Implementation of Pedestrian Meso Models in Portugal. VRU-TOO Deliverable 8..

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VRU-TOO

Vulnerable Road User Traffic Observation and Optimization

DRIVE II Project V2005
Deliverable 8
Workpackage CM1

Implementation of Pedestrian Meso Models in Portugal

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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; and FEUP-DEC, University of Oporto. 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.

EXECUTIVE SUMMARY

DRIVE I Project "An Intelligent Traffic System for Vulnerable Road Users" created a computer model VULCAN1, which simulated the crossing behaviour of pedestrians on a length of urban street, so as to predict the pedestrian safety effect of various street-based engineering measures. As part of the DRIVE II Project VRU-TOO, VULCAN has been updated (to create VULCAN2) to make it more behaviourally intelligent and hence to be more sensitive to the level of detail required by the modelling of ATT systems. VULCAN2 was calibrated with data collected in Bradford, U.K. Since it is intended that VULCAN should have widespead European use, it was planned to test its transferability, by applying it in Portugal.

This deliverable considers transferability of VULCAN to Portugal in three main areas:

- Pedestrian delay / car flow relationships
- Pedestrian route choice
- Usefulness of software

The results given show that:

- Pedestrian delay (for given levels of car flow) is generally lower in Portugal than in the UK.
- Route choice behaviour appears to be extremely similar.
- The VULCAN software "travelled" well.
- The main problem with transferability is concerned with differing physical infrastructure of the two road networks concerned, in particular with respect to signalised junctions and crossings.

Conclusions are given which lead to recommendations for further work.

TABLE OF CONTENTS

1 OBJECTIVES OF THE ACTIVITY

DRIVE I Project "An Intelligent Traffic System for Vulnerable Road Users" created a computer model VULCAN1, which simulated the crossing behaviour of pedestrians on a length of urban street. Furthermore, a car-based assignment model SATURN was used to assess the effect on cars of pedestrian-friendly policies. The attitude towards this modelling work were very "Northern European" in four important senses:

- The technical approach was based upon technology developed in Northern Europe for network models of cars, which are used widely throughout Northern Europe.
- The behavioural sub-models used in VULCAN1 and SATURN were all taken from empirical results obtained in Northern Europe.
- All data to feed and calibrate the models was collected at Northern European sites.
- All the partners in the DRIVE I project were from Northern Europe, and so the model development automatically followed their way of thinking.

The objectives of this deliverable are to assess the transferability of the modelling work of VULCAN1 (and subsequent updating in DRIVE II) and SATURN to Portugal. These objectives cover both the transferability of empirically created behavioural sub-models as well as the usefulness of the technology to the practical end user.

2 METHODS EMPLOYED

The transferability of Northern European modelling work to Portugal has concentrated on the following issues:

- Car flow / pedestrian delay relationships (Section 2.2)
- Logit route choice model (Section 2.3)
- Practical use of VULCAN (Section 2.4)
- Use of SATURN to assess effect on cars (Section 2.5)

Firstly, though, in Section 2.1 we give an overview of VULCAN and its route choice and pedestrian delay sub-models.

All modelling work in Portugal took place in Coimbra, whose centre is shown in Figure 1.

FIGURE 1: OBSERVATION AND MODELLING SITES IN COIMBRA CITY CENTRE

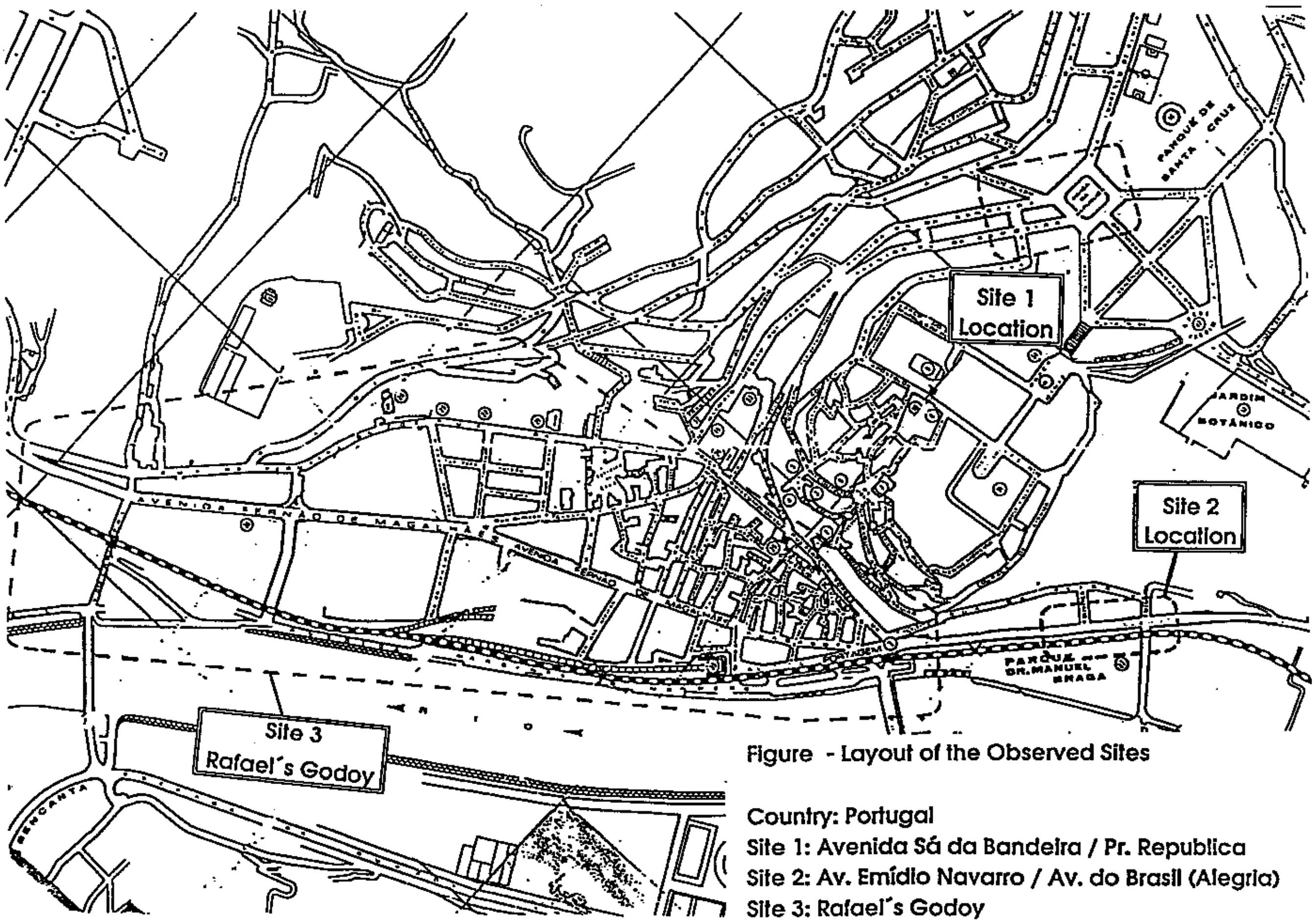

Figure - Layout of the Observed Sites

Country: Portugal
Site 1: Avenida Sá da Bandeira / Pr. Republica
Site 2: Av. Emídio Navarro / Av. do Brasil (Alegria)
Site 3: Rafael's Godoy

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, and transferability issues for this will be discussed in Section 2.3. Delay is clearly an important factor in pedestrian route choice, and delay is calculated by a formula dependent on car flow. The issues of transferability of this formula will be discussed next in Section 2.2.

2.2 PEDESTRIAN DELAY / CAR FLOW RELATIONSHIPS

2.2.1 Introduction

As stated in Section 2.1, 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 model of midblock delay assumes that a pedestrian arrives at the kerbside and is delayed for time D. D is assumed to have an exponential distribution with mean E(D) given by:

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

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

The default values of β, ψ and ω used in VULCAN1 were 0.0, 6.7×10^{-6}, and 2.0 respectively (taken from JURUE,1975). The user of the programme only had control over ψ. In VRU-TOO, it was decided that the user should have control over β and that default values should be taken from Goldschmidt (1977), giving values to β and ψ of 1.26, and 4.54×10^{-6} respectively. These figures result from surveys carried out at a significant number of midblock crossing points in London (i.e. crossings in areas with no special facilities).

VULCAN1 sites did not include zebra crossings. However, if they had done so, the following Goldschmidt linear relationship would have been used:

$$D = 0.97 + 2.3*10^{-3} * Q \tag{2.2}$$

In VRU-TOO it was considered to be important to check whether this type of relationship was sufficiently transferable to other environments, and in particular to Portugal.

2.2.2 Portuguese formulae

In order to allow comparision with the Goldschmidt results, it was decided to adopt a similar methodological approach adapted to the completely different scope of the current project.

It was decided to collect data from four crossings in Coimbra, two of the "mid-block" type and two at "zebras" in order to compare Goldschmidt's results for both environments. Furthermore, it was decided that all the situations should correspond to "forced" crossing situations on main pedestrian routes, i.e. that there was no likelihood of rerouting to an upstream or downstream crossing point. All four crossings are located in "Site 1" of Figure 1.

The regression technique was used to determine the relations between vehicle flows and average pedestrian delays in each of the crossing types: the results are given in Section 3.1.

2.3 PEDESTRIAN ROUTE CHOICE

2.3.1 VULCAN route choice model

The VULCAN nested logit route choice model has been fully documented by Brundell-Freij and Timms (1993). Each crossing alternative has a "generalised delay" term given by:

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[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.

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

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").

2.3.2 Issues concerning transferability

In any modelling context validity and transferability are regarded as important tools to describe the quality of a model. There is often confusion though as to the precise meaning of these terms. Validity is normally defined, coarsely, as whether or not the model is "true". However, there are two aspects to this "truth":

- whether the model output is correct for the observations that generated it
- whether it is possible to use the model in other situations

We shall only refer to the first of these aspects as "validity", whilst referring to the second as "transferability". As pointed out by Lundgren (1989), any (practical) use of a model includes some kind of transfer: in time or place or between changing values of variables. With this basic view, validity becomes a relatively minor question, except in terms of writing new software with all the associated problems of "bugs" and logic errors. This question will thus be dealt with when we come to discuss the performance of VULCAN as a computer programme in Section 2.4. In our discussion of the route choice model, though, we will concentrate solely on transferability.

When discussing transferability we need to distinguish between:

- a particular modelling **problem** (e.g. issues addressed, scenario, restrictions, general definition and level of aggregation for input and output variables)
- a particular model **formulation** (e.g. behavioural rules and functional forms)
- a particular model **specification** (choice and detailed definition of input variables)
- an **estimated** model (with specific parameter values)

Any of the above can be more or less transferable.

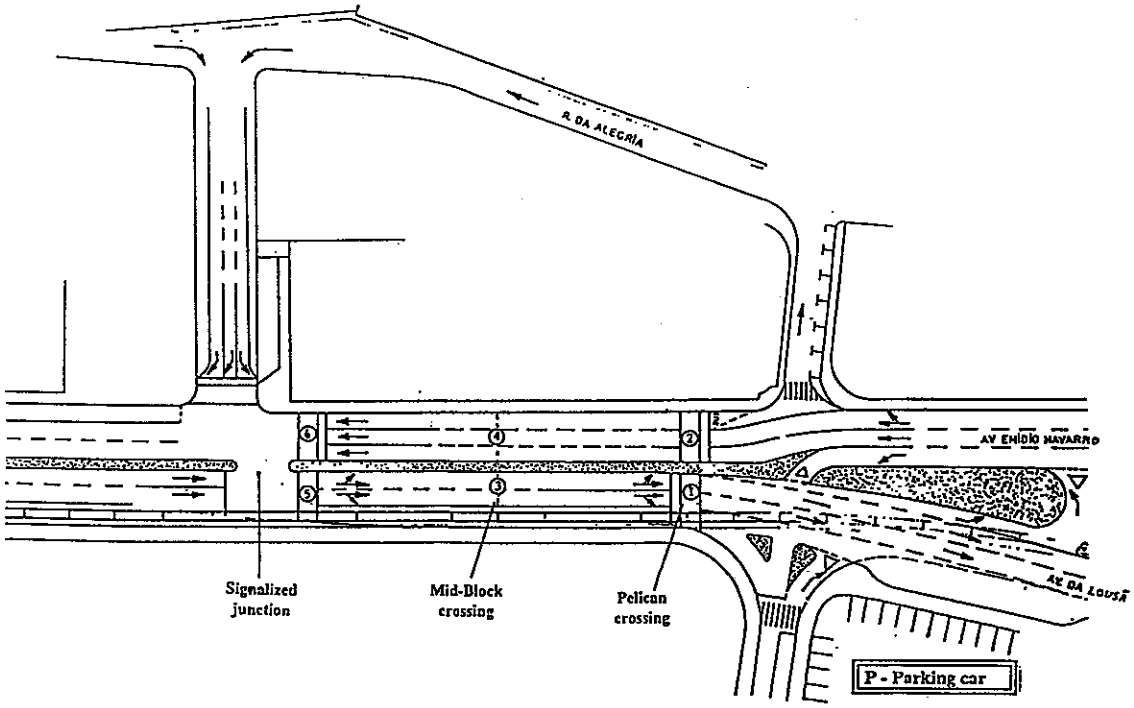
The border between problem and formulation, and between formulation and specification is often not clear-cut. However, the important point here with respect to this piece of research is that we are not restricting ourselves to considering solely the transfer of specific parameter values (although this will of course play an important part).

2.3.3 Portuguese data collection and analysis

In order to carry out the work referred to above, it was necessary to collect a significant amount of route choice data. Considering the amount of resources available, it was decided to select one site with a relatively simple layout and a significant number of pedestrians making crossings (it had already been concluded that, for the purpose of model development, it was necessary to collect a minimum of 250 route choice observations).

The selected site is shown in Figure 1 (where it is referred to as Site 2) and, in more detail, in Figure 2. As can be seen from Figure 1, the site is in the city centre of Coimbra. From Figure 2 it can be seen that it consists of a stretch of dual-carriageway, bounded on the eastern end by a signalised junction with only one formal main road crossing facility and on the western end by a pelican crossing immediately adjacent to an unsignalised junction (with no formal pedestrian crossing facility).

FIGURE 2: SITE FOR CREATION OF ROUTE CHOICE MODEL



The crossing behaviour of 277 pedestrians was observed over three days (19, 20 and 22 April 1993) within the period 08.45 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.

2.4 USE OF VULCAN

2.4.1 Introduction

Sections 2.2 and 2.3 cover issues where behaviour might be different between northern and southern Europe. Apart from behavioural issues, there is a question of practical usefulness when thinking about transferring technology from one country to another. In this section we look at the usefulness of transferring VULCAN from the country of its origin (England) to Portugal, whilst in Section 2.5 we carry out a parallel exercise for SATURN (which can model the effect on cars of pedestrian-friendly policies).

The assessment of usefulness will be carried out by answering three questions:

- How easy is it to use and understand the software and manual?
- How comprehensive and useful is the output?
- How sensitive is it to imprecisions or simplifications in the selection of its parameter values, as compared to variability in results from alternative strategies in real life?

It must be emphasised that the main question here is not so much whether the answers are correct (which was the issue in Sections 2.2 and 2.3) but whether this modelling tool is likely to be of help to the practising engineer, in view of the amount of work needed to use it.

2.4.2 Utilisation of software on a Portuguese site

In order to evaluate the usefulness and simplicity of usage of the software it was decided to apply it in a real life situation: Site 2 in Figure 1 (where the route choice data was collected) was selected.

The input data to VULCAN consists of three categories: description of the infrastructure (both pedestrian and car networks), a pedestrian O/D matrix and directional car flows. The first of these was obtained through both direct observation and consultation of city council records. The pedestrian O/D matrix was obtained by random interviewing of pedestrians at the entry/exit points to the pedestrian network followed by exhaustive countings of pedestrians at these points using video cameras. The car O/D matrix was obtained by consulting city council records.

The VULCAN program was installed on a 486 IBM-compatible micro computer equipped with a maths coprocessor, 4 Mb of RAM and 200 Mb of hard disk space.

2.4.3 Simulation runs and sensitivity analysis

A large number of runs were made with VULCAN to test its robustness and whether the internal logic of the model was being correctly represented (i.e. "validation" as defined above in Section 2.3.2). Many of the runs represented extreme conditions and were only of interest to the model developer in order to correct bugs or to include error messages for strange input. It is sufficient to report here that once these runs were complete, VULCAN was seen to give results in line with its internal logic.

Further runs were made for two purposes:

- to examine the likely effect of (realistic) changes to the network, especially with regard to signal timing at the pelican (which is where it is most likely that an ATT scheme would be implemented)

- to examine the sensitivity of the results to changes in some of the behavioural assumptions, with respect to the size of effects from actually changing the network

2.5 USE OF SATURN

Whilst the main emphasis of modelling work in both the DRIVE I project "An Intelligent System for Vulnerable Road Users" (V1031) and VRU-TOO has been on pedestrians, it has been recognised that it is important to try to predict the effect on cars of pedestrian-oriented policies. With this objective, an exercise was carried 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 fully documented by Carvalho (1990), and were reported by Timms and Carvalho (1991). These policies were classified into three main groups:

- Pelican crossing facilities
- Facilities at signal controlled road junctions
- Pedestrian areas (speed humps, nibs[2] and road closures)

It was decided that a similar exercise should be carried out in DRIVE II, 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. To this end, an area slightly larger than that shown as Site 3 in Figure 1 was coded into a SATURN network by Coimbra City Council.

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[2] Nibs are extensions to pavements (and hence narrowing of road-widths) at junctions.

3 RESULTS

3.1 PEDESTRIAN DELAY / CAR FLOW RELATIONSHIPS

3.1.1 Introduction

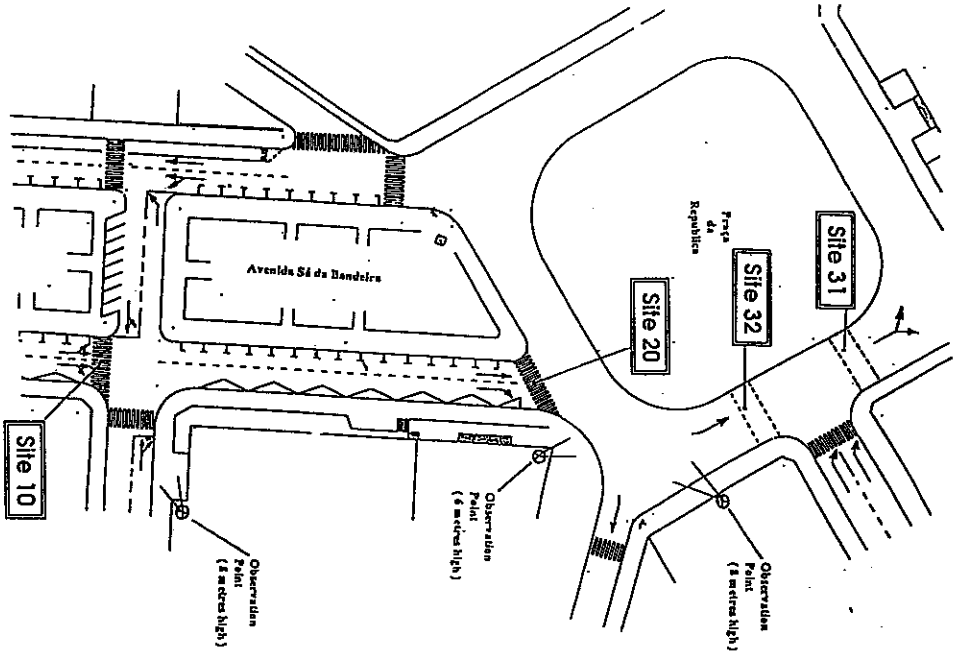
In order to create "Portuguese" pedestrian delay / car flow relationships, four crossing points in Coimbra were analysed, all of which were at two-lane, one-way city centre streets, where there is a very limited amount of heavy traffic. Figure 1 ("Site 1") shows the position of study area in the context of the centre of Coimbra, whilst Figure 3 shows the survey sites. The zebra crossings are labelled "Site 10" and "Site 20", whilst the midblock crossings are labelled "Site 31" and "Site 32".

511 pedestrian crossing situations were observed at the two zebras (194 at Site 10 and 317 at Site 20) throughout 19 five minute periods within one day (10 for Site 10 and 9 for Site 20).

175 pedestrian crossing situations were observed at the two "midblock" areas (57 at Site 31 and 118 at Site 32) throughout 15 five minute periods within one day (7 for Site 31 and 8 for Site 32).

For each five minute period, the average observed pedestrian delay was calculated and the vehicle flow was measured (subsequently scaled up to vehicles per hour).

FIGURE 3: SITES FOR COLLECTING PEDESTRIAN DELAY / CAR FLOW DATA



3.1.2 Midblock crossings

In order to gain flexibility, it was decided to try to fit a curve of the type:

$$D = \beta + \psi * Q^{\omega} \tag{3.1}$$

The best fit was found to be:

$$D = 0.53 + 22.08*10^{-6} * Q^{1.7255} \qquad (R^2 = 0.761) \tag{3.2}$$

More similarly to Goldschmidt (i.e. with $\omega = 2.0$), the following curve type was tried:

$$D = \beta + \psi * Q^{2} \tag{3.3}$$

The best fit was:

$$D = 0.893 + 2.8*10^{-6} * Q^{2} \qquad (R^2 = 0.759) \tag{3.4}$$

In view of the very similar results in terms of R^2 it was decided to adopt curve (3.4) for comparision purposes. The curve can be seen, along with Goldschmidt's curve and the actually observed data, in Figure 4.

There are two points worth making here:

1. There is a great similarity between the two regression equations in Figure 4, with only an almost constant shift towards reduction of delay (whatever the flow level) in the Portuguese situation. This could suggest that either 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.

2. There is a higher level of variability in the Site 31 delay data. This is probably explained by the more complex layout at this site, affecting the interactions between pedestrians and vehicles (see Figure 3).

3.1.3 Zebra crossings

After analysis of the data, and in order to compare with Goldschmidt's result (equation 2.2), it was decided to try to perform linear fits.

The relationship between car flows and pedestrian delays was found to be quite different at each of Sites 10 and 20 (see Figure 3), suggesting that it would be preferable to calculate two different functions.

For Site 10, the best linear fit was found to be:

$$D = 0.496 + 1.82 * 10^{-3} * Q \qquad (R^2 = 0.36) \tag{3.5}$$

For Site 20, the best linear fit was:

$$D = 0.824 + 0.29 * 10^{-3} * Q \qquad (R^2 = 0.0865) \tag{3.6}$$

These relationships can be seen in Figure 5 along with Goldschmidt's relationship. There are two points worth making about these results:

1. Differing pedestrian behaviour at zebras (such as Sites 10 and 20) 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).
2. Equations (3.5) and (3.6) both typically give smaller values of delay than the Goldschmidt relationship (equation (2.2)). This result is similar to the midblock case and similar possible conclusions can be drawn.

FIGURE 4: PED. DELAY / CAR FLOW RELATIONSHIPS AT MIDBLOCK CROSSINGS

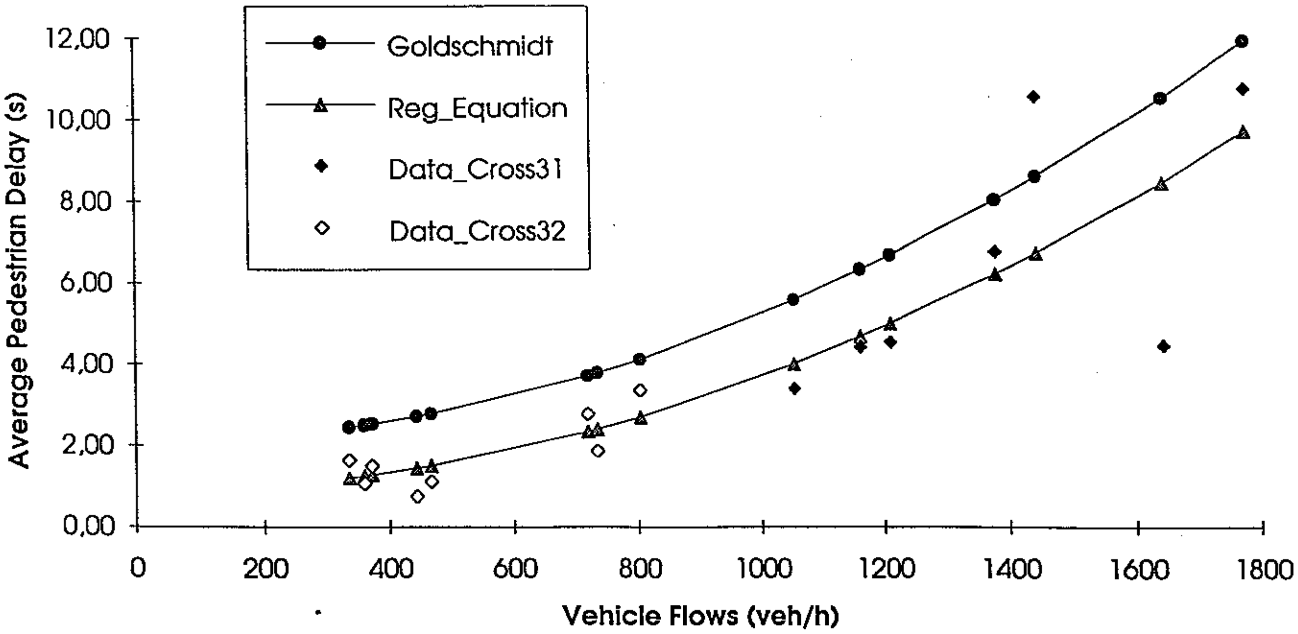
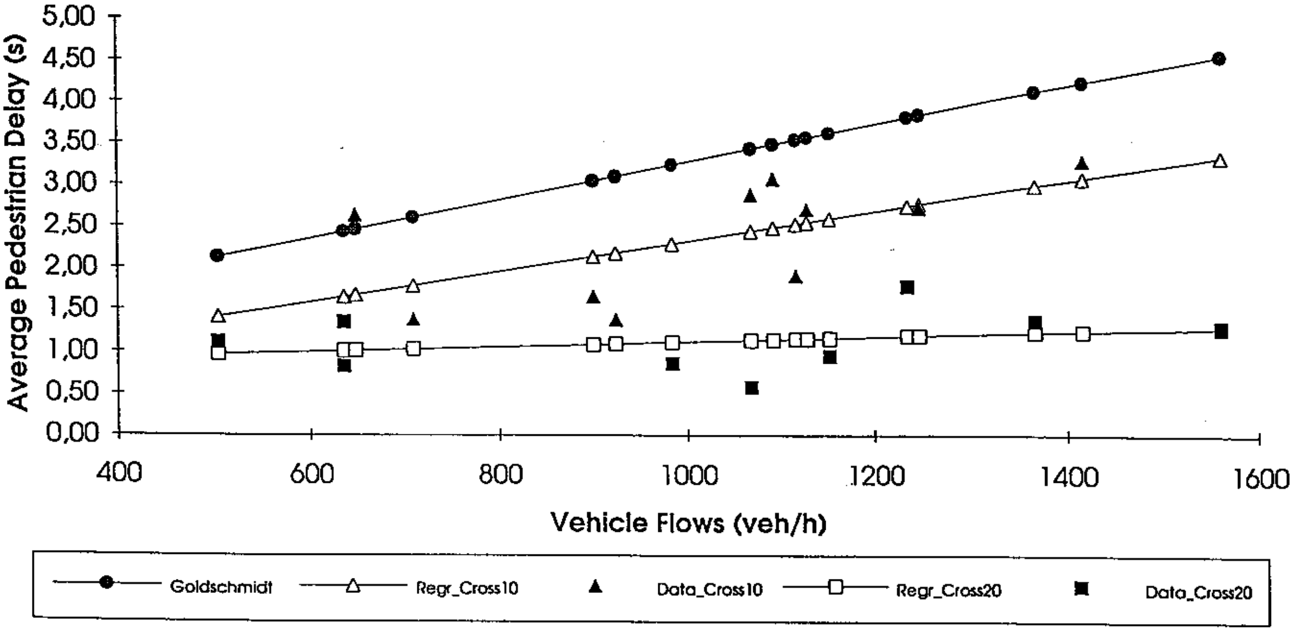


FIGURE 5: PED. DELAY / CAR FLOW RELATIONSHIPS AT ZEBRAS



3.2 PEDESTRIAN ROUTE CHOICE

In examining the transferability of the route choice model, we consider the four categories given in Section 2.3.2: modelling problem, model formulation, model specification and parameter estimates.

3.2.1 Modelling problem

A large effort was made to find a location that was "similar" to the network in Bradford where the data for the original route choice model was collected. Similarity is here defined in terms of:

- A stretch of urban street with a large number of pedestrians crossing it.
- A variety of different "crossing types", e.g. midblock, signalised and unsignalised junctions, and (importantly for potential ATT) a "pelican".
- The "trip matrix" of pedestrian movements revealing that for many pedestrians there was a choice of where to cross.
- A big enough car flow along the street to ensure that this was a significant factor in making a crossing choice.
- A similar road layout in terms of width and whether or not opposing road lanes were divided by a barrier.

The simple result of this exercise was that it was impossible to find exact similarity. The most similar location was a street that complied with all the above criteria except the last. Interestingly, this result was not down to "bad luck" but due to the different types of facilities (particularly with respect to traffic signals) existing in Bradford and Coimbra. It thus provided an important lesson for transferability between one country and another.

The site chosen in Coimbra is shown on Figure 2, where it can be seen that the road is divided by long middle islands. These islands are frequently used as middle-street pavements, allowing people to cross the two halves of the street at different locations along the street.

3.2.2 Model formulation

The nested logit model structure, used to describe route choice in VULCAN, is very flexible. Given a network of the VULCAN-type (as described in Section 2.1) 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 original Bradford site (as discussed above in 3.2.1). Essentially, this was due to the increased complexity of the network (and hence sets of crossing choices) due to middle islands. The same amount of data as collected in Bradford (and which was sufficient to create a statistically good nested logit structure) was not sufficient here to create stable and statistically significant results.

In order to apply transferability tests of specification and parameter estimates (in Subsections 3.2.3 and 3.2.4 respectively) 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).

3.2.3 Model specification

The question of differing pedestrian delay / car flow relationships in Bradford and Coimbra (and hence definition of delay in the route choice model) has been covered in Section 3.1.2. Along with our basic philosophy of "testing the Bradford model in Coimbra", the default Bradford relationships were used in the route choice model. This probably only had a limited effect on the estimation results, since the model formulation is rather robust to uniformly biased estimates of delay (as found in the results reported in Section 3.1.2): the choice probabilities are basically a function of differences in delay.

The other issue concerning pedestrian delay was whether, when a pedestrian is making a route choice decision at a signalised junction, it is modelled that the stage is "known" to the pedestrian at that junction. If this is the case, the pedestrian will base their estimate of delay upon the actual details of this stage. If knowledge is not assumed, the pedestrian's estimate of delay (for that crossing) will be averaged over all the stages of the signal cycle. On first thoughts, it seems perverse to assume the latter. However there are important data collection issues tied up with this assumption: essentially it is unfeasible to collect route choice data using interviews if the stage is assumed "known", since pedestrians would be expected to remember all the signal settings on crossings that they had refused as well as on the one they accepted (assuming of course that they had crossed at a signalised crossing). In the Bradford model, the signal stage was assumed "unknown" whilst in Coimbra (where data was collected by direct observation) it was assumed "known".

The set of input variables in the model estimations had to be extended to describe the more complex layout situation in Coimbra. This was done by creating two new dummy variables "split crossing" and "walking on middle island". The first of these is an ordinary dummy variable, taking values 1 or 0, depending on whether or not the two halves of the road are crossed in the same place. "Walking on middle island" is a discrete variable (in this case taking values 0.0, 0.5 and 1.0) representing the length walked along the middle island between the two halves of the crossing, normalised to the length between the pelican and the signalised junction.

It was initially assumed that in Coimbra (unlike Bradford) there would be a trade off between walking time and delay, meaning that people crossing would be willing to detour for a shorter delay when crossing. It would have been possible to respecify the model to allow for such behaviour, by incorporating a new variable "walking time", T_w, with a corresponding parameter α_w, in the expression (2.3). From the observations, however, it turned out that no one made such detours. It was thus possible to keep the basic variable specification from the VULCAN route choice model (apart of course from the two new variables given above).

3.2.4 Model estimates

Table 1 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 VULCAN1 ("Default") values[3]. 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 comparisions given below thus concentate 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 unsignalised

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[3] There are slight differences between default values in Table 1 and parameter estimates found in Timms and Brundell-Freij (1993), due to differences in the exact specification of dummy functions. The default values given here, calculated from the same original data set, are more fully comparable with the Coimbra results.

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.

TABLE 1: PARAMETER ESTIMATES FOR FIVE COIMBRA MODELS, WITH DEFAULT VULCAN 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

In general, Table 1 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.

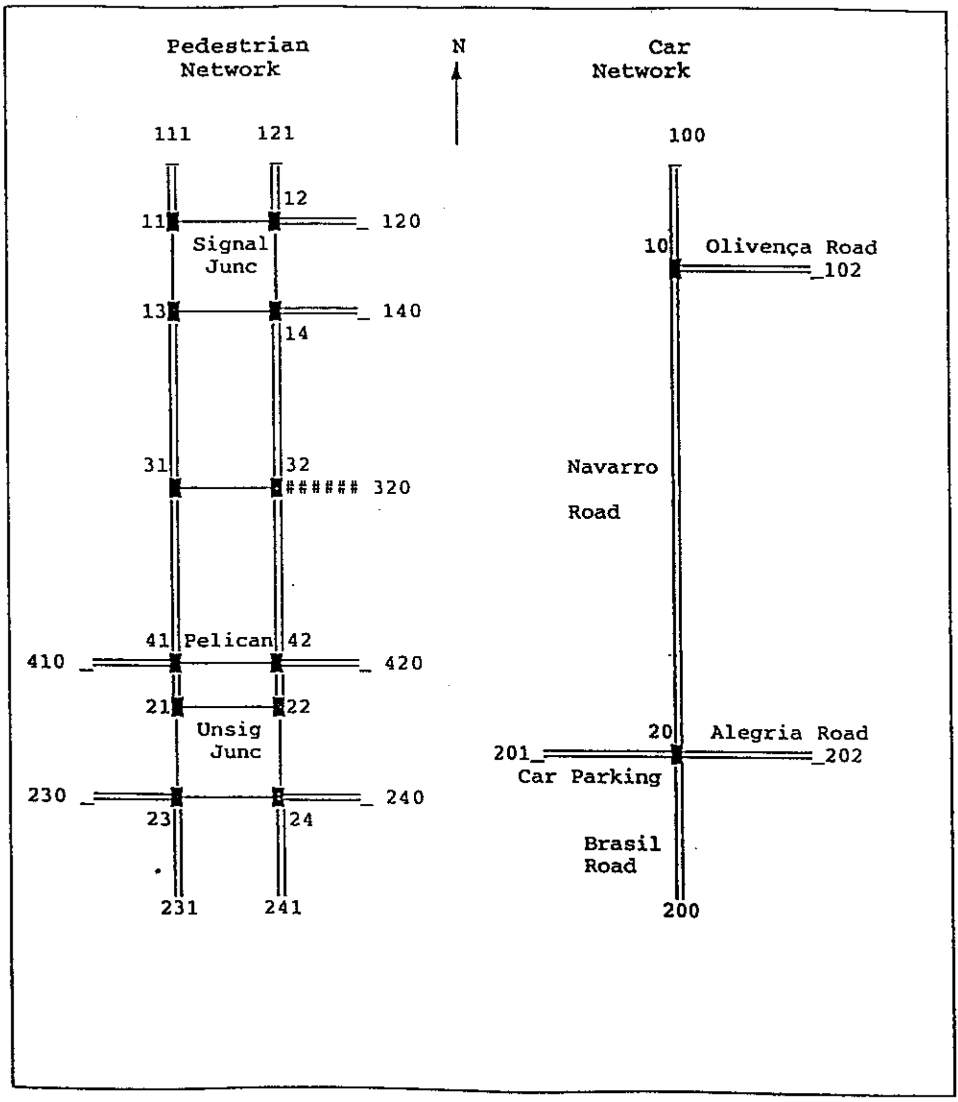
3.3 USE OF VULCAN

The VULCAN network shown in Figure 6 was set up to represent the street shown in Figure 2 As can be seen from from Figure 6, there are four "areas" in the network:

- a signalised junction with two crossing opportunities (referred to later as Crossing 1 and Crossing 2)
- a midblock area, modelled as having one crossing opportunity (Crossing 3)
- a pelican crossing (Crossing 4)
- an unsignalised crossing (Crossings 5 and 6)

The trip matrix for this network shows that 84% of the crossing movements (where there is route choice) are between the following origin-destination pairs: from 420 to 230 (18%); from 410 to 240 (17%); from 121 to 230 (12%); from 111 to 240 (11%); from 230 to 121 (7%); from 230 to 140 (7%); from 120 to 230 (6%); and from 111 to 420 (6%).

FIGURE 6: VULCAN NETWORK



3.3.1 Software performance and transferability

Hardware/software compatibility

There was no hardware/software incompatibility: VULCAN runs on easily available micro computer machines and thus from an equipment point of view there is no transferability problem.

Amount and characteristics of input data

The input data is of a kind which is readily available, with the exception of the pedestrian data. However, the problems with obtaining the pedestrian data do not seem different to those faced in other countries since it is data that is not usually readily available anywhere. Thus this is not a transferability issue unless fewer resources are available for data collection in Portugal than in other countries.

Simplicity and amount of effort needed to run VULCAN

It was concluded that, when the program is made available for widespread usage, it will need a good interactive input data system instead of the present method of inputting data via Ascii files. Not only will this speed up data input, but it will help avoid the introduction of wrong data (particularly useful when the user is not yet familiar with the program or when the user does not have English as a first language). On the other hand, the error messages presently given by the program were found to be quite useful.

3.3.2 Simulation runs and sensitivity analysis

The results from a selection of the runs on the Coimbra network are shown in Table 2. Clearly a large number of comments can be made about them: we select what we think are the most interesting. There is a general assumption here that we want more crossing pedestrians to use the pelican.

- The pedestrian route choice effects of adding extra time to the pedestrian stage at the pelican (Runs 2, 3 and 4) are not **by themselves** sufficient to make such a measure worthwhile. They do of course contribute to justifying such measures if there are other benefits.

- Having two pedestrian stages of ten seconds during a cycle (Run 5) has a substantial benefit in terms of route choice over having one stage of length 20 seconds (Run 1). This is exactly the sort of measure that can be arranged with ATT devices. The increasing benefit of having three pedestrian stages, still with total time of 20 seconds (Run 6), is not as marked: however the increased benefit of three stages over two stages is still greater than increasing the pedestrian stage by seven seconds (Run 4). The benefits of adding either one or two pedestrian stages is much greater than reducing the cycle time by 20 seconds at the expense of cars (Run 7).

- Interestingly, building a new pelican (Run 8) had less impact than either adding extra pedestrian stages or reducing the cycle time at the current pelican.

- In order to show that the model can be used to estimate the effects on pedestrians of a variety of measures, and not just pedestrian-orientated ATT, we include Run 9 where all car flows in the network are increased by 37.5%. As would be expected, the main impact of this was to reduce the number of pedestrians crossing in the mid-block.

TABLE 2: RESULTS OF VULCAN SIMULATION AND SENSITIVITY RUNS

Simulation of "realistic" measures		Crossing Facility (from North to South)						
		1 Sig junct	2 Sig junct	3 Mid block	4 Pel	5 Unsig junct	6 Unsig junct	Total
1	"Base" Situation with 20s ped phase in a cycle of 80s	94	70	50	527	4	66	811
2	Ped green time at pelican extended by 3s (same cycle length)	91	67	47	538	3	65	811
3	Ped green time at pelican extended by 5s (same cycle length)	88	64	46	546	3	65	811
4	Ped green time at pelican extended by 7s (same cycle length)	85	61	43	555	3	64	811
5	Two ped stages of 10s at pelican (same cycle length)	49	36	27	637	2	61	811
6	Three ped stages (7s,7s,6s) at pelican (same cycle length)	34	26	21	671	1	60	811
7	Cycle reduction to 60s on pelican (all from car stage)	64	45	33	605	2	62	811
8	New pelican in Midblock area: ped stage of 20s in 80s cycle	69	46	216*	413	3	64	811
9	All car flows increased by 37.5%	133	79	13	527	1	59	811
Sensitivity tests to model assumptions								
10	Delay parameters changed to observed Portuguese results	66	62	85	518	9	71	811
11	Stage situation assumed "known"	105	97	52	481	6	71	811
12	Ped stage corresponds only to green time (and not green and yellow)	96	73	52	520	4	66	811

* Includes 165 at new pelican and 52 on surrounding mid-block areas

- Due to the (approximate) "uniform shift in pedestrian delay" (between the Goldschmidt and observed Coimbra results) pointed out in Section 3.1.2, the model is less sensitive to changing the parameters in the delay model than might have originally been expected. Run 10 shows that the main effect of doing so was to increase the estimate of how many people are crossing in the midblock.

- In Run 11 we model the stage situation as "known" for a pedestrian making a decision at a signalised crossing. As explained in Section 3.2.3, this assumption is more realistic but might lead to costlier data collection: thus we want to see how significant it is. The result of this test was that the signalised junction (Crossings 1 and 2) becomes more attractive, mainly at the expense of the pelican. The conclusion that can be drawn here is that it is better to create a route choice model with the assumption of present signal stage "known", unless this requirement makes a comprehensive data collection exercise unfeasible.

- In Run 12 we assume that pedestrians only cross the pelican in "green" time rather than in "green and yellow" time (as in the other runs). It can be seen that the resulting changes in estimates are negligible.

3.4 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.

- Apart from "global" parameters, SATURN requires a large amount of site-specific input data, in particular zone-to-zone trip matrices for the period that is being simulated. such matrices are expensive to collect, and the use of limited resources (including skilled personnel) in such work could be controversial. One way of helping to lessen this problem is to use the programme ME2, which uses (easily obtained) link counts to help estimate trip matrices.

- 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 CONCLUSIONS AND NEXT STEPS

This was generally an extremely satisfying piece of research, creating a large number of interesting results in a relatively short period (in terms of person-months) with true international co-operation. Furthermore, some of the results were diametrically opposed to initial expectations, which is often a healthy sign. The main problem encountered was the difficulty in finding a "similar" infrastructural location (to the original site in Bradford) in Coimbra for comparing both VULCAN and its route choice sub-model.

The main behavioural results were:

- Pedestrian delays in Coimbra for the same car flows were almost uniformly lower than in Britain. This could be explained by either greater risk-taking by pedestrians in Portugal or greater courtesy of car drivers towards pedestrians. Further research is needed here since this issue clearly has important safety consequences.

- Route choice behaviour (given set levels of delay) in Bradford and Coimbra was seen to be remarkably similar: the main differences could probably be explained by the difference between city centre and residential location, rather than between countries.

The next usage of VULCAN will be to give advice to the planners of the VRU-TOO experiment in Leeds on the potential (pedestrian) route choice impacts of the variety of different forms of experiment that are possible. The experience in running the model in Portugal will be useful in this enterprise.

In Brundell-Freij and Timms (1993), a number of recommendations are made about the "next steps" for VULCAN and its sub-models, which will not be repeated here: we will concentrate solely upon transferability issues, being the main subject of this deliverable.

Clearly it would be an attractive option to have some standard tools for assessing the effects on pedestrians of a variety of DRIVE projects. We think that VULCAN satisfies a definite need, i.e. where there is interest in the pedestrian route choice effects of a measure in an area where the pedestrian movements (in terms of a localised "trip matrix") are complex. However, three measures would be needed before VULCAN became such a standard:

- Firstly the programme needs to made more user-friendly by having a good interactive data input system which can give warnings when input variables are outside expected ranges etc. This type of work is reasonably straightforward and should not take too long.

- More importantly, VULCAN needs to be able to incorporate all the "normal" infrastructure configurations throughout Europe

- Most importantly, the route choice sub-model needs to be created for many more data sets in locations throughout Europe

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