially if they stop *(Chi-2, $p<0.001$)*, but also if they do not stop *(sign test, $p<0.005$)*, i.e. cars seem to have an (even) stronger priority than in non-signalised situations.

The main conclusions of this study are:

- The behaviour of pedestrians which has been analyzed on a micro-level can be meaningfully classified in a number of relevant behavioural strategies;

- There are significant differences in the occurrence of the identified strategies dependent on situational characteristics and dependent on the presence and manoeuvres of approaching traffic;

- There are significant differences in the likelihood of conflict-encounter ratios dependent on the behaviour of the pedestrians crossing; the behaviour of the drivers, in particular speed of the approaching vehicle, is less relevant;

- The relationships found are valid for the range of countries that have been studied;

- Micro models of pedestrian-vehicular crossing would significantly increase their power in predicting safety effects if a number of well-defined pedestrian behavioural characteristics are taken into account.

4.3.3 Evaluation of the pilot project implementations

Pedestrian behaviour

A number of specific hypotheses were tested to assess the effect of the implementations on pedestrian behaviour. These hypotheses are:

- *The number of pedestrians that arrive during the red light stage and violate the red light will decrease.*
- *The time a pedestrian who arrives in the red light phase will have to wait for green light will decrease.*
- *The time a pedestrian who arrives in the red light phase actually waits before starting to cross will decrease.*

- *The number of pedestrians having a pedestrian/vehicle encounter will decrease.*
- *The pedestrians will not behave in a less normative manner.*
- *The number of pedestrians crossing in comfort will increase.*

The results are presented separately for each of the implementation sites.

In Elefsina (Greece), no change in red light violation could be detected. For pedestrians arriving during the red light phase, the expected delay decreased with 5 seconds on average. In particular the percentage of pedestrians that waited more than 30 seconds decreased (28% before implementation; 18% after implementation). The percentage of pedestrians involved in an encounter with a vehicle while crossing decreased from 38% before implementation to 23% after implementation. This change occurred both for first-lane and second-lane encounters. The normative behaviour of pedestrians did not deteriorate as a result of the implementation. In fact, for two of the indicators considered (stopping at red and head movements), an improvement in normative behaviour was found (75 to 83% and 55 to 66%, respectively). Pedestrian comfort, measured as "arrival at green lights" and "being able to cross completely during the green light phase" increased for both measures, although not significantly.

In Porto (Portugal) the results were measured for two parts of the crossing site separately (site 1 and 2). At site 1, red light violation increased from 84% tot 93%, while at site 2 red light violation decreased from 83% to 67%. Neither change is significant. At site 1 the implementation did not have any effect on the expected or realised delay for pedestrians. At site 2, the required waiting time decreased from 39 seconds to 25 seconds, but the realised waiting time increased. This last is probably due to the fact less pedestrians (and in particular children) violated red lights. At site 1, the percentage of pedestrians involved in an encounter with a vehicle while crossing increased (from 30 to 42%), while this percentage remained stable at site 2, except for children for whom the percentage of encounters decreased from 21% to only 9%. The normative behaviour remained stable at both site with a few exceptions. At site 1, the percentage of pedestrians making head movements before crossing increased (from 63 to 78%), but the percentage of pedestrians crossing in a straight line and making use of the crossing facility in fact decreased (from 74 to 60% and from 70 to 50%, respectively). At site 2, the same indicators increased (from 82 to 90% and from 69 to 83%, respectively). Pedestrian comfort, measured as "arrival at green lights" and "being able to cross completely during the green light phase" increased substantially (from 9 to 18% and from 22 to 45%, respectively).

In Leeds (UK) three sites were analyzed. Red light violation decreased (from 97 to 87%) at one of the sites and remained unchanged at the other two. At all three sites there was a significant decrease in the time pedestrians were expected to wait for green (site 1: from 34 to 23 secs; site 2: from 21 to 16 secs; site 3: from 34 to 20 secs). The time the pedestrians actually waited also decreased but not with the same magnitude. The percentage of pedestrians encountering a vehicle decreased at two of the sites and increased at the third (from 5 to 3%; from 11 to 9% and from 6 to 12%, respectively). The normative behaviour mainly remained unchanged. At site 1 crossing straight improved from 25 to 36%, and using the crossing facility improved from 36 to 50%. At site 2 head movements decreased from 23 to 12%. At site 3 stopping at red increased from 58 to 67%. Pedestrian comfort, measured as "arrival at green lights" and "being able to cross completely during the green light phase" increased at all three sites, although not all changes are significant.

Table 3 provides a summary of the results. It shows how far the "behavioural goals" of the implementations (as measured by the indicators) were achieved at the six different sites.

Table 3: Summary of Results of Behavioural Evaluation

	Elefsina	Porto 1	Porto 2	Leeds 1	Leeds 2	Leeds 3
red light violations	0	–	+	0	++	0
delay	0+	0+	+–	0+	++	0+
encounters	++	–	+	--	+	+
normative behaviour	++	+–	++	++	+–	++
comfort	+	++	+	++	0+	0+

Note: ++ significant improvement ($p<.05$); + slight improvement ($.05<p<.15$); 0 not improved; – slight deterioration ($.05<p<.15$); -- significant deterioration ($p<.05$)

Thus, it can be concluded that on the whole the implementations did not increase red light violations and at some sites improved pedestrian behaviour in this respect. Effects on pedestrians delay were on the whole positive. The effects on the likelihood of encountering a vehicle were dependent on site. Normative behaviour appeared to be generally improved with a few minor exceptions. Comfort for pedestrians increased overall.

Conflicts

In Elefsina, the conflict studies were carried out on two arms of the crossing. The overall number of conflicts appeared significantly changed between the before and after periods. 82 conflicts were observed in the before study and 64 in the after study (significant at the .05 level, one-tailed). On the arm which was equipped with the pedestrian detectors giving advanced green, a reduction from 43 to 21 conflicts, i.e. 51% ($p<.01$, one-tailed), was observed. On the other arm an increase from 39 to 43, i.e. of 10%, was observed.

In Porto, the conflict studies were carried out at two sites (i.e. at the crossings on each side of the tram lines), for both directions of pedestrian flow separately. The number of conflicts in the before study was 133, and the number in the after study was 130, so that the overall number of conflicts did not change significantly. On the side nearer the school, there was a (non-significant) reduction in conflicts from 79 to 74; on the other side, the conflict numbers increased from 54 to 56.

In Leeds, the conflict studies were carried out at all three implementation sites. The number of observed conflicts appeared to be extremely low for two of the sites. At the first site (Portland Crescent), 4 conflicts were observed before the implementation and 1 afterwards. This change is significant at the .10 level but not at the .05 level ($p=.09$, one-tailed). At the second site (Merrion

Centre), the number of conflicts decreased from 41 before implementation to 34 after implementation. This reduction is not significant (p=.14, one-tailed). At the third site (Garden of Rest), 10 conflicts were observed before and 10 after the implementation. If the three sites in Leeds are combined, the total number of conflicts observed was 55 before implementation and 45 after implementation. This change is significant at the .10 level, but not at the .05 level (p=.08, one-tailed).

In conclusion, there is some evidence that conflicts were reduced by the pilot project implementations. In Elefsina, there was a dramatic reduction in conflicts (to an extent where some extraneous factor may be involved). In Leeds, there was a less dramatic reduction. In addition, it should be noted that, overall, the changes were in the direction of increased safety.

Overall conclusions

Pedestrian behaviour tends to be highly adaptive to momentary circumstances. Many different strategies are followed when crossing the road and these strategies differ substantially in the likelihood of resulting in an encounter with vehicular traffic and in the likelihood of this encounter turning into a conflict. Moreover, pedestrian behaviour tends to deviate substantially from the normative behaviour. Red light violations are frequent. As a consequence, detailed analysis is required to assess effects of measures that aim to improve pedestrian safety and comfort. Conflict studies on their own provide little or no understanding of the way pedestrians will adapt their behaviour to the changed circumstances. The behavioural studies have revealed that the effects of the pilot project implementations are indeed in the expected direction. The normative behaviour generally improved, there is evidence for a decrease in red light violations and at the majority of sites, the number of pedestrian-vehicle encounters decreased. These positive results are only partly confirmed by the results of the conflict observations, but the overall conclusion that some safety gains are made, seems warranted. The results with regard to pedestrian comfort are more straightforward. Overall, the required delay was reduced after the implementations, and pedestrian were more often arriving when the pedestrian lights were green and more often able to complete the crossing during the green light stage.

5 CONCLUSIONS

The project has achieved all it main objectives. It has implemented three demonstrations of automatic detection technology at signalized pedestrian crossings. A detailed evaluation has shown that pedestrian safety and comfort were generally increased at all the locations. This shows that the VRU-TOO system is highly adaptable to the various countries, signal systems, types of location, junction layouts and mix of pedestrians. As intended, the benefits to pedestrians were obtained without causing any major side effects to vehicular traffic. It must be conceded that the observed benefits were not huge, but in spite of the constraints imposed — in particular that of causing little or no detriment to the efficiency of other traffic — they were generally positive. It can therefore be presumed that, if these restraints were relaxed, there would be significant safety and comfort benefits to pedestrians.

The VULCAN computer model has been extensively refined and implemented in a new environment. It can now serve as a useful and robust planning tool.

The behavioural studies have achieved new insights into how pedestrians behave as they encounter car traffic, showing which pedestrian strategies are most likely to result in a traffic conflict. This work provides the basis for future micro-simulation models which have the potential to predict pedestrian risk with far greater accuracy than traditional meso-level statistical models. Such models would provide a powerful tool for fine-tuning signal systems so that they are truly adapted to pedestrian needs and for ensuring that accident risk is minimized.

Telematics, then, holds out the promise of major safety improvements for vulnerable road users. It is hoped that this promise can be realized through further development work and more extensive and ambitious implementations.

6 REFERENCES

Brundell-Freij, K. and Timms, P. (1993) Final version of Pedestrian Meso Model. Deliverable 7 of DRIVE II Project V2005 (VRU-TOO). Institute for Transport Studies, University of Leeds.

Carvalho, M.S. (1990) Using SATURN to assess the effects on traffic of pedestrian friendly policies. MSc dissertation. Institute for Transport Studies, University of Leeds.

Godoy, R.P. (1992) Setting up SATURN in Coimbra for assessing pedestrian friendly policies. MSc dissertation. Institute for Transport Studies, University of Leeds.

Goldschmidt, J. (1977) Pedestrian delay and traffic management. TRRL Supplementary Report 356.

Hydén, C. (1987) The development of a method for traffic safety evaluation: The Swedish traffic conflicts technique. Bulletin 70. Department of Traffic Planning and Engineering, Lund Institute of Technology.

Timms, P. and Carvalho S. (1991) Inclusion of pedestrians and cyclists in network planning models. In *Advanced Telematics in Road Transport: Proceedings of the DRIVE Conference, Brussels, February 4–6, 1991*. Amsterdam: Elsevier Science Publishers.

Van Vliet, D. (1982) SATURN: A modern assignment model. *Traffic Engineering and Control,* 23, pp 578–581.

7 PUBLIC DELIVERABLES AND GENERAL PUBLICATIONS

7.1 PUBLIC DELIVERABLES

da Costa, P., Hodgson, F., Seco, A. and Sherborne, D.J. (1995) Assessment of effectiveness of the Portuguese implementation. Deliverable 12. Institute for Transport Studies Working Paper 440.

Rothengatter, J.A., Houten, Y. van and Hodgson, F.C. (1995) Micro-level behaviour and conflict changes in the VRU-TOO pilot projects. Deliverable 15. Institute for Transport Studies, Working Paper 438.

Seco, A. and da Costa, P. (1992) Feasibility: Details of existing site in Portugal. Deliverable 1. West Yorkshire Highways Engineering and Technical Services, Leeds.

Tillis, T. (1992) Details of existing site in Greece. Deliverable 2. West Yorkshire Highways Engineering and Technical Services, Leeds.

Sherborne, D.J. (1992) Existing techniques for detecting vulnerable road users. Deliverable 4. Institute for Transport Studies, Working Paper 383.

Sherborne, D.J. (1993) Assessing the pedestrian implications for Leeds city centre scheme. Deliverable 5. West Yorkshire Highways Engineering and Technical Services, Leeds.

Sherborne, D.J. and Hodgson, F. (1995) Assessment of effectiveness of the English implementation. Deliverable 16. Institute for Transport Studies Working Paper 441.

Tillis, T., Hodgson, F. and Sherborne, D.J. (1995) Assessment of effectiveness of the Greek implementation. Deliverable 14. Institute for Transport Studies Working Paper 442.

Timms, P., Seco, A.J. da M., Brundell-Freij, K. and da Costa, A.H.P. (1994) Implementation of pedestrian meso models in Portugal. Deliverable 8. Institute for Transport Studies, Working Paper 415.

Westra, E.J. and Rothengatter, J.A. (1993) Behaviour-conflict-safety relations for pedestrians. Deliverable 6. Traffic Research Centre, University of Groningen, Haren.

7.2 GENERAL PUBLICATIONS

Carsten, O.M.J. (1992) VRU-TOO: An ATT project for vulnerable road user safety. *VTI Rapport*, 380A, Part 3.

Carsten, O.M.J. (1993) Pedestrian problems: Can RTI help? In: A.M. Parkes and S. Franzén (eds.) *Driving Future Vehicles*. London: Taylor & Francis.

Carsten, O.M.J. and Hodgson, F.C. (1994) Pedestrian behaviour and pedestrian signal design. Presented at Seventh ICTCT Workshop, Prague.

Carsten, O.M.J., Timms, P.M., Brundell-Freij, K. and Seco, A.J. da M. (1995) Safe interaction of pedestrians and vehicles: Behaviour and ATT solutions. In: *Towards an Intelligent Transport System: Proceedings of the First World Congress on Applications of Transport Telematics and Intelligent Vehicle-Highway Systems.* Boston and London: Artech House.

Draskóczy, M. (1992) Traffic conflicts as indicators of pedestrian safety in a 'DRIVE' project. Presented at the Fifth ICTCT Workshop, Tallinn, Estonia.

Godoy, R.P. (1992) Setting up SATURN in Coimbra for assessing pedestrian friendly policies. MSc dissertation. Institute for Transport Studies, University of Leeds.

Hodgson, F.C. and Sherborne, D.J. (1993) Adaptive traffic signals for pedestrian safety. Presented at 6th Biennial Symposium on Recent Developments and Research in Road Safety, University of Salford.

Rothengatter, J.A. and Sherborne, D.J. (1995) Responsive signal settings for pedestrians in urban areas. In: *Towards an Intelligent Transport System: Proceedings of the First World Congress on Applications of Transport Telematics and Intelligent Vehicle-Highway Systems.* Boston and London: Artech House.

Rothengatter, J.A., Westra, E.J., Forward, S. and Costa, A. (1993) The behaviour of pedestrians at signalized and non-signalized intersections. In: *Advanced Transport Telematics: Proceedings of the Technical Days,* Volume 2. Brussels: Directorate General XIII.

APPENDIX 1: END PRODUCTS

End Product Description Sheet

1. Name or Title

Techniques for Detection of VRUs

2. Description and Purpose

Report outlining the techniques available at the present time for identifying pedestrians. The report outlines the advantages and disadvantages of each method and specifies some situations where they could be used.

3. Type of Output (e.g. brochure, report, software, specification, prototype)

Report

4. Producer (name of project/subproject, Task Force, Topic Group, etc.)

VRU-TOO

5. Name and Address of Contact Person

Mr D.J. Sherborne
Leeds City Council
Department of Highways and Transportation
Sweet Street
Leeds LS11 9DD, UK

6. Date when available

Existing

7. Related Documents (give exact reference, e.g. deliverable number)

"Existing Techniques for Detecting VRU"
VRU-TOO Deliverable 4

8a. Intended Client(s)/users (Who profits from the product? If several clients, list in priority order)	**8b Benefits Expected** (Explain what benefits will the client(s) get from the end product)
Engineers working in Highway Authorities, both in national and local areas. Researchers wishing to develop total systems to assist pedestrians.	To assist in developing systems which will increase the safety and mobility for pedestrians and provide the opportunity for cities to control the priorities given to different classes of road user.

9. Other Comments

The conclusions from this report were used extensively in the selection of the detection equipment used in the three pilot trials carried out in VRU-TOO.

End Product Description Sheet

1. Name or Title

Results from the Pilot Trial using pedestrian detection in Porto, Portugal

2. Description and Purpose

Description of the results from the Portuguese pilot trial detailing whether the pre-stated objectives have been achieved and highlighting the principal conclusions.

3. Type of Output (e.g. brochure, report, software, specification, prototype)

Report

4. Producer (name of project/subproject, Task Force, Topic Group, etc.)

VRU-TOO

5. Name and Address of Contact Person

Professor A. H. Pires da Costa
Faculdade de Engenharia da Universidade do Porto
Rua dos Bragas, 4099 Porto Codex
Portugal

6. Date when available

Existing

7. Related Documents (give exact reference, e.g. deliverable number)

"Assessment of Effectiveness of Portuguese Implementation"
VRU-TOO Deliverable 12

8a. Intended Client(s)/users (Who profits from the product? If several clients, list in priority order)	**8b Benefits Expected** (Explain what benefits will the client(s) get from the end product)
Engineers working in Highway Authorities, both in national and local areas, who wish to examine ways to improve the safety and mobility for pedestrians. Researchers wishing to develop total systems to assist pedestrians.	Knowledge relating to how effective the trial was in meeting the pre-stated objectives and what lessons were learnt from it. Assistance in developing their own systems which will increase the safety and mobility for pedestrians.

9. Other Comments

End Product Description Sheet

1. Name or Title

Results from the Pilot Trial using pedestrian detection in Elefsina, Greece

2. Description and Purpose

Description of the results from the Greek pilot trial detailing whether the pre-stated objectives have been achieved and highlighting the principal conclusions.

3. Type of Output (e.g. brochure, report, software, specification, prototype)

Report

4. Producer (name of project/subproject, Task Force, Topic Group, etc.)

VRU-TOO

5. Name and Address of Contact Person

Mr Tasos Tillis
Transport Environment Development Systems (TRENDS)
9 Kondylaki St
GR-11141 Athens, GREECE

6. Date when available

Existing

7. Related Documents (give exact reference, e.g. deliverable number)

"Assessment of Effectiveness of Greek Implementation"
VRU-TOO Deliverable 14

8a. Intended Client(s)/users (Who profits from the product? If several clients, list in priority order)	**8b Benefits Expected** (Explain what benefits will the client(s) get from the end product)
Engineers working in Highway Authorities, both in national and local areas, who wish to examine ways to improve the safety and mobility for pedestrians. Researchers wishing to develop total systems to assist pedestrians.	Knowledge relating to how effective the trial was in meeting the pre-stated objectives and what lessons were learnt from it. Assistance in developing their own systems which will increase the safety and mobility for pedestrians.

9. Other Comments

End Product Description Sheet

1. Name or Title

Results from the installation of pedestrian detection in a City Centre traffic management scheme in Leeds, UK

2. Description and Purpose

Description of the results from the British implementation detailing whether the pre-stated objectives have been achieved and highlighting the principal conclusions.

3. Type of Output (e.g. brochure, report, software, specification, prototype)

Report

4. Producer (name of project/subproject, Task Force, Topic Group, etc.)

VRU-TOO

5. Name and Address of Contact Person

Mr D.J. Sherborne
Leeds City Council
Department of Highways and Transportation
Sweet Street
Leeds LS11 9DD, UK

6. Date when available

Existing

7. Related Documents (give exact reference, e.g. deliverable number)

"Assessment of Effectiveness of British Implementation"
VRU-TOO Deliverable 16

8a. Intended Client(s)/users (Who profits from the product? If several clients, list in priority order)	**8b Benefits Expected** (Explain what benefits will the client(s) get from the end product)
Engineers working in Highway Authorities, both in national and local areas, who wish to examine ways to improve the safety and mobility for pedestrians. Researchers wishing to develop total systems to assist pedestrians.	Knowledge relating to how effective the trial was in meeting the pre-stated objectives and what lessons were learnt from it. Assistance in developing their own systems which will increase the safety and mobility for pedestrians.

9. Other Comments

End Product Description Sheet

1. Name or Title

Pedestrian detection system in Porto, Portugal

2. Description and Purpose

The actual installation is available for inspection.

3. Type of Output (e.g. brochure, report, software, specification, prototype)

Permanent installation

4. Producer (name of project/subproject, Task Force, Topic Group, etc.)

VRU-TOO

5. Name and Address of Contact Person

Professor A H Pires da Costa
Faculdade de Engenharia da Universidade do Porto
Rua dos Bragas, 4099 Porto Codex
PORTUGAL

6. Date when available

Existing

7. Related Documents (give exact reference, e.g. deliverable number)

Further details given in "Assessment of Effectiveness of Portuguese Implementation"
VRU-TOO Deliverable 12

8a. Intended Client(s)/users (Who profits from the product? If several clients, list in priority order)	**8b Benefits Expected** (Explain what benefits will the client(s) get from the end product)
Engineers working in Highway Authorities, both in national and local areas, who wish to examine ways to improve the safety and mobility for pedestrians. Researchers wishing to develop total systems to assist pedestrians.	Knowledge relating to how the implementation actually looks and works in practise.

9. Other Comments

The implementation can now be considered as a permanent workshop on how the system is functioning.

End Product Description Sheet

1. Name or Title

Pedestrian detection system in Elefsina, Greece

2. Description and Purpose

The actual installation is available for inspection.

3. Type of Output (e.g. brochure, report, software, specification, prototype)

Permanent installation

4. Producer (name of project/subproject, Task Force, Topic Group, etc.)

VRU-TOO

5. Name and Address of Contact Person

Mr Tasos Tillis
TRENDS
9 Kondylaki Street
GR - 11141 Athens, GREECE

6. Date when available

Existing

7. Related Documents (give exact reference, e.g. deliverable number)

Further details given in "Assessment of Effectiveness of Greek Implementation"
VRU-TOO Deliverable 14

8a. Intended Client(s)/users (Who profits from the product? If several clients, list in priority order)	**8b Benefits Expected** (Explain what benefits will the client(s) get from the end product)
Engineers working in Highway Authorities, both in national and local areas, who wish to examine ways to improve the safety and mobility for pedestrians. Researchers wishing to develop total systems to assist pedestrians.	Knowledge relating to how the implementation actually looks and works in practise.

9. Other Comments

The implementation can now be considered as a permanent workshop on how the system is functioning.

End Product Description Sheet

1. Name or Title

Pedestrian detection system within the City Centre traffic management scheme in Leeds, UK

2. Description and Purpose

The actual installation is available for inspection.

3. Type of Output (e.g. brochure, report, software, specification, prototype)

Permanent installation

4. Producer (name of project/subproject, Task Force, Topic Group, etc.)

VRU-TOO

5. Name and Address of Contact Person

Mr D.J. Sherborne
Leeds City Council
Department of Highways and Transportation
Sweet Street
Leeds LS11 9DD, UK

6. Date when available

Existing

7. Related Documents (give exact reference, e.g. deliverable number)

Further details given in "Assessment of Effectiveness of British Implementation"
VRU-TOO Deliverable 16

8a. Intended Client(s)/users (Who profits from the product? If several clients, list in priority order)	**8b Benefits Expected** (Explain what benefits will the client(s) get from the end product)
Engineers working in Highway Authorities, both in national and local areas, who wish to examine ways to improve the safety and mobility for pedestrians. Researchers wishing to develop total systems to assist pedestrians.	Knowledge relating to how the implementation actually looks and works in practise.

9. Other Comments

The implementation can now be considered as a permanent workshop on how the system is functioning.

End Product Description Sheet

1. Name or Title

Rules for pedestrians interactions and conflicts

2. Description and Purpose

A detailed analysis of pedestrian behaviour in road crossing, comparing safe with unsafe behaviours.

3. Type of Output (e.g. brochure, report, software, specification, prototype)

Database and report.

4. Producer (name of project/subproject, Task Force, Topic Group, etc.)

VRU-TOO

5. Name and Address of Contact Person

Professor J.A. Rothengatter
Traffic Research Centre
University of Groningen
PO Box 69, 9750 AB Haren
The Netherlands

6. Date when available

Existing

7. Related Documents (give exact reference, e.g. deliverable number)

"Formal Rule Specifications for Pedestrian Interactions and Conflicts"
VRU-TOO Deliverable 11

8a. Intended Client(s)/users (Who profits from the product? If several clients, list in priority order)	**8b Benefits Expected** (Explain what benefits will the client(s) get from the end product)
Designers of pedestrian facilities, highway authorities, researchers.	Better understanding of the behaviours that lead to conflicts with vehicles, and therefore guidance on strategies for reducing conflicts.

9. Other Comments

End Product Description Sheet

1. Name or Title

Behaviour and conflict changes in the VRU-TOO Pilot Projects

2. Description and Purpose

An assessment of the changes brought about by the VRU-TOO implementations on pedestrian behaviour and pedestrian/vehicle conflicts.

3. Type of Output (e.g. brochure, report, software, specification, prototype)

Results of assessment (reports).

4. Producer (name of project/subproject, Task Force, Topic Group, etc.)

VRU-TOO

5. Name and Address of Contact Person

Professor J.A. Rothengatter
Traffic Research Centre
University of Groningen
PO Box 69, 9750 AB Haren
The Netherlands

6. Date when available

Existing

7. Related Documents (give exact reference, e.g. deliverable number)

"Micro-Level Behaviour and Conflict Changes in the Pilot Projects"
VRU-TOO Deliverable 15

8a. Intended Client(s)/users (Who profits from the product? If several clients, list in priority order)	**8b Benefits Expected** (Explain what benefits will the client(s) get from the end product)
Designers of pedestrian facilities, highway authorities, researchers.	Understanding of how pedestrian behaviour and safety is modified by pedestrian detection at signalized crossings.

9. Other Comments

End Product Description Sheet

1. Name or Title

VULCAN

2. Description and Purpose

Mesoscopic street-level pedestrian simulator for assessing the route choice and safety effects of ATT schemes upon pedestrians

3. Type of Output (e.g. brochure, report, software, specification, prototype)

Software

4. Producer (name of project/subproject, Task Force, Topic Group, etc.)

VRU-TOO

5. Name and Address of Contact Person

Dr Paul Timms
Institute for Transport Studies
University of Leeds
Leeds LS2 9JT, UK

6. Date when available

Existing

7. Related Documents (give exact reference, e.g. deliverable number)

VRU-TOO Deliverables 7 and 8

8a. Intended Client(s)/users (Who profits from the product? If several clients, list in priority order)	**8b Benefits Expected** (Explain what benefits will the client(s) get from the end product)
Local Authority Planners and Engineers. Consultants to Local Authorities	Improved safety and reduced delay to pedestrians.

9. Other Comments

VULCAN can be used in a variety of Fourth Framework Projects.

End Product Description Sheet

1. Name or Title

VRU-TOO Brochure

2. Description and Purpose

A summary of project work with photographs of the implementation sites

3. Type of Output (e.g. brochure, report, software, specification, prototype)

Brochure

4. Producer (name of project/subproject, Task Force, Topic Group, etc.)

VRU-TOO

5. Name and Address of Contact Person

Dr O.M.J. Carsten
Institute for Transport Studies
University of Leeds
Leeds LS2 9JT, UK

6. Date when available

Existing

7. Related Documents (give exact reference, e.g. deliverable number)

8a. Intended Client(s)/users (Who profits from the product? If several clients, list in priority order)	**8b Benefits Expected** (Explain what benefits will the client(s) get from the end product)
Designers of pedestrian facilities, highway authorities, user groups	Summary information on project approach and achievements

9. Other Comments

APPENDIX 2: SYSTEM ARCHITECTURE

SYSTEM ARCHITECTURE OF PEDESTRIAN DETECTION SYSTEM

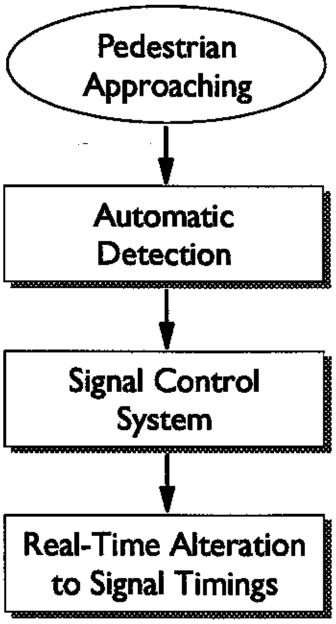

Figure A: Overall System Architecture

The basic system flow is as shown in Figure A. Its main components are as follows:

1. There must be a route or collection of routes taken by pedestrians who are going to cross the road. The ideal for this is the central island on a dual carriageway, where it can be certain that all approaching pedestrians are going to cross the road. (There are very many cases like this in urban areas.) The worst case is on a narrow footway at a cross road where approaching pedestrians may cross the roads in either direction or just turn a corner. In such situations, preliminary investigations may be necessary to ascertain the actual percentage of pedestrians making certain movements.

2. Once a location is selected where a significant number of approaching pedestrians are going to cross the road, then the pedestrian detection system is positioned. The detection system consists of a microwave detector which has a field of view sufficient to "see" the approaching pedestrians. In a typical situation the detector is positioned 3 metres above ground level. In the majority of cases the detector can be attached to the signal head. It is then aimed at the approaching pedestrians with a detection angle in the range 30–50

degrees. The minimum approach speed is 3 km/h and in this case approaching pedestrians are detected approximately 10 meters prior to reaching the detector position.

The positioning of the detector is critical to the operation, it must be positioned such that it picks up the desired pedestrians but not other signals. In particular care must be taken to ensure that it is not triggered by approaching vehicles. In most cases this is not a problem, but in extreme cases it may be necessary to fix a "blinker" to the detector whichn indicates when it has been triggered. This can be used to verify detection.

3. The response from the detector then needs to be fed through to the traffic signal control box. This has not proved to be a problem in any of the implementations, and the necessary connections between the signal poles and the controller have been available. However when the system is being proposed it is vital that the check is made to ensure that the required connections are available. It is also vital to ensure that in all the connections on the signal poles the correct voltages are available.

4. Once all the connections have been made, all that is required is that the overall strategy is decided and the actual requirements of the individual site are taken into account. Since the principal aim of the detectors is to provide a real-time response to actual pedestrian need it is important to determine what detections are important and how they should be responded to. Examples of the manipulations that can be carried out by using such detections include:

   (a) Replacing the push-buttons by the detections. In this case the pedestrian demand is received before the pedestrian reaches their crossing point.

   (b) Extending the pedestrian green time if pedestrians are still approaching the crossing point whilst the lights are green for pedestrians.

   (c) Increasing the pedestrian green time if a large number of pedestrians are crossing

   (d) Increasing the priority for pedestrians if a large number of pedestrians have approached the crossing point.

These real-time adjustments to the signal timings can then easily be programmed in to the actual signal controller.

EXAMPLE

The flow-chart in Figure B shows the signal settings for a typical intersection in Portugal which is run under independent signal control. The system runs on four stages with a variable cycle time. The junction is controlled by a SFIM (Castor-8000 Series) controller which has been set up in accordance with best current practise. One significant feature of the existing signal settings is that although the junction has a school on one corner, and therefore there is a significant pedestrian usage of the junction which will fluctuate wildly throughout the day. There is no way of altering the signal timings to favour pedestrians at those periods when there is heavy demand. There are pedestrian push-buttons that control the red and green men pedestrian signals, but that is all the buttons do control; they do not have any effect upon the timing or duration of the pedestrian lights. (There is no pedestrian only stage within the cycle). Indeed it will be noted that the only stage of the cycle that is variable is the fourth stage which allows traffic out of the minor road. In this case if there is a detected vehicle demand (from loops) then the length can be extended by up to 16 seconds. This extension does in fact help pedestrians cross part of the major road, but this was purely coincidental.

It was clear that this type of situation was not ideal, especially for pedestrians, but in the absence of new techniques it was difficult to improve the situation for pedestrians without drastically reducing the vehicle capacity of the intersection. The main problems associated with doing this were:

- Pedestrians, especially children, do not often press the push-buttons
- Pedestrians, especially children, do not like waiting at the kerb
- Motorists become impatient if the lights are green for pedestrians for a long period when there are no pedestrians wishing to cross.

It is these factors which have up to now prevented a more pedestrian responsive system from being used at standard intersections. However the use of microwave pedestrian detection devices overcomes all of the problems listed above by automatically detecting pedestrians before they reach their crossing point and only giving the pedestrians time within the cycle when there is a demand.

When the pedestrian detectors were attached to the appropriate signal poles and the connections made to existing inputs within the controller, this meant that the signal controller could now receive information as to the location and occupancy level of pedestrians. The controller was then able, without any further modification, to be re-programmed on site to be able to cater for this additional knowledge of real-time pedestrian need. The way in which the needs of pedestrians should be catered for will obviously vary in each case and in fact one of the major benefits of the system is that it is possible to cater for different demands in different situations (what we are demonstrating here is just one typical usage). The flow chart in Figure C shows that the system is still being run on a four stage cycle with a variable length. However in this after situation the system is able to take "decisions" at many occasions throughout the cycle to see if there is a pedestrian need and if there is then the signal timings can be amended. All of the options that are shown within this flow chart were chosen on site as a result of data collected at the site. In addition all of the alterations to the timings are capable of being done within the controller box without have to modify any of the processor.

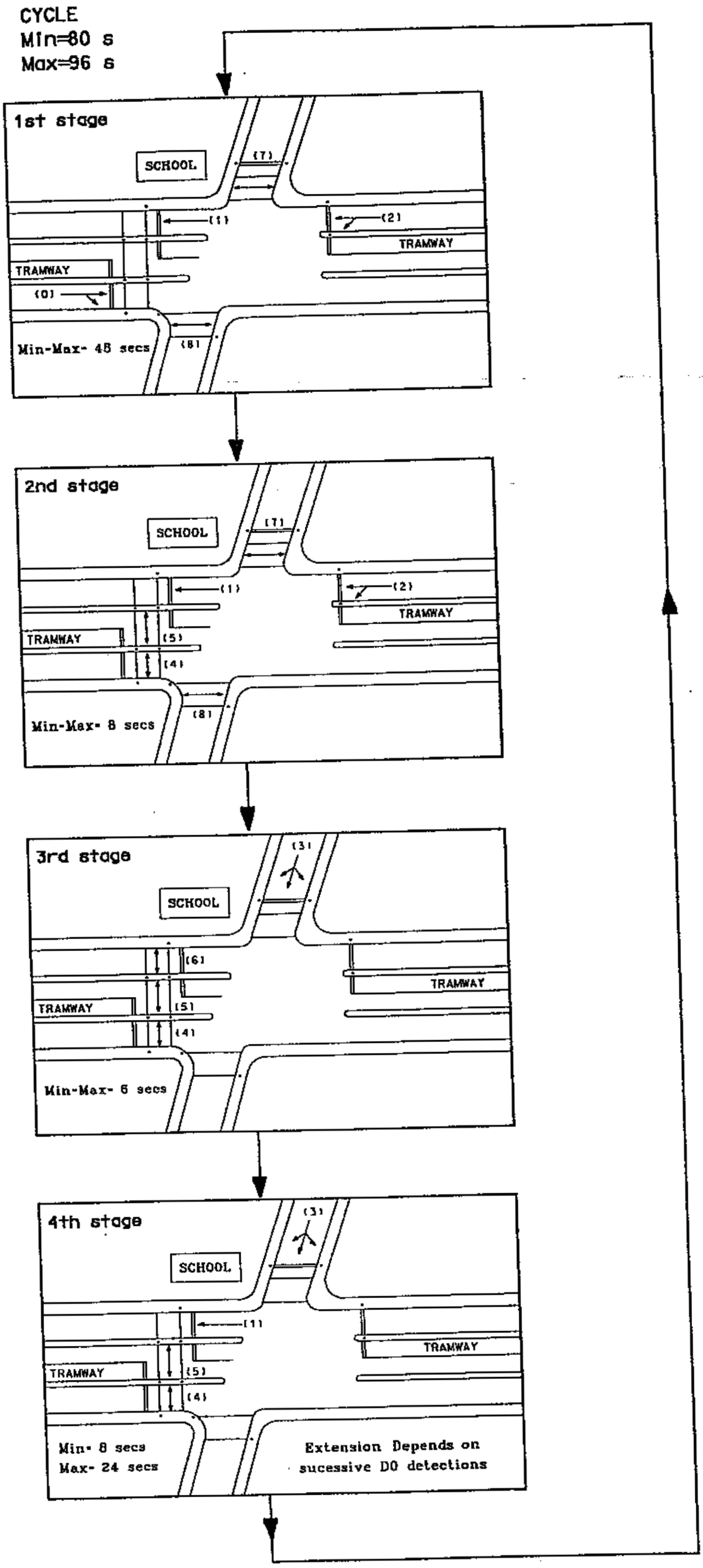

Figure B: Signal Stages in the Before Situation

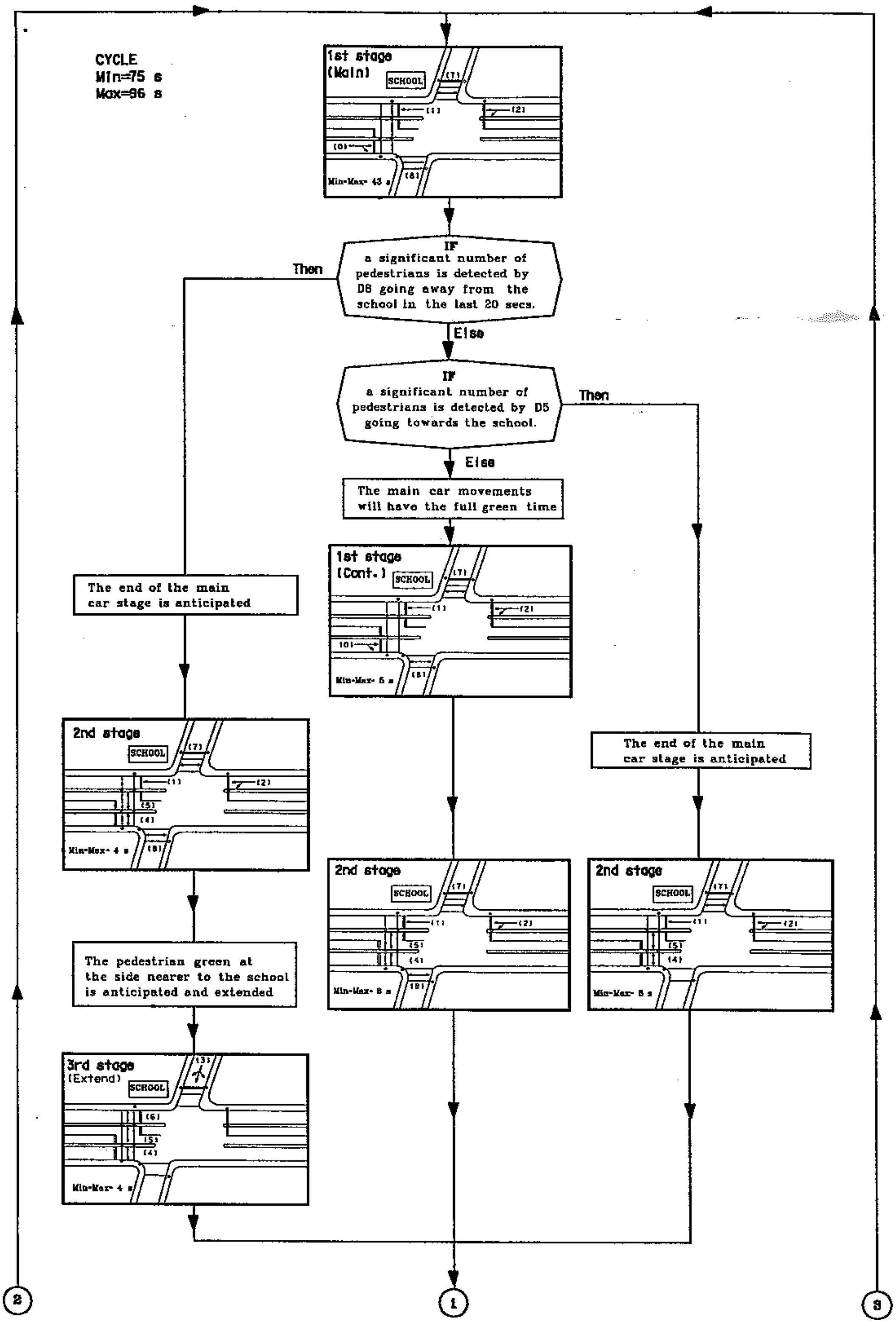

Figure C: Signal Stages in the After Situation

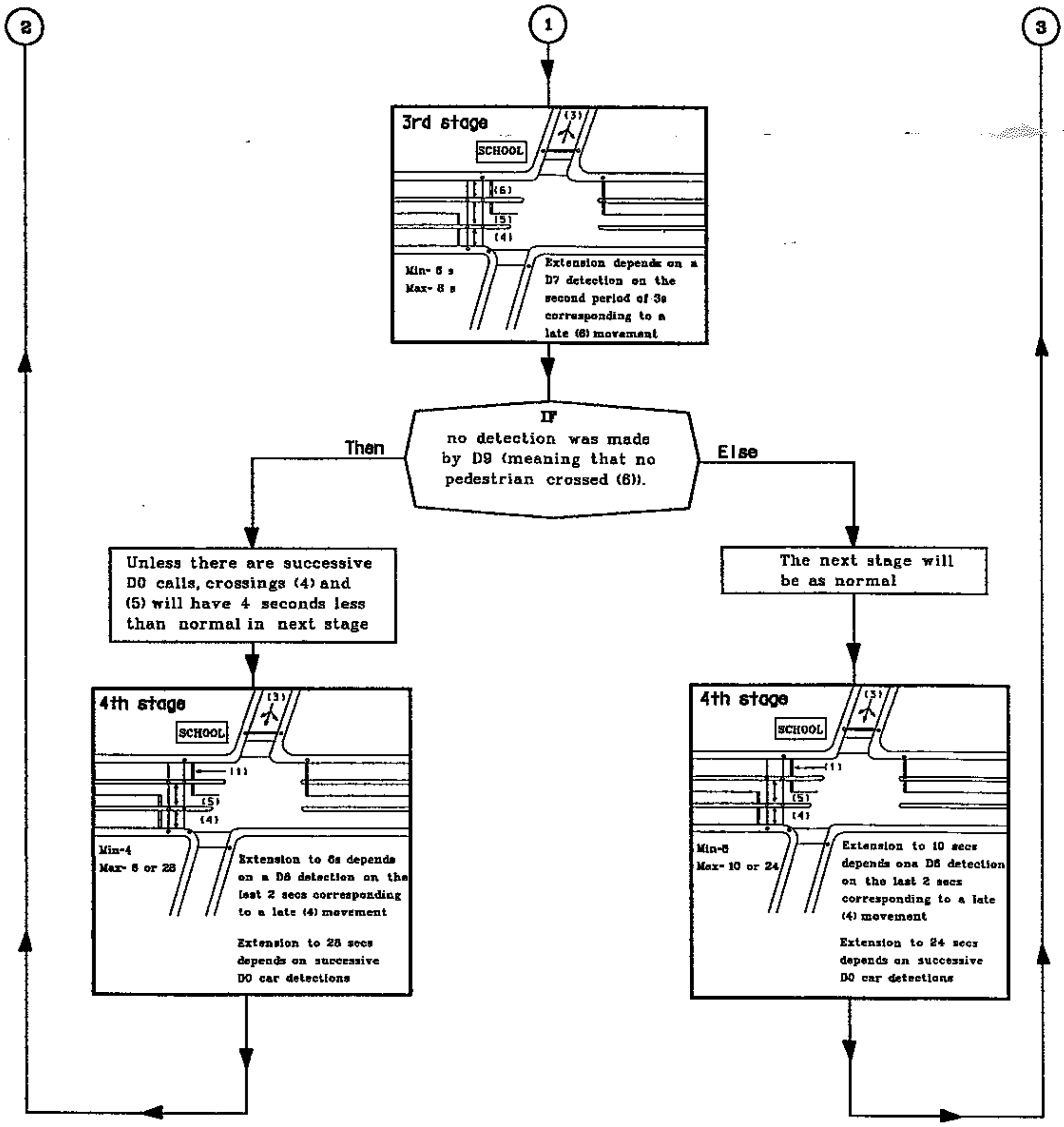

Figure C (continued): Signal Stages in the After Situation