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NON-JUNCTION ACCIDENTS ON URBAN SINGLE-CARRIAGEWAY ROADS

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Prepared for: **Road Safety Division, DOT**
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CONTENTS

Page

EXECUTIVE SUMMARY

Although most accidents on built-up roads in Great Britain occur at or within 20m of a junction, about 60,000 of the personal injury accidents (PIAs) which occur each year on these roads are non-junction accidents, located mainly on single-carriageway roads, and of these about 1000 are fatal accidents.

This report describes a full-scale study, undertaken on behalf of the Road Safety Division of the Department of Transport, of non-junction accidents on one and two-way urban single-carriageway roads. It forms part of a Department of Transport project to study on accidents on urban road links and at urban T-junctions.

This study is one of a series investigating accidents at different junction and link types. The reports previously published are: four-arm roundabouts (Maycock and Hall, 1984); rural T-junctions (Pickering, Hall and Grimmer, 1986); four-arm single carriageway urban traffic signals (Hall, 1986). Reports from three further studies are published concurrently with this report: accidents at 3-arm priority junctions on urban single-carriageway roads (Summersgill et al, 1996); three-arm single carriageway urban traffic signals (Taylor et al, 1996); four-arm priority junctions (Layfield et al, 1996). These are detailed technical reports, intended to disseminate the research methods used and the results obtained, and at this stage contain only limited advice on model application.

The main objective of the study was to investigate the frequency and character of the accidents in relation to traffic flow, road features, layout, geometry, land-use and other variables. Accident frequencies by accident group were related to the explanatory variables using generalised linear modelling techniques. Accident predictive models have been developed ranging from whole section total accident models to full geometric models for individual groups of accidents.

The study was based on a national sample of 300 complete road links between major junctions, stratified by annual average daily total vehicle flow (AADT) and by pedestrian flow crossing the road. A twelve hour classified count of vehicle and pedestrian flow was taken at one point along the complete road link. The road link was then split into its component link and junction sections. A total of 970 link sections were used in this study. For these link sections, four counts of vehicle and pedestrian flow were made during four separate periods of the day (am peak, am off-peak, pm off-peak and pm peak). Detailed measurements were made including: the lengths of the sections; the width of the roads; the occurrence, location and dimensions of all features; visibilities; and gradients.

A total of 1590 PIAs occurred on these link sections over the period April 1983 to March 1988. Detailed tabulations are given showing accident densities, severities and rates by region. The accidents are also tabulated by accident group, road-user involvement and number of casualties per accident.

Some of the more important findings of the study were as follows:

(i) The models predict on average more accidents on link sections with a pedestrian crossing than on those without, for given vehicle and pedestrian density. However, those link sections in the sample without crossings had substantially lower pedestrian densities than those with crossings, and the error structure of the models must reflect that. So caution should be exercised in interpretation. Because the relationship between accident frequency and pedestrian density is non-linear (with index less than one) it is the case that the mean number of accidents per pedestrian crossing the road on those sections *with* pedestrian crossings was similar to the mean number on those sections without. It is clear that further work would be needed to resolve the issue of the model predictions in respect of pedestrian crossings. The usual non-accident based criteria (TA 52/87 and LTN 1/95) should therefore continue to be used for assessing the need for a crossing.

(ii) Rear shunt and lane-changing accidents increased on link sections with a zebra crossing.

(iii) This study was not intended or designed to investigate speed mechanisms and relationships in depth, and speed was not measured directly. Some of the physical variables in the models were correlated with speed, for example, increased visibility in the opposite direction of travel resulted in increased total, vehicle-only and pedestrian accidents. It is likely that this and some of the other variables found to affect accidents do so by modifying speeds. Traffic calming measures such as speed humps, speed cameras and chicanes were not tested in the study.

(iv) There was no difference in the predictions for a one-way link section and for one direction of a two-way link section from the full models for total, vehicle-only and pedestrian accidents. There were more parking and parked vehicle accidents but fewer private drive accidents on one-way link sections.

(v) Other key results were: more vehicle-only and single vehicle accidents with a higher proportion of PSVs; more single vehicle accidents with more refuges per kilometre; more parking and parked vehicle accidents with a higher proportion of road occupied by parked vehicles; more pedestrian accidents with shopping land-use and fewer with sport/open space land-use; increased total, vehicle-only and several accident groups on link sections in Greater London.

The models are intended to be used to identify potential design improvements and to provide accident estimates for the economic appraisal of road improvements. In conjunction with traffic assignment models, they can be used to predict the effect on accidents of traffic management schemes; to identify casualty-reducing schemes and to optimise safety/mobility for all road users. At this stage, the research programme to develop accident models for all junction (and link) types is incomplete and therefore the results are not intended to replace the standard models used in COBA and URECA. Once models are available for the full set of junction types, the complex process of standardising on particular functions of vehicle flow will need to be undertaken in order to incorporate the results into the Department's cost-benefit appraisal programs.

NON-JUNCTION ACCIDENTS ON URBAN SINGLE CARRIAGEWAY ROADS

ABSTRACT

The report gives the findings of a study of accident risk based on a national stratified sample of 300 urban single carriageway roads (1590 non-junction personal injury accidents). The study includes one-way and two-way roads, with 30 mph or 40 mph speed limits and sites with and without pedestrian crossings. Tabulations are given showing accident frequencies, severities and rates by road type and region. The accidents are also tabulated by accident group, road user involvement and number of casualties per accident. The main objective of the study was to investigate the frequency and character of the non-junction accidents in relation to traffic flow, road features, layout, geometry, land use and other variables. Accident frequencies by accident group were related to the explanatory variables using the techniques of generalised linear modelling.

1. INTRODUCTION

In 1990 there were 191,000 reported accidents involving injury on built-up roads in Great Britain (74 per cent of all personal injury accidents - PIAs - in GB), of which 2320 were fatal accidents (49 per cent of all fatal PIAs in GB). Most of the accidents on built-up roads occurred at or within 20 metres of a junction. However 60,000 of the PIAs and 1012 of the fatal accidents were non-junction accidents located mainly on single carriageway roads (Department of Transport, 1991).

There is clearly a need to have the fullest understanding of the characteristics of these non-junction accidents and how they are related to vehicle and pedestrian flows, and the layout and other features of the road. These can be used to identify safer designs. Accordingly, the Transport Research Laboratory (TRL) has undertaken a study, on behalf of the Road Safety Division of the Department of Transport, of non-junction accidents on built-up single carriageway roads.

This study is one of a series investigating accidents at different junction and link types. The reports previously published are: four-arm roundabouts (Maycock and Hall, 1984); rural T-junctions (Pickering, Hall and Grimmer, 1986); four-arm single carriageway urban traffic signals (Hall, 1986). Reports from three further studies are published concurrently with this report: accidents at 3-arm priority junctions on urban single-carriageway roads (Summersgill et al, 1996); three-arm single carriageway urban traffic signals (Taylor et al, 1996); four-arm priority junctions (Layfield et al, 1996). These are detailed technical reports, intended to disseminate the research methods used and the results obtained, and at this stage contain only limited advice on model application.

The study reported here is part of a Department of Transport project to study accidents on urban road links and at urban T-junctions. Only those parts of the project relating to non-junction accidents are presented in this report. The study of urban T-junctions is reported elsewhere (Summersgill, Kennedy and Baynes, 1996).

The study can be divided into a number of stages:

stage 1 was the design and execution of a reconnaissance survey, the selection of a sample of the junctions for later full scale data collection, the identification of a suitable database system for storing the data and the setting up of a database framework;

stage 2 was the design of the data collection programme, recruiting and training field staff, the collection of data at the junctions, the extraction of accident data, the coding and entering of the data into the databases, the validation of the data, the testing of the databases, and the production of accident tabulations;

stage 3 was the development of accident predictive relations;

The contents of the Report are as follows. Section 2 presents the objectives of the study and the overall methodology used. Section 3 describes the reconnaissance survey, whilst Section 4 indicates the way in which the sample of links for the main survey was selected. Section 5 describes the main survey and outlines the way in which the data was processed. Section 6 presents tabulations of the basic characteristics of the link sections, whilst Section 7 provides accident tabulations. The methodology of the regression analysis is described in Section 8. Sections 9, 10 and 11 present the form of the models and the modelling procedure used to determine the accident predictive relations which are the main aim of the study. Section 12 sets out the expected applications for the models and Section 13 gives a brief summary and conclusions.

2. STUDY APPROACH

The main objectives of the study were:

(i) to investigate the characteristics of non-junction accidents on built-up single carriageway roads by producing accident tabulations that would give insights into accident problems.

(ii) to estimate average accident rates and to investigate the effects of: one-way or two-way vehicle flow; speed limit; London; crossing type (zebra, pelican or no crossing).

(iii) to derive relationships between accident frequency, traffic and pedestrian flows and the features and layout of the road. These relations are intended to be used to identify potential design improvements, to provide accident estimates for the economic appraisal of road improvements; and in conjunction with traffic assignment models, to predict the effect on accidents of traffic management schemes, to identify casualty-reducing schemes and to optimise safety/mobility for all road users.

Non-junction accidents occur on sections of road that are at least 20 metres from the nearest junction. On built-up roads these tend to be relatively short and hence the study had to include a large number of them. It was therefore convenient to select complete road links as sites for study. A link site is a length of road over which the through traffic flow is broadly constant. In particular, the ends of the site are defined to be major junctions (where the traffic on the identified link has to give way or stop, changes of speed limit, or where the road layout changes from single to dual-carriageway or from one-way to two-way flow or the reverse.) The major junctions have not been treated as part of the link site which begins 20 metres in from each major junction.

The road links were divided into link sections and junction sections. Link sections are lengths of 'pure link' which may contain private accesses but not minor junctions. These link sections form the basis of the study reported here.

The road links included in the study had to satisfy the following specific conditions:

(i) the link was either one-way or two-way single carriageway but not dual-carriageway.

(ii) the speed limit on the link was either 30 mph or 40 mph

(iii) the site characteristics and flow patterns were stable, apart from trend effects, over the period from 1983 to 1988.

(iv) the link was situated in an urban area with a population greater than 20,000.

(v) the link was not an internal part of either a housing estate or an industrial estate.

(vi) there was no bus lane.

(vii) the link was lit.

(viii) links with special characteristics which could not be adequately tested in the statistical analysis because of a limited number of examples were avoided.

In order to fulfil the study objectives a representative sample of 300 link sites was required, comprising 250 links with two-way traffic and 50 links with one-way traffic and covering not less than 150 kilometres of road. A wide geographical spread of links throughout GB was needed with a substantial component in London (about 75 links) so that any regional effects, similar to those occurring in a recent study of 4-arm signal controlled junctions (Hall, 1986), could be investigated. This has shown that the accident rate in Greater London was about 50 per cent greater than occurred elsewhere when all explanatory variables used in that study were taken into account. The sample was required to include a significant number of links with 40 mph speed limits so that a full range of vehicle speeds and associated geometric variables were available for testing.

3. RECONNAISSANCE SURVEY

The reconnaissance survey of suitable link sites commenced in December 1987 and ended in August 1988. Sites of urban T-junctions were also sought as part of this survey but the details are not of concern here.

Specific urban areas were identified and contact letters sent to local authorities. These were followed by a visit to agree a shortlist of potential sites with the assistance of the local authority staff. Every effort was made to establish the stability of the sites over the study period from 1983 to 1988 but it was not always possible to be totally confident of this. This procedure generally yielded an excess of about 50 per cent of sites for each area and a selection was then made by the study team to obtain an appropriate set for the reconnaissance survey.

The survey was conducted by regional teams and in order to ensure consistency of approach all teams were visited prior to the survey and a detailed survey manual produced to guide the data collection.

The data collected at each site consisted of the following:

(i) a map of the site was drawn or obtained from one of several sources.

(ii) photographs of the site showing details of all the junctions.

(iii) site descriptions to complement the map data indicating for example, road widths, banned turns and gradients.

(iv) 15-minute counts of vehicle flow along the link.

(v) 15-minute counts of pedestrians crossing at the busiest point along the link measured either on a zebra or a pelican crossing or along a 100 metre length of kerb.

It was desirable that the final sample of 300 links would be stratified by main road annual average daily total vehicle flow (AADT) and by pedestrian movement across the road link. In order to achieve this, the reconnaissance survey sought for a moderate proportion of sites with AADT's in excess of 16,000 vehicles per day and others with pedestrian flows exceeding 500 pedestrians per hour per 100 metres of kerb. The estimates of flow were derived from the short period counts taken at the site (typically 15 minutes per count). For pedestrian flow this involved the use of a simple factor to adjust from the observation period to one hour, that is, a factor of 4 for a 15-minute count. For the vehicle AADT estimates, the Department of Transport's Link Flow Validation Suite was used.

Approximately equal numbers of links with main frontage type: shop, commercial, industrial, residential, open land and other types were sought. Links with pelican or zebra crossings and with no special pedestrian facilities were included.

The reconnaissance survey provided 522 links from which a sample of 300 was to be selected. There were 430 two-way links with 30 mph speed limits, 31 two-way links with 40 mph speed limits, and 61 one-way links with 30 mph speed limits. The low number of links with 40 mph speed limits was attributable to major difficulties encountered in finding such sites with a range of layout and flow characteristics: most 40 mph links tended to be associated with low pedestrian flow and high vehicle flow residential or industrial locations in suburban areas.

The total length of link surveyed in the reconnaissance was 310 kilometres which represents 0.2 per cent of the estimated 146,000 kilometres of single carriageway built-up road in GB in 1988 (Department of Transport, 1989a).

4. SAMPLE SELECTION

Links for the main survey were selected from those identified in the reconnaissance survey mainly on the basis of vehicle flow, pedestrian flow, speed limit and whether the link was one-way or two-way. Care was taken to ensure there was a broad range of values for other characteristics in the sample whenever there was a choice of sites. These were: Region, main frontage land use, length of link, number of junctions, main parking regulations, and pedestrian facilities.

The sample selected comprised 222 two-way links with 30 mph speed limits, 28 two-way links with 40 mph speed limits and 50 one-way links with 30 mph speed limits.

The stratification of vehicle and pedestrian flows ensured that a wide range of flows was represented in the sample and that there was a low correlation between them. The reason for selecting a stratified sample is as follows. A stratified sample allows the effect of variables and factors on accidents to be much more reliably determined than would a purely random sample of the same size. This also means however that the sample is biased towards links with higher flows and is not likely to be representative of the national population of roads in relation to many other characteristics.

The distribution of link sites selected for the main survey is shown in Table 1. The one-way links were well distributed across the stratification matrix, whereas the two-way links with 30 mph speed limits were concentrated towards the low pedestrian flow cells especially where the vehicle flow was low. All of the two-way 40 mph links appeared in the low pedestrian flow cells. This is characteristic of the suburban locations where most of the 40mph link sites were found.

The selected links were well distributed across the Standard Regions with 41 sites in Yorkshire and Humberside, 22 sites in the North West, 38 in the West Midlands, 27 sites in the South West, 27 sites in the South East excluding Greater London, 79 sites within Greater London, 35 sites in Scotland and 31 in Wales. None of the sites were in the Northern, East Midland or East Anglian Regions since no reconnaissance was conducted there. The sites outside London were located within 20 different towns; the sites inside London were located within 11 different London Boroughs.

The main frontage development for the two-way links was largely residential (90 sites), retail (55 sites) and mixed retail with residential (37 sites); whereas on the one-way sites retail (21 sites), commercial (10 sites) and residential (7 sites) were the most strongly represented.

The selected sample of 300 links had a total length of 172 kilometres. The one-way sites were in general shorter than the two-way sites, with average lengths of 259 metres and 636 metres respectively. Four one-way links were less than 100 metres in length and five exceeded 500 metres. At the two-way sites only one link was shorter than 100 metres and thirty six links exceeded 1 kilometre in length.

The selected links were broken down into 2561 component sections: 970 link sections that are the subject of this report, 1288 sections of 3-arm priority junctions, and 303 sections of 4-arm priority junctions. The link sections comprised about 50 per cent (87 km) of the 172 kilometres of the link sites.

TABLE 1

Stratification of 300 link sites selected from the reconnaissance survey

One-way link sites with 30 mph limits (50 sites)			
		Vehicle flow (vehicles/day)	
Pedestrian flow (pedestrians/hr/100m)	0 - 8000	8001 - 16000	> 16000
0 - 100	10	5	6
101 - 200	4	3	2
> 200	3	11	6
Two-way link sites with 30 mph limits (222 sites)			
		Vehicle flow (vehicles/day)	
Pedestrian flow (pedestrians/hr/100m)	0 - 8000	8001 - 16000	> 16000
0 - 100	76	43	33
101 - 200	8	14	13
> 200	1	14	20
Two-way link sites with 40 mph limits (28 sites)			
		Vehicle flow (vehicles/day)	
Pedestrian flow (pedestrians/hr/100m)	0 - 8000	8001 - 16000	> 16000
0 - 100	7	7	14
101 - 200	0	0	0
> 200	0	0	0

5. THE MAIN SURVEY

The main survey was conducted on both the link and junction component sections of the selected sample of link sites. This report is concerned with the link sections and therefore those aspects of the main survey that relate to these are emphasised. The surveys were carried out on weekdays during June, September, October and November 1988 avoiding school holidays. A fully detailed survey manual and a carefully designed set of forms for data recording were prepared to aid this substantial data collection exercise.

All of the data used to develop accident predictive relations was stored in a serious of databases constructed using dBaseIV. Most of the layout details and similar variables from the main survey were transferred to computer files from the forms on which they were recorded, and were then loaded directly into the databases. However, most of the counts were processed prior to entry into the databases. Much of the required accident data was available on 'Stats 19' and a large part of this was transferred to the databases.

5.1 LINK AND JUNCTION SECTIONS

For the main survey, each link site was divided into its component link sections and junction sections (see Fig 1). The division was determined by the following criteria:

- a link section is the section of road between adjacent junctions. It contains no junctions, although it may contain minor accesses.

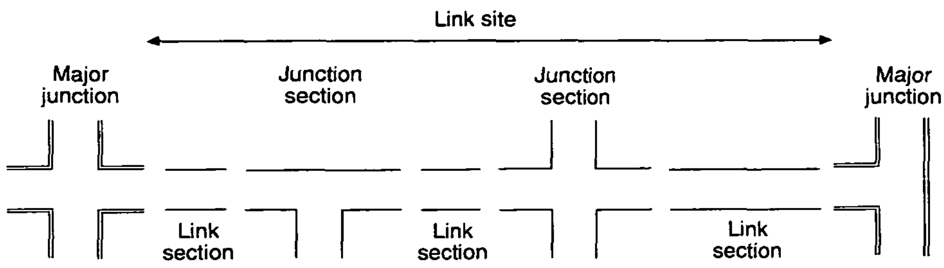


Fig. 1 Link site with link and junction sections

- a junction section contains a single priority junction (3 arm - T-junction; or 4 arm - crossroad or staggered junction), which includes the junction proper and lengths of road extending to 20 metres along the minor arms and, usually, 20 metres along the major arms of the junction.

In practice, it was inconvenient to handle very short link sections less than 20 metres long and link sections were usually only introduced when the separation between the minor arms of adjacent junctions exceeded 60 metres.

If separation between the minor arms of adjacent junctions was less than 40 metres the length of the major arms was reduced to below 20 metres. If the separation was between 40 and 60 metres, the distance over 40 metres was divided equally between the two adjacent junction sections so as to give major arms of up to 30 metres in length.

5.2 LINK SECTION LAYOUT

The length of each link section, the half-width of each side of the road, and the occurrence, location and dimensions of each feature and road marking within the section was recorded. Dimensions were obtained using measuring tapes and wheels. The widths, lengths and locations of ghost island hatching with or without right or left turning arrows, and of solid islands and pedestrian refuges were measured. The lengths and locations of all types of centre road marking were measured. A recording of the locations of pedestrian crossing and zebra crossings including those operated by school crossing patrols together with the periods of patrol was made. At each side of the road, the lengths and locations of parking bays, bus bays, bus stop markings and guard rails were measured and the locations of bus stops noted. The number of marked traffic lanes, private accesses and public accesses were counted on each side of the road.

5.3 LINK SECTION CHARACTERISTICS

The number of warning, other order and information/ direction traffic signs were separately counted on each side of the road within each link section. The type of street lighting was recorded.

The gradient of the road was measured using a clinometer. The visibility was measured from the centre of each link section in the direction of traffic movement at both sides of the road.

The frontage land use within the link section was recorded separately for each side of the road. The percentage of the total length occupied by up to three land use categories was included. The land use categories were: retail, commercial, recreational, industrial, educational, public building, residential, retail with residential, commercial with residential, religious and open space.

5.4 PARKING AND LOADING ON LINK SECTIONS

The length of all types of parking and loading regulations were measured on each side of the road for every link section.

Parking occupancy was also measured by counting the number of parked and waiting vehicles in each of four periods of the day, separately by side of road and by parking regulation. The periods were: 0800-0930 (am peak), 1030-1200 (am off-peak), 1400-1530 (pm off-peak) and 1630-1800 (pm peak).

5.5 VEHICLE FLOW ON LINK SECTIONS

5.5.1 Vehicle counts

The counts that were made of vehicle flow varied between link sites. All link sites had at least one 12 hour manual classified vehicle count, either at a junction section or at a link section.

On those link sites that contained a junction that was part of a selected sample for the study of accidents at 3-arm urban single carriageway priority junctions, turning counts at the junction were made over a 12 hour period from 0700h to 1900h. The counts were disaggregated by vehicle class; pedal cycles, motorcycles, cars, taxis, light goods vehicles (LGV), heavy goods vehicles (HGV), and public service vehicles (PSV) with and without open rear platforms.

Shorter period classified vehicle turning counts were taken on all the other junction sections on these link sites, and the flows entering and exiting the junctions on the main road were used to calculate equivalent link section counts. On up to six of the busy junction sections, 15 minute counts were taken in the same four periods of the day as parking occurrence was measured. The remaining junction sections had single 15 minute counts made in an off-peak period. A less disaggregated vehicle classification was used than for the 12 hour counts which separated only pedal cycles, motorcycles and other vehicles.

On those link sites that did not have a 12 hour junction count, a 12 hour manual classified directional vehicle count was taken on the same link section as the 12 hour pedestrian count was measured. This used the same level of vehicle classification as the 12 hour junction counts. No vehicle counts were made on the other link sections, but the junction sections were counted over 15 minute periods in the manner explained above.

5.5.2 Estimating 12-flows on each link section

The four 15-minute and single 15-minute turning counts on the junction sections were factored to produce 12 hour estimates. For each movement, the count of total vehicles in each 15-minute period was obtained. Count totals of vehicles from the major arms were scaled using an observed 12 hour flow profile for vehicles travelling in the same direction on the link site. Count totals of vehicles from the minor arms were scaled using average profiles for the same vehicle movement obtained from the associated study of 3-arm priority junctions on which 12 hour turning counts had been made.

An estimate of the 12-hour directional vehicle flow along each link section could now be obtained simply by summing the appropriate exit flows from the upstream junction section. Similarly, a further estimate could be obtained by summing the appropriate entry flows at the downstream junction section. It is also clear that 12-hour counts on an internal junction or another link section might form the basis of an estimate if the entering and exiting flows on the intervening junctions are taken into account. These are some of the more obvious cases, but it can be shown that the turning flows at all junction sections along the link site contribute information about the flow on each link section. For this reason a method was developed at TRL which would use all of the available information to estimate 12 hour total vehicle flows on the link sections.

Although separate counts for pedal cycles, motorcycles and other vehicles were made on the junction sections, those were not used in the study. Analyses at TRL showed that owing to the short period of the counts and low proportion of these categories of vehicle, better estimates of vehicle category proportions could be obtained from the 12-hour counts made on the site.

The 12 hour vehicle flow estimates are based on scaled 15 minute counts and are necessarily less precise than actual 12 hour counts. It is desirable that such uncertainties be taken into proper account in the development of accident predictive relations. For this reason work at TRL was conducted to develop a method of estimating the uncertainty in the 12-hour vehicle flows that were based on short period counts.

5.5.3 AADT's of vehicle flow

The Department of Transport's ROTAN suite was used to obtain factors to convert the 12 hour flow estimates to AADT's.

Separate factors and their associated uncertainties were used according to vehicle class, to the day of the week and month of the year when the count was taken, and to class of road and geographical region. Similarly disaggregated annual factors were used to correct AADT estimates in the year when the count was taken to the mean AADT for the period over which accident data was collected. The uncertainties in the ROTAN factors were combined with those in the 12 hour estimates to give estimates of the overall uncertainty (coefficient of variation) for the total vehicle AADT's.

5.6 PEDESTRIAN FLOW ACROSS LINK SECTIONS

5.6.1 Pedestrian counts

The counts that were made of pedestrian flow crossing the link section varied between link sites. All link sites had at least one 12-hour manual classified count of pedestrians crossing the road, either at a junction section or at a link section.

About a quarter of the link sites contained a junction that was part of a selected sample for the study of accidents at 3-arm urban single carriageway priority junctions. A 12-hour manual classified count of pedestrian flow from 0700-1900 was taken at the junction. The junction counts were recorded separately for each arm and were disaggregated by direction of crossing, by sex and estimated age (less than 15 years; 15-60 years, more than 60 years).

On the other link sites, a 12-hour manual classified count of pedestrians crossing the road was taken on one of the link sections. The link section counts were taken over a 100 metre length of the section or over the length of the whole section if this was shorter, and were disaggregated by the direction of crossing, by sex and estimated age.

On link sections on which a 12-hour pedestrian count was not made, 15-minute counts were taken in each of four periods of the day. The periods were the same as those used in the parking occupancy survey. The counts were disaggregated by crossing direction. On sections where there was a zebra or a pelican crossing, two sets of counts were made. One set was taken for pedestrians using the crossing and the other set was taken for pedestrians off the crossing but up to 50 metres on either side or to the section boundaries whichever was the shorter.

5.6.2 Estimating 12-hour pedestrian flow

The pedestrian counts measured on each link section were processed to provide estimates of 12-hour flows crossing the road, by direction and by age and sex. No attempt was made to estimate the total pedestrian flow for the period over which accident data was collected since the required conversion factors are not available; the pedestrian flows have therefore been treated as if they were constant throughout the study period.

The scaling factors used to multiply the four 15-minute counts to produce the 12-hour estimates were based on average flow profiles obtained from all 12-hour counts of pedestrians crossing the link sites. The age and sex proportions observed in the 12-hour counts for each link site were applied to the 12-hour estimates for the relevant link sections.

The uncertainties of the 12-hour estimates for pedestrian flow were estimated from empirical formulae developed at TRL.

5.7 SITE CHARACTERISTICS

It was convenient to measure some characteristics across the whole link site rather than at each link section. Bendiness, vehicle speeds and the sex and age of drivers and riders fell into this category.

Mean vehicle speeds by direction were obtained by measuring the journey times through the site of about 20 vehicles in each of four periods of the day. These periods were the same as those in which parking occupancy was measured.

The sex and approximate age of riders of pedal cycles and motorcycles, and the drivers of other vehicles were separately recorded by direction in each of four periods of the day, at a selected point along the link. The counts were of 15 minute duration in each period and the ages were: under 25 years, 25 years and over. The periods were as described previously.

The link sections are components of the whole site and operate within this context. It is likely therefore that the characteristics of neighbouring junction sections will have some sort of effect on accident occurrence on a link section. For this reason alone, it was important to record the main characteristics of the junction sections and of the terminations of the sites. The survey collected information from the junction sections at the same level of detail as has been described for the link sections. In addition the location of link sections in relation to other sections was recorded together with important data relating to the link terminations.

5.8 ACCIDENT DATA

The records of all reported personal injury accidents occurring on the link sites were provided by the relevant local highway authority for the five year period from April 1983 to March 1988 inclusive. These records included essential text descriptions of the nature and location of each accident. The accidents were sorted according to location and allocated to the link sections and the junction sections. Local authority records were used in preference to 'Stats 19' records since they are checked locally and are therefore likely to be more reliable and because the text descriptions are not available with 'Stats 19'. However, the format of the computer listings differed between local authorities and some authorities did not keep computer records. For this reason, 'Stats 19' records on a computer medium were used whenever possible to provide accident details, whilst the local authority records were used for checking and were the sole means of determining accident occurrence and location.

Each accident was assigned a detailed accident type code according to the nature of the accident and the movements of the vehicles and pedestrians involved, and was allocated to one side of the link section or the other.

Table 2 gives the conflict diagrams for the main types of accident. These refer to the primary impact rather than the subsequent consequences, so that if a vehicle hit another vehicle and was then deflected into a pedestrian, this was treated as a vehicle only accident and not as a pedestrian accident.

The allocation of accidents to a particular side of a link section was simple when all the vehicles involved in the accident were on the same side of the link. The following rules were used to allocate the more complex accidents:

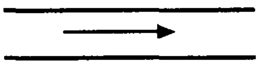
(i) where possible, head-on accidents were assigned to a particular link section side on the basis of the accident location and vehicle manoeuvre information contained in the plain language description or the Stats 19 codes; the allocation of the link side being determined by the original link side of the vehicle that appeared to have made the manoeuvre that resulted in the collision. In cases where there was insufficient data to do this, the accidents were assigned to either of the two sides on a roughly equal basis. The number of head-on accidents on a link section is the sum of head-on accidents assigned to each side.

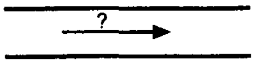
(ii) for U-turn accidents, the allocation to a particular link side was determined by the original link side of the vehicle that was making the U-turn.

(iii) for parked/parking vehicle hit accidents, the allocation to a particular link side was determined by the link side on which the vehicle was parked or on which the parking manoeuvre was being made. For one-way links, parking accidents included accidents on either side of the link.

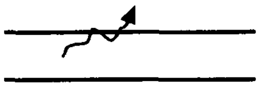
(iv) for private drive accidents, the allocation to a particular link side was determined by the side of the link where the relevant private drive was located. For one-way links, private drive accidents included accidents on both sides.

Single vehicle


Known position



Unknown position


Leaves carriageway

Rear shunt

Vehicle A is the leading vehicle

Changing lanes/overtaking

Vehicle A is Changing lanes

To left

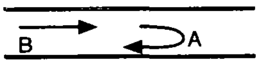
To right

Head-on

Two vehicles

Overtaking in one direction

U-Turn



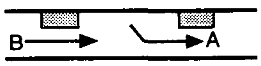
With vehicle in same direction

With vehicle in opposite direction

Parked/parking

Parked vehicle hit

Entering parking place other vehicle same side



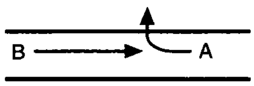
Leaving parking place other vehicle same side

Leaving parking place other vehicle opposite side

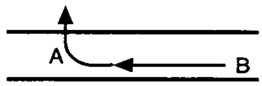
Table 2 Conflict diagrams for the main accident types

Private drive

Turning right into drive

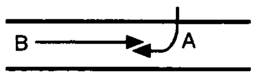


Other vehicle in opposite direction

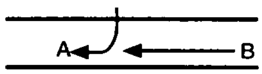


Other vehicle in same direction

Turning right out of drive

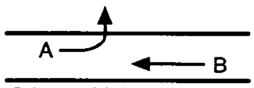


Other vehicle in opposite direction

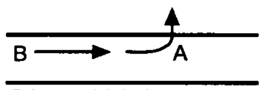


Other vehicle in same direction

Turning left into drive

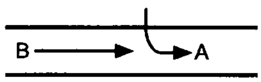


Other vehicle in same direction



Other vehicle in same direction

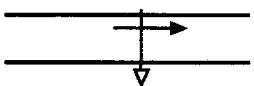
Turning left out of drive



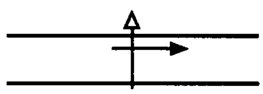
Other vehicle in same direction

Pedestrian

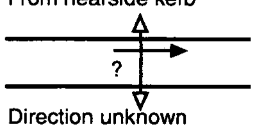
Pedestrian crossing road



From nearside kerb

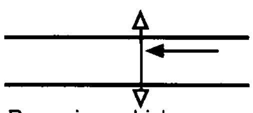


From offside kerb

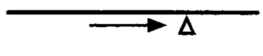


Direction unknown

Other pedestrian accidents



Reversing vehicle hits pedestrian



Pedestrian in carriageway not crossing

Pedestrian hit on footway

Table 2 Conflict diagrams for the main accident types (cont)

6. LINK SECTION CHARACTERISTICS

The basic characteristics of the link sections are set out in this section of the report.

6.1 NUMBER OF LINK SECTIONS

Table 3 gives the number of link sections by the categories of one-way or two-way traffic, speed limit, whether in London or outside London, and by crossing type. In total, there were 970 sections of which 918 did not contain a pedestrian crossing. Only a small number of link sections had a zebra (14), or a pelican crossing (38) within their boundaries since pedestrian crossings tend to be located near junctions. About 80 per cent of the 75 zebra crossings and 65 per cent of the 110 pelican crossings that were identified on the 300 link sites in the main survey were located within 20m of a junction side road and hence allocated to the relevant junction sections. None of the link sections had more than one pedestrian crossing within their boundaries.

There were 771 two-way 30 mph sections; 110 two-way 40 mph sections, all outside London and none with a zebra crossing; and 89 one-way 30 mph sections. All of the no crossing categories were represented by 60 or more sections, except the one-way 30 mph in London category which contained only 18 sections. The zebra and pelican crossing categories were represented by fewer than 10 sections except for the two-way 30 mph pelican outside London category which had 20 sections.

Care must be taken when applying the results of the predictive models to link sections with features or combinations of features that are represented in the sample by small numbers of link sections. The estimates of any safety effects are likely to be less precise, the small number of link sections chosen to represent the feature may not be typical of the whole population of such link sections and presence of any measurement errors in the explanatory variables are likely to have a greater effect than for link sections that are better represented.

6.2 LENGTH OF LINK SECTIONS

Although the criterion for minimum section length was set at 20 metres, in practice there were 20 link sections that were less than 20 metres. The shortest link section was 11 metres in length; the longest was 916 metres.

Table 4 shows the average length of the link sections according to section category. Over all link sections, the average length was 90 metres. Link sections in 40 mph speed limits had a higher average value (183m) than equivalent 30 mph sites (80m). Link sections with pedestrian crossings had a higher average value (about 120m) than no crossing sites (89m). The one-way 30 mph link sections outside London had an average value of about 80 metres, but those within London were shorter with an average length of only 55 metres.

6.3 VEHICLE AND PEDESTRIAN FLOW

Table 5 presents the ranges of vehicle flow per 24 hour day along the link section by section category. The vehicle flow is the sum of the directional flows for the two-way link sections. The mean flow on the pelican sections (17,000 vehicles per day) was much higher than on the zebra sections (12,400) or on the no crossing sections (10,800). The lowest mean flow (9,000) occurred on the 7 two-way 30 mph zebra sections outside London whereas the highest mean flow (27,500) was on the 5 two-way 40 mph pelican sections.

Table 6 shows the ranges of pedestrian density by section category expressed in terms of the pedestrian flow crossing the section per metre in a 12 hour day. The spread of the mean pedestrian densities was much greater than for the mean vehicle flows: 66.2 on the pelican sections, 21.9 on the zebra sections and 8.9 on the no crossing sections. The lowest mean density (1.4) occurred on the 105 two-way

TABLE 3

Number of link sections by category

Crossing type	Two-way traffic 30 mph London	Two-way traffic 30 mph Outside London	Two-way traffic 40 mph Outside London	Oneway traffic 30 mph London	Oneway traffic 30 mph Outside London	Total
No crossing	234	501	105	18	60	918
Zebra	4	7	0	1	2	14
Pelican	5	20	5	0	8	38
Total	243	528	110	19	70	970

TABLE 4

Average length (metres) of link section by category

Crossing type	Two-way traffic 30 mph London	Two-way traffic 30 mph Outside London	Two-way traffic 40 mph Outside London	Oneway traffic 30 mph London	Oneway traffic 30 mph Outside London	Total
No crossing	77	78	181	51	80	89
Zebra	120	124	-	131	98	120
Pelican	57	108	234	-	97	116
Total	77	80	183	55	82	90

TABLE 5

Vehicle flow along link section by category (thousands of vehicles per 24 hour day)

Crossing type	Two-way traffic 30 mph London	Two-way traffic 30 mph Outside London	Two-way traffic 40 mph Outside London	Oneway traffic 30 mph London	Oneway traffic 30 mph Outside London	Total
No crossing						
min.	0.6	0.8	2.7	4.1	0.6	0.6
mean.	11.9	10.0	12.2	15.7	9.4	10.8
max.	42.6	31.3	35.8	32.7	37.9	42.6
Zebra						
min.	14.9	5.4	-	-	-	5.4
mean.	20.3	9.0	-	13.7	7.7	12.4
max.	26.9	12.1	-	-	-	26.9
Pelican						
min.	16.0	3.6	11.0	-	9.9	3.6
mean.	19.6	15.0	27.5	-	13.6	17.0
max.	29.2	24.4	35.6	-	29.9	35.6

40 mph no crossing sections whilst the highest (143.9) was on the 8 one-way 30 mph pelican sections outside London.

Table 7 gives the ranges of pedestrian flows per 12 hour day crossing the zebra and pelican crossings. The mean flow on the pelican crossings (3,650) was about two and a half times that on the zebra crossings (1,410). On average, the pedestrian crossing flow on the one-way sections was about four times that on the two-way sections. The lowest mean flow (350) occurred on the 5 two-way 40 mph pelican crossings and the highest (8,830) was on the 8 one-way 30 mph pelican crossings outside London.

6.4 ACCIDENTS

The numbers of injury accidents by section category are shown in Table 8. There were 1590 accidents in total and as might be expected, these were distributed in a broadly similar way to the numbers of sections presented in Table 3.

Table 9 shows the number of injury accidents on the link sections by accident type and group. Similar accident types were amalgamated into accident groups to provide sufficient numbers of accidents for statistical analysis. Vehicle only accidents formed 56 per cent of the total. The vehicle only groups in order of size were: rear shunt (16 per cent), single vehicle (15 per cent), parked/parking vehicle (9 per cent), head-on and U-turn (8 per cent), private drive (7 per cent), and other vehicle accidents (2 per cent). Three head-on/U-turn accidents that occurred on one-way roads were assigned to the 'other vehicle' group.

For pedestrian accidents which formed 44 per cent of total accidents, the groups in order of size were: accidents

TABLE 6

Pedestrian density across link section by category (pedestrians per metre per 12 hour day)

Crossing type	Two-way traffic 30 mph London	Two-way traffic 30 mph Outside London	Two-way traffic 40 mph Outside London	Oneway traffic 30 mph London	Oneway traffic 30 mph Outside London	Total
No crossing						
min.	0.0	0.0	0.0	0.0	0.1	0.0
mean.	9.9	8.5	1.4	17.5	19.6	8.9
max.	148.2	206.9	20.7	59.7	141.6	206.9
Zebra						
min.	4.9	0.0	-	-	4.1	0.0
mean.	19.2	16.8	-	82.9	14.6	21.9
max.	40.0	55.7	-	-	25.2	82.9
Pelican						
min.	17.3	0.6	1.3	-	4.1	0.6
mean.	88.6	44.9	4.9	-	143.9	66.2
max.	229.5	222.0	15.7	-	265.2	265.2

TABLE 7

Pedestrian flow on pedestrian crossing by category (thousands of pedestrians per 12 hour day)

Crossing type	Two-way traffic 30 mph London	Two-way traffic 30 mph Outside London	Two-way traffic 40 mph Outside London	Oneway traffic 30 mph London	Oneway traffic 30 mph Outside London	Total
Zebra						
min.	0.35	0.01	-	-	0.29	0.01
mean.	1.69	0.46	-	8.24	0.75	1.41
max.	3.11	0.95	-	-	1.20	8.24
Pelican						
min.	1.06	0.06	0.25	-	0.37	0.06
mean.	2.65	2.66	0.35	-	8.83	3.65
max.	4.88	10.46	0.57	-	21.00	21.00

TABLE 8

Number of accidents by link section category

Crossing type	Two-way traffic 30 mph London	Two-way traffic 30 mph Outside London	Two-way traffic 40 mph Outside London	Oneway traffic 30 mph London	Oneway traffic 30 mph Outside London	Total
No crossing	482	562	146	26	52	1268
Zebra	40	18	-	8	1	67
Pelican	27	125	30	8	73	255
Total	549	705	176	34	126	1590

TABLE 9

Accidents by group and type

Group	Type		Number of accidents	Percentage of total accidents
Single vehicle	Position known		134	8.4
	Position unknown		6	0.4
	Leaves carriageway		95	6.0
	Total		235	14.8
Rear shunts and lane changing	Rear shunt		179	11.3
	Changing lane to left		34	2.1
	Changing lane to right		38	2.4
	Other lane changing		2	0.1
	Total		253	15.9
Head-on and U-turns	Head-on; two vehicles		84	5.3
	Head-on; overtaking in one direction		3	0.2
	U-turn with vehicle in same direction		35	2.2
	U-turn with vehicle in opposite direction		6	0.4
	Total		125	7.9
Parked/ parking vehicle hit	Parked vehicle hit		125	7.9
	Entering parking place;	other vehicle same side	1	0.1
	Leaving parking place;	other vehicle same side	15	0.9
	Leaving parking place;	other vehicle far side	4	0.3
	Total		145	9.1
Private drive	Turning right into;	with vehicle in opposite direction	24	1.5
	Turning right into;	with vehicle in same direction	20	1.3
	Turning right out of;	with vehicle in opposite direction	29	1.8
	Turning right out of;	with vehicle in same direction	5	0.3
	Turning left into;	with vehicle in opposite direction	1	0.1
	Turning left into;	with vehicle in same direction	17	1.1
	Turning left out of;	with vehicle in same direction	9	0.6
	Other private drive		3	0.2
	Total		108	6.8
Other vehicle	Reversing		3	0.2
	PSV passenger falls from stationary/starting PSV		17	1.1
	Pedal cyclist entering or crossing road from kerb		8	0.5
	Head-on/U-turn accidents on one-way streets		3	0.2
	Total		31	1.9
	Total vehicle only accidents		897	56.4

TABLE 9: CONTINUED

Group	Type	Number of accidents	Percentage of total accidents
Pedestrian	Pedestrian from nearside kerb	392	24.7
from nearside	Pedestrian direction unknown	5	0.3
	Total	397	25.0
Pedestrian from offside	Pedestrian from offside kerb	207	13.0
	Total	207	13.0
Other	Reversing vehicle hits pedestrian	24	1.5
pedestrian	Pedestrian in carriageway (not crossing)	30	1.9
	Pedestrian hit on footway	20	1.3
	Pedestrian walks into parked vehicle	2	0.1
	Pedestrian crossing road hit by vehicle from private drive	1	0.1
	Pedestrian/pedal cyclist on footway hit by vehicle entering private drive	3	0.2
	Pedestrian/pedal cyclist on footway hit by vehicle leaving private drive	9	0.6
	Total	89	5.6
Total pedestrian only accidents		693	43.6
Total accidents		1590	100.0

involving pedestrians from the nearside kerb (25 per cent), from the offside kerb (13 per cent), other pedestrian accidents (6 per cent).

7. ACCIDENT TABULATIONS

7.1 INTRODUCTION

One of the main aims of the study was to investigate the characteristics of a sample of non-junction accidents on built-up single carriageway roads by producing accident tabulations that would give insights into accident problems. However, the sample of sites in the study were stratified to provide a good range of vehicle and pedestrian flows and other explanatory variables and the distribution of characteristics in the sample may differ from those in the national population. It is unlikely, for example, that the quoted accident densities will match those based on the national population of sites. This section presents a series of summary accident tabulations.

The tabulations use two basic measures of accident occurrence:

(i) average accident density: the average number of accidents per kilometre of link section per year over the five year period April 1983 - March 1988;

(ii) average accident rate: the average number of accidents per 100 million vehicle kilometres travelled on the link sections over the five-year period April 1983 - March 1988.

Road user involvement in accidents is handled using the concept of average involvement rates:

(iii) average vehicle involvement rate: the average number of vehicles of the particular class involved in accidents per 100 million vehicles of that class travelling through a 100 metre length of link section.

(iv) average pedestrian involvement rate: the average number of pedestrians involved in accidents per 100 million pedestrians crossing a 100 metre length of link section. The pedestrian flows used in calculating the pedestrian involvement rates in this report are simply the 12 hour (7am - 7pm) counts or estimates times the number of link section days, no attempt being made to account for seasonal variation or flow in the period 7pm - 7am. *The pedestrian involvement rates are not, therefore, directly comparable with the vehicle involvement rates.*

7.2 ACCIDENT SEVERITIES, DENSITIES AND RATES

Table 10 shows for all link section categories, the number of sections, the number of kilometre-years, the numbers of accidents classified as fatal, serious and slight, and the accident severity defined as the percentage of injury accidents that are fatal or serious.

Accident severity on the two-way 40 mph sections (28 per cent) was slightly greater than on the two-way 30 mph sections (23 per cent) which was in turn greater than on the one-way 30 mph sections (16 per cent). Accident severities for sections with pelican crossings were similar to those for sections with no crossings, but there is evidence that the severity for sections with zebra crossings was lower than elsewhere.

Table 11 shows the average accident densities and rates together with the average 24 hour vehicle flows (thousands of vehicles) and the average 12 hour pedestrian density (thousands of pedestrians per kilometre) for the various link section categories. Accident densities and rates for sections with no crossings are considered first.

The average accident density for the two-way 30 mph sections (3.7 accidents per kilometre per year) was greater than for the two-way 40 mph sections (1.5) and for the one-way 30mph sections (2.7). These categories of link sections differed in many ways and therefore differences in accidents density were expected.

Accident rates take account of differences in vehicle flows, but the average vehicle flows for the categories of no crossing section were similar and hence the accident rates varied in much the same way as the accident densities. The average accident rate for the two-way 30 mph sections (95 accidents per 100 million vehicle-kilometres) was greater than for the two-way 40 mph sections (34) and for the one-way 30mph sections (68).

Average pedestrian densities were different for the link section categories and although these could be expected to explain a part of the variation in accident rates, they did not provide a complete explanation. The average daily pedestrian density (8.9 thousand pedestrians per kilometre) was greater than on the two-way 40 mph sections (1.4), but less than on the one-way 30 mph sections (19.1). It is clear that other variables and factors must be taken into consideration if the observed differences in accident rates are to be fully explained, and that is the purpose of the model development presented later in this report.

The sections with zebra crossings had accident densities that were about twice those of the no crossing sections,

TABLE 10

Numbers and severity of accidents by link section category

Link section category	Number of Sect.	Number of Km years	Fatal	Serious	Slight	Total	Accident severity % fatal and serious	
Two-way 30mph								
No crossing	735	283.9	19	221	804	1044	23	(1.3)
Zebra	11	6.7	2	6	50	58	14	(4.6)
Pelican	25	12.2	2	40	110	152	28	(3.6)
Total	771	303.0	23	267	964	1254	23	(1.2)
Two-way 40mph								
No crossing	105	94.9	5	36	105	146	28	(3.7)
Pelican	5	5.9	2	6	22	30	27	(8.1)
Total	110	100.8	7	42	127	176	28	(3.4)
All two-way	881	403.8	30	309	1091	1430	24	(1.1)
One-way 30mph								
No crossing	78	28.5	0	13	63	78	17	(4.3)
Zebra	3	1.6	0	1	8	9	11	(10.4)
Pelican	8	3.9	1	10	62	73	15	(4.2)
All one-way	89	34.0	1	24	135	160	16	(2.9)
All link sections	970	437.8	31	333	1226	1590	23	(1.1)

( )Figures in brackets are standard errors of the mean values.

TABLE 11

Accident density and rate by link section category

Link section category	Number of Sect.	Km years	Average 24 hour vehicle flow (000)	Average 12 hour ped. density	Accident density per km per year	Accident rate per 100 million veh-km
Two-way 30mph						
No crossing	735	283.9	10.6	8.9	3.7 (0.1)	95 (3)
Zebra	11	6.7	13.1	17.7	8.7 (1.1)	182 (24)
Pelican	25	12.2	15.9	53.6	12.5 (1.0)	215 (17)
Total	771	303.0	10.8	10.5	4.1 (0.1)	104 (3)
Two-way 40mph						
No crossing	105	94.9	12.2	1.4	1.5 (0.1)	34 (3)
Pelican	5	5.9	27.5	4.9	5.1 (0.9)	51 (9)
Total	110	100.8	12.9	1.5	1.7 (0.1)	36 (3)
All two-way	881	403.8	11.1	9.4	3.5 (0.1)	86 (2)
One-way 30mph						
No crossing	78	28.5	10.9	19.1	2.7 (0.3)	68 (8)
Zebra	3	1.6	9.7	37.4	5.6 (1.9)	158 (53)
Pelican	8	3.9	13.6	143.9	18.7 (2.2)	378 (44)
All one-way	89	34.0	11.1	31.0	4.7 (0.4)	116 (9)
All link sections	970	437.8	11.1	10.4	3.6 (0.1)	90 (2)

( ) Figures in brackets are standard errors of the mean values.

whilst the accident densities for the pelican sections were three or more times those of the no crossing sections.

Average vehicle flows on the sections with crossings were higher in general than those on the no crossing sections. The average accident rates for the zebra sections were about twice the rates for no crossing sections and those for pelican sections were still higher. However, the pedestrian densities on the zebra sections were also about twice those on the no crossing sections, whilst the pelican sections had pedestrian densities that were about five times those on the no crossing sections.

Table 12 compares the average severity, density and rate between sites in different DOT Regions. Accident density was higher than the overall average (3.6 accidents per kilometre per year) in London (5.9), Midlands (4.8) and Scotland (4.3). These are also the regions with the highest accident rates: London (130 accidents per 100 million vehicle-kilometres), Midlands (121) and Scotland (108) compared with an overall average of 90. The average severity of accidents in London (18 per cent) is less than the overall average (23 per cent) which indicates that the excess accidents are mainly slight injury accidents. However, the accident severity in the Midlands (25 per cent) is close to the overall average and that for Scotland (32 per cent) is notably high.

Accident densities were lower than the overall average in Eastern & South East (2.5), North West (2.8), South West (2.7), Yorkshire and Humberside (2.2) and Wales (2.4). These regions with the exception of the South West and Wales also had markedly lower accident rates than the overall average: Eastern & South East (61), North West (54), South West (74), Yorkshire and Humberside (56) and Wales (78). Average severities in the North West (17 per cent) and the South West (19 per cent) were low but not statistically significantly different from the overall average severity.

7.3 ACCIDENT GROUPS

The distribution of accidents into groups has already been discussed in Sections 5.8 and 6.4. The number and percentage of accidents in each group is given in Table 9. The percentage of accidents in each group by link section category is given in Tables 13 and 14.

TABLE 12

Accident severity, density and rate by region

DTp Region	Number of accidents	Accident severity % fatal & serious	Accident density per km per year	Accident rate per 100 million veh-km
Eastern & South East	116	27 (1.4)	2.5 (0.3)	61 (6)
London	583	18 (1.6)	5.9 (0.2)	130 (5)
East & West Midlands	262	25 (2.7)	4.8 (0.3)	121 (7)
North West	63	17 (4.7)	2.8 (0.4)	54 (7)
South West	83	19 (4.3)	2.7 (0.3)	74 (8)
Yorkshire & Humberside	219	28 (3.0)	2.2 (0.1)	56 (4)
Scotland	142	32 (3.9)	4.3 (0.4)	108 (9)
Wales	122	21 (3.7)	2.4 (0.2)	78 (7)
Total	1590	23 (1.1)	3.6 (0.1)	90 (2)

( ) Figures in brackets are standard errors of the mean values.

TABLE 13

Accidents by accident group, speed limit and one-way/two-way traffic.

Accident group	Percentage by link section category			
	Two-way 30 mph	Two-way 40 mph	One-way 30 mph	Total
Single vehicle	14	22	16	15
Rear shunt & lane changing	15	20	19	16
Head-on and U-turn	9	9	0	8
Parked vehicle	9	10	9	9
Private drive	7	13	2	7
Other vehicle	2	0	3	2
Pedestrian from nearside	26	14	29	25
Pedestrian from offside	14	9	9	13
Other pedestrian	5	2	13	6
All vehicle groups	55	75	49	56
All pedestrian groups	45	25	51	44
All groups	100	100	100	100
Number of accidents	1254	176	160	1590

Although pedestrian accidents formed 44 per cent of the overall total, there was considerable variation between link section categories: two-way 30 mph (45 per cent), two-way 40 mph (25 per cent), one-way 30 mph (51 per cent), no crossing (40 per cent), zebra (54 per cent), and pelican (60 per cent). These differences are related, at least in part, to the different pedestrian densities for these categories.

The distribution of pedestrian accidents across the relevant groups is fairly similar for all categories, and the same applies to the distribution of vehicle only accidents across the vehicle groups with certain clear exceptions. Rear shunt accidents were strongly represented on the sections with zebra crossings.

TABLE 14

Accidents by accident group and pedestrian crossing

Accident group	Percentage by link section category			
	No crossing	Zebra	Pelican	Total
Single vehicle	16	4	11	15
Rear shunt & lane changing	15	30	16	16
Head-on and U-turn	9	1	3	8
Parked vehicle	11	4	3	9
Private drive	7	4	6	7
Other vehicle	2	1	2	2
Pedestrian from nearside	22	30	38	25
Pedestrian from offside	12	18	17	13
Other pedestrian	6	6	5	6
All vehicle groups	60	46	40	56
All pedestrian groups	40	54	60	44
All groups	100	100	100	100
Number of accidents	1268	67	255	1590

Table 15 presents accident severity by accident group. Pedestrian accidents had on average a greater percentage of accidents with fatal or serious casualties (28 per cent) than vehicle only accidents (19 per cent). The percentages of rear shunt accidents (11 per cent), private drive accidents (14 per cent), and other pedestrian accidents (13 per cent) that had fatal or serious casualties were relatively low, whilst the percentage for 'pedestrian from the offside kerb' (36 per cent) was high.

7.4 ROAD USER INVOLVEMENT

Table 16 shows the proportion of all accidents which involve road users from each class including pedestrians. It is important to note that in general, a single accident will involve more than one user class. Pedal cycles were involved in more than 8 per cent of all accidents, motor cycles in 17 per cent, public service vehicles in 10 per cent, and pedestrians in 45 per cent.

Table 16 also shows the distribution of accidents for each user class between the various accident groups. A small number of accidents involving pedestrians were included in 'vehicle only' accident groups as the primary accident did not involve a pedestrian.

The percentage of accidents involving car or taxis that were classified as a pedestrian accident group (44 per cent) was substantially higher than for any of the other classes of vehicle. The percentage of accidents involving motor cycles in the 'pedestrians crossing from the nearside' accident group (19 percent) was similar to that for cars (25 percent) but the percentages of accidents involving motor cycles in the 'offside' and 'other' pedestrian accident groups were much lower than that for cars.

7.4.1 Two-wheeled vehicles

For accidents involving pedal cycles, the distribution of the vehicle accident groups was similar to that for cars except for 'rear shunt and lane changing' (31 per cent) ,'parked vehicle' (25 per cent) and 'other vehicle' (6 per cent) which were substantially higher than the respective percentages for cars (19, 11 and 1 per cent).

When the accidents involving pedal cyclists were examined in more detail it was found that about half of the 27 'rear shunt' accidents involving pedal cyclists were accidents in which a pedal cyclist was hit by a vehicle from behind; the remainder were accidents in which a pedal cyclist ran into the vehicle in front. Half of the 14 'lane changing' pedal cycle accidents were accidents involving a cyclist colliding with an overtaking vehicle that was changing lanes to the left; the remainder were accidents involving a cyclist changing lanes to the right colliding with an overtaking vehicle. Almost all of the 19 'private drive' pedal cycle accidents were accidents in which the pedal cyclist cycling along the road collided with a vehicle entering or leaving a private drive. The 4 'other pedestrian' pedal cycle accidents were mainly accidents in which the cyclist was classed as a pedestrian (cyclists using the footway colliding with vehicles entering or leaving private drives).

TABLE 15

Accidents by severity and by accident group

Accident group	Fatal	Serious	Slight	Total	Accident severity % fatal & serious	
Single vehicle	11	46	178	235	24	(2.8)
Rear shunt & lane chg.	2	27	224	253	11	(2.0)
Head-on and U-turn	3	25	97	125	22	(3.8)
Parked vehicle	0	32	113	145	22	(3.4)
Private drive	0	15	93	108	14	(3.3)
Other vehicle	0	8	23	31	26	(7.8)
Pedestrian from nearside	6	102	289	397	27	(2.2)
Pedestrian from offside	6	69	132	207	36	(3.4)
Other pedestrian	3	9	77	89	13	(3.7)
All vehicle groups	16	153	728	897	19	(1.3)
All pedestrian groups	15	180	498	693	28	(1.7)
All groups	31	333	1226	1590	23	(1.1)

( ) Figures in brackets are standard errors of the mean values

TABLE 16

Accidents by class of user involved and accident group

	Accidents involving a: Pedal cycle	Motor cycle	Car & taxi	LGV	HGV	PSV	Pedest -rian	All accidents
Number of accidents	133	264	1225	141	41	162	710	1590
(percentage of total)	8.4	16.6	77.0	8.9	2.6	10.2	44.7	100.0
Percentage by accident group								
Single vehicle	9	11	8	11	0	53	1	14.8
Rear shunt & lane chg.	31	20	19	26	37	12	1	15.9
Head-on and U-turn	6	14	9	14	7	4	0	7.9
Parked vehicle	25	11	11	16	22	4	1	9.1
Private drive	14	17	8	9	7	1	0	6.8
Other vehicle	6	1	1	0	2	10	0	1.9
Pedestrian from nearside	5	19	25	13	10	9	56	25.0
Pedestrian from offside	1	6	14	6	2	2	29	13.0
Other pedestrian	3	1	5	4	12	4	12	5.6
Total	100	100	100	100	100	100	100	100.0

Accidents involving motor cycles were notable in that the percentage for the accident group 'private drive' (17 per cent) was substantially higher than for accidents involving cars (8 per cent).

When the accidents involving motor cyclists were examined in more detail it was found that about one-fifth of the 28 'single vehicle' motor cycle accidents were accidents in which the motor cyclist left the carriageway. About half of the 26 'rear shunt' motor cycle accidents were accidents in which a motor cyclist was hit by a vehicle from behind; the remainder were accidents in which a motor cyclist ran into the vehicle in front. A quarter of the 26 'lane changing' motor cycle accidents were accidents involving a motor cyclist colliding with a vehicle that was changing lanes to the left; half were accidents involving a motor cyclist colliding with a vehicle changing lanes to the right. Three-quarters of the 20 'U-turn' motor cycle accidents were accidents involving a motor cyclist colliding with a vehicle making a U-turn. Three-quarters of the 45 private drive motor cycle accidents were accidents in which a motor cyclist collided with a vehicle entering or leaving a private drive.

7.4.2 Other minority vehicle groups

For accidents involving light goods vehicles, the distribution of the vehicle accident groups was similar to that for cars but the distribution of pedestrian accident groups was different; 23 per cent of light goods vehicle accidents involved pedestrians compared to 44 per cent for cars.

The percentage of accidents involving heavy goods vehicle that were 'rear shunts' (37 per cent) and 'parked vehicle' (22 per cent) was higher than the respective percentages for cars (19 and 11 per cent). No heavy goods vehicles were involved in single vehicle accidents. In almost all of the 41 accidents involving a heavy goods vehicle, the occupants of the heavy goods vehicle were uninjured.

The percentage of accidents involving public service vehicles (PSVs) that were 'single vehicle' (53 per cent) was much higher that the percentage for cars (8 per cent). The PSV 'single vehicle' accidents were mainly those in which passengers were injured inside moving vehicles; 44 per cent of the passengers injured were aged 60 or over; 52 per cent were standing and 31 per cent were in the process of boarding or alighting.

Ten per cent of accidents involving PSVs were 'other vehicle' accidents. These accidents were mainly those in which passengers were injured when boarding or alighting a stationary PSV; 59 per cent of the passengers were aged 60 or over; 60 per cent were boarding the PSV and 24 per cent alighting.

7.4.3 Road user involvement rates

Table 17 presents the total numbers and percentages of involvements by road user class. In general, each accident will contribute more than one involvement: for example, an accident between a car and a motor cycle will contribute one involvement to both the car and the motor cycle classes. Pedal cycles account for 4 per cent of total involvements, motor cycles 9 per cent, public service vehicles 5 per cent, and pedestrians 23 per cent.

Table 17 also shows the accident involvement rates for a standardised 100 metre length of link section by road user class and accident group. For total accidents, the ratios of the rates for individual classes of road user to the rate for cars and taxis was as follows: pedal cycle (3.6), motor cycle (5.6), light goods vehicle (1.0), heavy goods vehicle (0.7), and public service vehicle (3.7).

7.5 ACCIDENTS BY NUMBER OF CASUALTIES

Table 18 gives the number of casualties per accident by accident group and category of link section. Two-way 30 mph and one-way 30 mph sections have similar numbers of casualties per accident: 1.18 (two-way) and 1.14 (one-way). The two-way 40 mph sections had a much larger 1.48 casualties per accident. Over all link section categories, head-on and U-turn accidents had the highest number of casualties per accident (1.48) followed by single vehicle accidents (1.34) and rear shunts (1.31). Other accident groups had less than the average (1.21) casualties per accident.

7.6 ACCIDENTS BY TIME PERIOD

The distribution of accidents by year, month, day of week and time of day are presented in Tables 19 to 22 for the five year period April 1983 - March 1988. The percentages of accidents in years 1983 and 1988 are lower than average because accident details were not collected for the full 12 months in these years. The tables give average accident densities to take account of such differences, as well as the percentage distributions. Each of the tables gives the distribution for all link sections since it was found that there were no significant differences in the way the accidents were distributed in time between the various link sections categories.

The tables also include comparative figures from national statistics (Department of Transport, 1989b) though for Tables 20, 21, 22 appropriate accident data were not readily available, so casualty and driver data for all roads have been given. Bearing in mind such differences, it can be seen that the distribution of accidents by year, month, day of week and time of day at the sections generally reflected the national patterns.

TABLE 17

Vehicles and pedestrians involved in accidents and involvement rates[1] by accident group for a 100 metre section of link

	Accidents involving a: Pedal cycle	Motor cycle	Car & taxi	Light goods vehicle	Heavy goods vehicle	Public service vehicle	Pedest-rian[2]
Number of involvements	137	270	1630	146	42	162	733
(percentage of total)	4.3	8.6	51.6	4.6	1.3	5.1	23.2
Involvement rate by accident group							
Single vehicle	3.5	6.5	0.7	1.2	0.0	22.0	0.9
	(1.0)	(1.2)	(0.1)	(0.3)	(0.0)	(2.4)	(0.3)
Rear shunt & lane changing	12.4	12.9	2.8	2.8	2.8	5.1	0.8
	(1.9)	(1.7)	(0.1)	(0.5)	(0.7)	(1.1)	(0.3)
Head-on and U-turn	2.6	9.0	1.4	1.6	0.6	1.5	0.0
	(0.9)	(1.4)	(0.1)	(0.3)	(0.3)	(0.6)	(0.0)
Parked vehicle	9.8	6.9	1.5	1.9	1.7	1.8	0.5
	(1.7)	(1.3)	(0.1)	(0.4)	(0.6)	(0.7)	(0.2)
Private drive	5.5	10.4	1.0	1.1	0.6	0.5	0.1
	(1.3)	(1.5)	(0.1)	(0.3)	(0.3)	(0.4)	(0.1)
Other vehicle	2.0	0.5	0.1	0.0	0.2	4.4	0.2
	(0.8)	(0.3)	(0.025)	(0.0)	(0.2)	(1.1)	(0.1)
Pedestrian from nearside	2.0	11.3	2.1	1.4	0.7	3.6	38.5
	(0.8)	(1.6)	(0.1)	(0.3)	(0.4)	(1.0)	(1.9)
Pedestrian from offside	0.6	3.9	1.2	0.7	0.2	1.0	20.6
	(0.4)	(1.0)	(0.1)	(0.2)	(0.2)	(0.5)	(1.4)
Other pedestrian	1.2	0.9	0.5	0.5	0.9	1.5	8.4
	(0.6)	(0.5)	(0.1)	(0.2)	(0.4)	(0.6)	(0.9)
Total	39.5	62.4	11.1	11.1	7.6	41.5	69.9
	(3.4)	(3.8)	(0.3)	(0.9)	(1.2)	(3.3)	(2.6)

1 The vehicle involvement rate is the number of vehicles of the particular type involved in accidents per 100 million vehicles of that type travelling through 100 m of link section. The pedestrian flows used in calculating the pedestrian involvement rates are simply the 12-hour (7 am - 7 pm) counts (or estimates) times the number of link section days, no attempt has been made to account for yearly or seasonal variation in pedestrian flow. The pedestrian involvement rates are not, therefore, directly comparable with the vehicle involvement rates.

2 A few pedestrians were injured in secondary collisions associated with non-pedestrian accidents.

( ) Figures in brackets are the standard errors of the mean values.

TABLE 18

Casualties by accident group and link section category

	Number of accidents	Average number of casualties per accident			
		Fatal	Serious	Slight	Total
Accident group:					
Single vehicle	235	0.04	0.28	1.02	1.34
Rear shunt & lane chg.	253	0.02	0.15	1.14	1.31
Head-on and U-turn	125	0.03	0.34	1.12	1.48
Parked vehicle	145	0.00	0.16	1.02	1.18
Private drive	108	0.00	0.27	0.88	1.15
Other vehicle	31	0.00	0.18	0.82	1.00
Pedestrian from nearside	397	0.01	0.28	0.80	1.09
Pedestrian from offside	207	0.03	0.27	0.85	1.15
Other pedestrian	89	0.03	0.15	0.89	1.07
All groups	1590	0.02	0.24	0.95	1.21
Link section category:					
Two-way 30mph	1254	0.02	0.24	0.92	1.18
Two-way 40mph	176	0.04	0.29	1.15	1.48
One-way 30mph	160	0.01	0.16	0.98	1.14

TABLE 19

Accidents by year April 1983 - March 1988

All sample link sections	1983	1984	1985	1986	1987	1988
Percentage of accidents	17.8	19.5	18.8	20.5	18.6	4.8
Accident density (per km year)	4.2	3.5	3.4	3.7	3.3	3.5
Accident density ratio[1]	1.16	0.97	0.95	1.03	0.92	0.97
National statistics for built-up roads[2]						
Accident density ratio[1]	1.01	1.04	1.00	1.00	0.96	0.98

1. Accident ratio = $\frac{\text{Accident density for specific year}}{\text{Average accident density over 1983-1988}}$

2. (Department of Transport, 1989b)

TABLE 20

Accidents by month over the years 1983 - 1988

Month	Percentage of accidents	Accident density (per km year)	Density ratio [1] Link section (accidents)	National statistics [2] (casualties)
January	6.9	0.25	0.83	0.83
February	7.2	0.26	0.87	0.78
March	8.1	0.29	0.97	0.92
April	7.3	0.26	0.87	0.90
May	8.3	0.30	0.99	1.02
June	8.4	0.30	1.00	1.02
July	8.6	0.31	1.02	1.08
August	9.3	0.34	1.11	1.03
September	7.8	0.28	0.93	1.14
October	8.6	0.31	1.03	1.15
November	10.2	0.37	1.23	1.06
December	9.3	0.34	1.12	1.06

1. Density ratio = $\frac{\text{Density for specific month}}{\text{Average density for all months}}$
2. The national density ratio is based on casualty data relating to all roads (Department of Transport, 1989b), as relevant accident data were not readily available.

TABLE 21

Accidents by day of week over the years 1983-1988

Day of week	Percentage of accidents	Accident density (per km year)	Density ratio [1] All sample link sections (accidents)	National statistics[2] (drivers involved)
Monday	12.6	0.47	0.88	0.97
Tuesday	14.0	0.52	0.98	0.96
Wednesday	14.4	0.53	1.01	0.98
Thursday	15.7	0.58	1.10	1.03
Friday	18.2	0.67	1.27	1.21
Saturday	15.9	0.59	1.12	1.04
Sunday	9.3	0.34	0.65	0.80

1. Density ratio = $\frac{\text{Density for specific day of week}}{\text{Average density for all days}}$
2. The national density ratio is based on numbers of motor vehicle drivers involved in accidents on all roads (Department of Transport, 1989b), as relevant accident data were not readily available.

TABLE 22

Accidents by time of day and day of week over the years 1983-1988

Time period	Saturday and Sunday Percentage of Accidents	Percentage of National statistics[1] (casualties)	Monday to Friday Accidents	National Statistics[1] (casualties)
00-02h	7.0	7.9	1.4	2.3
02-04h	4.0	3.9	0.6	0.9
04-06h	1.3	1.2	0.7	0.7
06-08h	2.5	2.0	3.9	5.4
08-10h	5.0	4.7	11.8	12.1
10-12h	8.3	10.0	10.5	8.8
12-14h	13.3	12.2	12.4	11.0
14-16h	16.3	14.7	12.3	12.4
16-18h	14.3	13.4	19.4	17.7
18-20h	6.8	10.6	10.4	11.6
20-22h	9.8	8.3	8.4	8.4
22-24h	11.8	10.6	8.3	8.7

1. Published casualty data for all roads (Department of Transport, 1989b) has been used as relevant accident data were not readily available.

7.7 ACCIDENTS BY LIGHT, WEATHER AND ROAD SURFACE CONDITIONS

Table 23 sets out the percentage of accidents by group that occurred under specified adverse conditions. The variation between accident groups for different weather and road surface conditions is limited. A high proportion of 'single vehicle', 'head-on and U-turn', 'parked vehicle' and 'pedestrian from the offside' accidents occurred after dark.

8. REGRESSION ANALYSIS

8.1 METHOD

The objective of the analysis is to relate the accident frequency (the average number of accidents per year) on the link sections to a range of 'explanatory variables', thus providing a model for examining the effect of vehicle and pedestrian flow and section characteristics. Such a model might also be used for predicting site-specific mean accident frequencies.

The statistical method used was a form of multiple regression analysis and is the same as that employed in a number of previous accident studies, in particular the study of accidents at four-arm roundabouts (Maycock and Hall, 1984), at rural T-junctions (Pickering, Hall and Grimmer, 1986) and at four-arm single carriageway urban traffic signals (Hall, 1986). Reference should be made to such reports for full details of the method, as only a brief outline is given here.

The set of 'explanatory' or 'independent' variables of the regression are functions of the traffic and pedestrian flows, and the site, geometric and other characteristics of the link sections. Since, however, the numbers of accidents in a given period do not follow a Normal distribution and, in particular, do not have a constant variance, classical least squares regression could not be used. Instead, the 'generalised linear modelling' technique available in the computer programs GENSTAT (Alvey et al, 1977) and GLIM (Baker and Nelder, 1978) has been used. These programs allow the dependent variable in the regression analysis to be drawn from one of a family of distributions, in particular the Poisson distribution, and also allow non-linear models to be fitted by means of suitable transformations.

The regression modelling was undertaken in three main stages:

(i) relating total accident frequency at the link sections to various functions of the traffic and pedestrian flows;

(ii) relating accident frequency by traffic direction for each main accident group to various functions of the traffic flow;

TABLE 23

Accidents by light, weather and road surface conditions

	Number of accidents	Percentage by condition				
		Light	Weather		Road surface	
		After dark	Rain	Snow or fog	Wet	Snow or ice
Accident group:						
Single vehicle	235	37.0	17.9	0.9	34.9	2.6
Rear shunt	253	20.2	19.4	1.2	32.4	3.2
Head-on and U-turn	125	40.6	20.3	1.6	37.5	3.1
Parked vehicle	145	39.3	17.2	0.7	35.2	2.8
Private drive	108	21.3	23.1	0.0	35.2	0.0
Other vehicle	31	17.9	17.9	0.0	42.9	0.0
Pedestrian from nearside	397	27.8	15.4	1.3	29.5	1.0
Pedestrian from offside	207	42.5	21.7	0.0	36.7	0.5
Other pedestrian	89	29.2	11.2	2.2	24.7	2.2
All groups	1590	31.4	18.1	0.9	33.2	1.8
National statistics for built-up roads 1988[1]	-	28.5	15.0	0.9	31.8	1.2

1. Department of Transport, 1989.

(iii) extending the best accident-flow models of (ii) to include the geometric variables and factors.

At each of the first two stages, differences in accident frequency between the link section categories were examined in terms of whether the flow was one-way or two-way, whether the speed limit was 30 mph or 40 mph, whether the section was in London or not, and whether there was a zebra, a pelican or no crossing, by the inclusion of suitable factors into the model.

Stages (i) and (ii) of the modelling aimed only to produce models that were a good fit to the data. It must be recognised that since only a limited number of factors are tested in these stages, those that do appear in the models may well be acting merely as proxies for other causal variables with which they are associated and which are not tested until stage (iii). The stage (i) and stage (ii) models cannot be regarded as causal.

At stage (iii), however, a very comprehensive range of measurable link section and flow characteristics was taken into account and it is unlikely that plausible physical explanatory factors or variables have been omitted. It is therefore likely that the full accident-accident-flow-geometry models are causative (but that is not to say the mechanisms are fully understood).

8.2 SIGNIFICANCE TESTING

The aim of the modelling was to obtain the best 'trade-off' between the number of variables included in the model (keeping the number as small as possible to make interpretation easier) and the ability of the model to represent the data (keeping the fit as good as possible).

Each model was fitted in a step-by-step procedure, starting with the 'null' model, which simply fitted the mean value of the dependent variable. At each step, the statistic calculated was the 'scaled deviance' which gave a measure of the goodness of fit of the 'current' model relative to the 'full' model which fits all the data points exactly. Thus the smaller the scaled deviance the better the fit the model was to the data.

A simple approach to the analysis assumes that the accident numbers follow a Poisson distribution. In using the Poisson distribution, provided the predicted mean value of accidents in the study period is greater than about 0.5 (see Maycock and Hall, 1984), the scaled deviance is asymptotically distributed as χ^2 with (n-p-1) degrees of freedom, (where n is the number of data points and p the number of independent variables fitted) and may be used as a test of the goodness of fit of the model.

The significance of adding one or more terms to a model also needs to be assessed. Generally, the difference in scaled deviance between two nested models with degrees of freedom df_1 and df_2 will be distributed like χ^2 with $(df_1 - df_2)$ degrees of freedom and so may be used to assess the significance of adding one or more terms to a model. Thus for the addition of one term, a value of at least 3.8 is required for significance at the 5% level.

The Poisson assumption takes account only of the within-site variation of accident numbers, that is, the variation that occurs between successive samples of accidents taken from the same site. The accidents in this study however, occur at a large number of link sections with different mean accident frequencies and densities. This adds an additional component of variation called between-site variation. The effect is to make the variance to mean ratio for the accident numbers greater than one (the ratio is one for a Poisson distribution) and is known as over-dispersion. A further complication is that when accidents are formed into groups, the mean number of accidents per section in the study period is less than 0.5, and this reduces the scaled deviance below that expected for χ^2. The problems of over-dispersion and low mean values have been discussed by Maycock and Maher (1988), and taken into account in the analyses presented in this report.

A quasi-likelihood method was used to take account of over-dispersion in the presence of low mean values. The procedure was as follows. Each model was initially calculated assuming a Poisson distribution of accidents which has a variance to mean ratio (the scale factor) of one. The amount of over-dispersion was then determined by calculating the ratio of the generalised Pearson χ^2 function, to the number of degrees of freedom (df) for that model. This provided a revised estimate of the scale factor (s) which was used to recalculate the model. The model parameters themselves were unchanged, but both the scaled deviance and the standard errors of the parameters were affected by s. The addition of one term requires a scaled deviance drop of 3.8 multiplied by s and the true standard errors are estimated by multiplying the Poisson model standard errors by $s^{0.5}$. *In all of the results presented in this report, the standard errors shown refer to a Poisson model and have already been scaled by the scale factors given.*

8.3 THE EFFECT OF UNCERTAINTIES IN THE VEHICLE AND PEDESTRIAN FLOW ESTIMATES

The generalised linear modelling technique that was used in the development of the models assumes that the values of all the 'explanatory' variables are precisely known. But the vehicle and pedestrian flow variables that were tested in the models were estimates which contained uncertainty. The effect of ignoring such uncertainties and applying the generalised modelling technique in the usual way is to introduce bias into the estimation of the model parameters. The extent of the bias was not precisely known prior to this study but was expected to depend on the degree of uncertainty in the flows. The effect was expected to be negligible when flows were based on 12 hour counts but to increase when 15 minute counts were the basis of flow estimation. Following enquiries, it quickly became clear that there was no existing procedure for properly analysing such data.

TRL has let a small extra-mural research contract with the Statistical Services Unit of the Department of Probability and Statistics at the University of Sheffield to develop a suitable procedure. This has produced computer packages based on GLIM and GENSTAT which use iterative procedures and which take account of the uncertainties in the flow estimates and eliminate bias in the models. In order to use the packages, estimates of flow and of the associated coefficient of variation are required.

Unfortunately, the packages that have so far been developed do not handle many of the forms of model that are presented in this report. They do, however, present an opportunity to assess properly the extent of the bias in the model parameters obtained when using standard GLIM or GENSTAT. For the models to which they could be applied, the bias was small (less than about 10 per cent of the parameter value) and well within the quoted standard errors. For the sake of consistency, all the models presented in this report are those developed using standard GENSTAT.

9. TOTAL ACCIDENT - FLOW MODELS

9.1 INTRODUCTION

The first stage of the modelling for link sections was to relate the total accident frequency at the link sections to various functions of the vehicle and pedestrian flows. The basic unit of analysis was the link section (both sides combined). The total number of analysis units was 970.

The model with the best flow function was then extended to include some basic section classification factors.

The same procedure was then carried out for vehicle only accidents, pedestrian accidents, off-crossing pedestrian accidents, and on-crossing pedestrian accidents.

9.2 THE FORM OF THE MODELS

9.2.1 Vehicle and pedestrian flow

The basic form of the model relating accident frequency to flow that has been successful in the previous junction studies is:

$$A = kQ^{\alpha} \qquad (9.1)$$

where A is the accident frequency (accidents per year),

Q is the flow function, an algebraic combination of the vehicle and pedestrian movements,

k, α are the parameters estimated by the regression.

Often a product of two flows was tried as the flow function, giving the alternative form of model:

$$A = kQ_a^{\alpha} Q_b^{\beta} \qquad (9.2)$$

where A is the accident frequency (as above).

Q_a and Q_b are separate flow functions,

k, α and β are the parameters to be estimated.

This model simply allows the exponents of the two parts of the flow product to take separate values rather than being constrained to one value as in model (9.1).

However in order that the dependent variable may be regarded as having a Poisson error distribution the above model is multiplied by the number of years (YR) for which each link section is studied, to give:

$$A.YR = YR.\ kQ_a^{\alpha} Q_b^{\beta} \qquad (9.3)$$

so that (A.YR) is the number of accidents at the site.

Before fitting, the model is transformed to the linear form using the standard $\log_e$ transformation to give:

$$\log (A.YR) = \log(YR) + \log (k) + \alpha \log (Q_a) + \beta \log (Q_b) \qquad (9.4)$$

The term log (YR) is assigned as the 'offset variable', its coefficient being constrained to the value 1 in the fitting process.

A difficulty arises if either Q_a or Q_b are zero for any of the sites as the logarithm then takes the value minus infinity. This can occur if the observed count is zero and only the count is used to estimate the true flow. In this study, the problem was avoided by using the information from the distribution of counts for the same vehicle or pedestrian movement across all link sections, and then combining this with the observed zero count using a Bayesian statistical procedure to form an improved estimate of the true flow. This approach produced very small rather than zero estimates for these flows.

The forms of model discussed so far do not include a length variable and are therefore suitable for components of the road network that have a constant or near constant length such as junctions or components that are short such as zebra or pelican crossings.

For components of the road network that have extended and varying lengths such as link sections, models which include section length as a primary explanatory variable are required. The models for total accidents, vehicle only accidents, pedestrian accidents and off-crossing pedestrian accidents are of this type.

The approach used initially for the first three of these categories of accident was as follows. Q_a was represented by QT and Q_b was represented by PT, the total pedestrian flow across the link section summed over both directions (thousands of pedestrians per 12 hour period) and a new term to represent section length SL (km) was introduced. The linear form of the model was:

$$\log(A.YR) = \log(YR) + \log(k) + \alpha \log(QT) + \beta \log(PT) + \gamma \log(SL) \qquad (9.5)$$

where γ was a new parameter determined by the regression. The value of γ varied from 0.58 (pedestrian accidents), through 0.76 (total section accidents) to 0.88 (vehicle only accidents), indicating a distinctly non-linear and varying relationship between accident frequency A and section length SL which was difficult to explain.

A more thorough analysis has shown that an identical fit to the data can be obtained by introducing the variables in an alternative form which produces models that can be much more readily understood. In this form, Q_b is represented by PTSL, the pedestrian density across the link section (thousands of pedestrians per kilometre per 12 hour period) which is simply PT/SL. The linear form of the model is then:

$$\log(A.YR) = \log(YR) + \log(k) + \alpha \log(QT) + \beta \log(PTSL) + \gamma \log(SL) \qquad (9.6)$$

It turns out that for this model γ is close to and not different statistically from 1 when tested at the 5 per cent level of significance for all the total accident-flow models. The model can therefore be simplified to:

$$\log(A.YR) = \log(YR) + \log(SL) + \log(k) + \alpha \log(QT) + \beta \log(PTSL) \qquad (9.7)$$

where the term log(SL) is assigned as an 'offset variable' with its coefficient constrained to the value 1 in the fitting process.

This is a simple and comprehensible result. It shows that the accident frequency A is a function of vehicle flow and pedestrian density and is directly proportional to the length of the link section.

Model (9.7) has the property that it predicts zero accidents for zero pedestrian flow. This is appropriate for pedestrian accidents and off-crossing accidents. For the latter the variable PTOFFSL, the off-crossing pedestrian density across the link section (thousands of pedestrians per kilometre per 12 hour period) which is simply PTOFF divided by SL where PTOFF is the off-crossing pedestrian flow, is more logical than PTSL. The linear form of the model is

$$\log(A.YR) = \log(YR) + \log(SL) + \log(k) + \alpha \log(QT) + \beta \log(PTOFFSL) \quad (9.8)$$

Vehicle only accidents do not involve pedestrians in the primary collision, and pedestrian flows or densities appear in the models for two main reasons. Firstly, pedestrian activity is likely to increase the complexity of the driving task and hence increase accident risk. Secondly, pedestrian flow or density variables may simply be acting as proxies for causal variables with which they are associated and which have not been tested at this level of the modelling. In either case vehicle only accidents are not likely to be eliminated if the pedestrian flow is zero. Total section accidents which include both vehicle only accidents and pedestrian accidents have a similar property. For these accident categories, an alternative form of model was introduced and tested which has the linear form:

$$\log(A.YR) = \log(YR) + \log(SL) + \log(k) + \alpha \log(QT) + b\, PTSL^{\beta} \quad (9.9)$$

The parameter b is determined by the regression but ß must be obtained by trial and error until a good fit to the data is obtained.

The model for on-crossing pedestrian accidents does not require a length variable and so log(SL) is not assigned as an offset variable in this model. In the model, Q_a is represented by QT, the total vehicle flow along the link section summed over both directions on two-way roads (thousands of vehicles per 24 hours) and Q_b is represented by PTON, the pedestrian flow across the pedestrian crossing summed over both directions (thousands of pedestrians per 12 hour period). The linear form of the model is:

$$\log(A.YR) = \log(YR) + \log(k) + \alpha \log(QT) + \beta \log(PTON) \quad (9.10)$$

9.2.2 Features

In order to test the effect on accidents of the main features of the link sections, it is necessary for each feature to group the data into two mutually exclusive subsets (that is, link sections 'without' and 'with' the feature). This grouping is done by defining a factor for each feature which has a level value of 1 for link sections 'without' the feature and 2 for those 'with'.

The addition of a factor to the linear model provides 'parallel' regressions for each level of the factor, that is separate values of the constant log (k), whilst sharing common values of the other parameters. Interactions between factors can also be included in the same way to provide different constants for combinations of levels of the factors.

The effect of including a 2-level factor is to add one 'dummy' variable (taking only the values 0 or 1) to the model:

$$\log(A.YR) = \log(YR) + \log(k) + \text{other terms} + dD \quad (9.11)$$

where D is the dummy variable relating to the second level of the factor and d is the coefficient estimated by the regression giving the difference from log (k) of the constant for the second level of the factor.

Interactions between a variable and a factor may also be added to permit 'non-parallelism', that is, in this instance, to provide separate flow exponents as well as separate constants for each sub-group of the data defined by the factor. The linear model then becomes, for example:

$$\log(A.YR) = \log(YR) + \log(k) + \text{other terms} + \alpha \log(Q_a) + dD + \delta \log(Q_a)D \quad (9.12)$$

where δ is estimated by the regression and measures the difference from α for the second level of the factor.

9.3 VARIABLES AND FACTORS TESTED

The variables and factors tested in the total accident flow models are given in Tables 24 and 25. The variables include: the accident period in years YR, the link section length SL, the total vehicle flow along the link section QT, the total pedestrian flow across the link section PT, the pedestrian flow across a pedestrian crossing PTON, the off crossing pedestrian flow PTOFF, the pedestrian density across the link section PTSL, and the off-crossing pedestrian density PTOFFSL. The factors include: within London LONDON, zebra crossing ZEB, pelican crossing PEL, effect of pelican compared with base of sections with zebra crossings PEL(Z), 40 mph speed limit SP40, one-way section ONEWAY.

9.4 MODELLING PROCEDURE

The first stage in the modelling procedure was to identify well fitting logical models including only the key vehicle flows, pedestrian flows or densities and section length. None of the factors representing link section categories or

TABLE 24

Explanatory variables for total link section accident-flow models

Variable name	Description
k	Constant term
YR	Years (offset variable)
SL	Link section length (km) (offset variable)
QT	Total vehicle flow along link section, sum of both directions (thousands of vehicles per day)
PT	Total pedestrian flow across link section, sum of both directions (thousands of pedestrians per 12 hr period)
PTON	Pedestrian flow across pedestrian crossing, sum of both directions (thousands of pedestrians per 12 hr period)
PTOFF	Pedestrian flow off pedestrian crossing, sum of both directions (thousands of pedestrians per 12 hr period)
PTSL	Pedestrian density across link section PT/SL (thousands of pedestrians per km per 12 hr period)
PTOFFSL	Pedestrian density off pedestrian crossing, sum of both directions (thousands of pedestrians per km per 12 hr period)

TABLE 25

Factors for total link section accident-flow models

Factor name[1]	Description	Level
LONDON	Sites within the DTp London Region	1 = outside London 2 = within London
ZEB	Zebra crossing	1 = Zebra absent 2 = Zebra present
PEL	Pelican crossing	1 = Pelican absent 2 = Pelican present
PEL(Z)	Effect of pelican compared with base of zebra sites	1 = Zebra present 2 = Pelican present
SP40	30 mph or 40 mph speed limit	1 = 30 mph limit 2 = 40 mph limit
ONEWAY	One-way or two-way traffic	1 = Two-way traffic 2 = One-way traffic

Note 1: The name of the factor relates to the level 2 effect

physical features were tested at this stage. The basic unit of analysis was the link section (both sides combined). The total number of analysis units was 970. The model with the best flow-function was then extended to include some basic junction classification factors.

Table 26 provides an overall summary of the variables and factors that appeared in the models. The level of significance at which variable and factor appears in the models is also indicated. The model formulae are contained in Table 27.

The factors and their interactions with each other and with flows were accepted into the models on the basis of testing at the 5 per cent level of significance and simple logic; for example, interaction terms were excluded if they allowed accident frequency to decrease with increasing vehicle flow, pedestrian flow or pedestrian density.

TABLE 26

Variables and factors in the best accident-flow models

Explanatory variables and factors	Accident groups: Total accidents	Vehicle only accidents	Pedestrian accidents	Off-crossing pedestrian accidents	On-crossing pedestrian accidents
Vehicle flow:					
LQT	++	++	++	++	++
Pedestrian density:					
$PTSL^{\beta}$	++	++			
LPTSL			++		
LPTOFFSL				++	
LPTON					++
Factors:					
ONEWAY	2-		2-	2-	
SP40	1-		2-	2-	
LONDON	++	++			
ZEB	+		++		
PEL	++		++	++	
Interactions:					
$PTSL^{\beta}$.LONDON	2-	2-			
ONEWAY.PEL			++	+	

L prefix indicates log form of variable e.g. LQT = log (QT)
++/+ Statistically significant at 1%/5% level (increasing effect on accidents)
2-/1- Statistically significant at 1%/5% level (decreasing effect on accidents)

It is important to recognise that there are a large number of variables and factors that might have a causal effect on accident risk. Many of these will not be in the list of factors tested at this level of modelling. If there was no association between any of the variables and factors, then given sufficient data, the important causal variables and factors that were tested would be expected to be statistically significant and the remainder non-significant. The models presented in this section would simply lack the causal variables and factors that had not been tested. Unfortunately, variables and factors almost always occur in association and it is possible for an non-causal variable or factor to be statistically significant and appear in a model, though for the main flow variables the sample of sites was stratified to reduce these associations.

If all possible variables and factors are tested, as in the case of the full models presented in Section 11, it is likely that the causal variables and factors will have the more consistent and hence the more statistically significant effects, and the non-causal variables with which they are associated are likely to be excluded from the models. But if not all variables and factors are tested, as is the case of the models presented in this section, then non-causal variables and factors can be expected to appear.

9.5 TOTAL SECTION ACCIDENTS

The best model without factors was:

$$A = 0.0778\ SL\ QT^{0.790} \exp(1.631\ PTSL^{0.15}) \quad (9.13)$$

where A is the accident frequency *on the link section (both sides combined)*, QT is the total vehicle flow, PTSL is the two-way total pedestrian flow density and SL is the section length.

The best model with factors was:

$$A = 0.0829\ SL\ QT^{0.737} \exp(1.606\ PTSL^{0.15}) \quad (9.14)$$

The effect of the factors on accidents was as follows: one-way (decrease by a factor of 0.73); 40 mph (decrease by a factor of 0.74); London (increase by a factor of 4.20 and the

TABLE 27

Total accident - flow models[1]

Model	Model terms[2]	Parameter values	Exp[3]	s.e.[4]	Deviance	Degrees of freedom	Scale factor
Total accidents (1590)							
Null	Lk	1.290	3.633	0.049	2750	969	3.89
Without factors	Lk	-2.553	0.079	0.189	1707	966[5]	1.97
	LQT	0.790		0.057			
	$PTSL^{0.15}$	1.631		0.093			
With factors	Lk	-2.490	0.083	0.236	1567	960[5]	1.80
	LQT	0.737		0.058			
	$PTSL^{0.15}$	1.606		0.147			
	ONEWAY	-0.309	0.734	0.122			
	SP40	-0.297	0.743	0.130			
	LONDON	1.435	4.200	0.306			
	ZEB	0.419	1.520	0.176			
	PEL	0.375	1.455	0.117			
	$PTSL^{0.15}$.LONDON	-0.785		0.228			
Vehicle only accidents (897)							
Null	Lk	0.717	2.048	0.048	1626	969	2.14
Without factors	Lk	-2.029	0.131	0.202	1242	966[5]	1.58
	LQT	0.820		0.067			
	$PTSL^{0.20}$	0.653		0.080			
With factors	Lk	-2.273	0.103	0.205	1139	964[5]	1.41
	LQT	0.782		0.063			
	$PTSL^{0.20}$	0.748		0.093			
	LONDON	1.394	4.031	0.245			
	$PTSL^{0.20}$.LONDON	-0.540		0.173			
Pedestrian accidents (693)							
Null	Lk	0.460	1.583	0.071	1979	969	3.54
Without factors	Lk	-1.959	0.141	0.215	1183	967	1.58
	LQT	0.745		0.080			
	LPTSL	0.510		0.028			
With factors	Lk	-1.717	0.180	0.212	1121	962	1.49
	LQT	0.719		0.082			
	LPTSL	0.435		0.035			
	ONEWAY	-0.870	0.419	0.228			
	SP40	-0.690	0.502	0.209			
	ZEB	0.594	1.811	0.216			
	PEL	0.346	1.413	0.150			
	ONEWAY.PEL	0.942		0.310			

TABLE 27: CONTINUED

Model	Model terms[2]	Parameter values	Exp[3]	s.e.[4]	Deviance	Degrees of freedom	Scale factor
Off-crossing pedestrian accidents (608)							
Null	Lk	0.329	1.389	0.067	1693	969	2.79
Without factors	Lk	-1.854	0.157	0.221	1161	967	1.56
	LQT	0.726		0.084			
	LPTOFFSL	0.468		0.031			
With factors	Lk	-1.666	0.189	0.216	1110	963	1.47
	LQT	0.708		0.084			
	LPTOFFSL	0.419		0.036			
	ONEWAY	-0.722	0.486	0.227			
	SP40	-0.721	0.486	0.212			
	PEL	0.422	1.525	0.173			
	ONEWAY.PEL	0.750		0.353			
On-crossing pedestrian accidents (85)							
Null	Lk	-1.118	0.327	0.181	136	51	2.81
Without factors	Lk	-3.702	0.025	1.05	101	49	2.05
	LQT	0.855		0.361			
	LPTON	0.403		0.127			

1. log (YR) is included as an offset variable in all null, with and without factor models. log (SL) is included as an offset variable in all null, with and without factor models except those for 'on-crossing pedestrian accidents'
2. L prefix indicates log form of variable e.g. LQT = log (QT)
3. Exp column gives exponential values of constants and factors
4. Standard error of estimate. The values of the standard errors quoted *have been scaled by the square root of the scale factor.*
5. The number of degrees of freedom has been reduced by 1 because the exponent of PTSLhas been empirically determined using the value that gave the lowest scaled deviance

( ) Figures in brackets are the number of accidents

coefficient of $PTSL^{0.15}$ reduced to 0.821); zebra (increase by a factor of 1.5); pelican (increase by a factor of 1.5). The mean effect of the London factor over the range of PTSL was to increase accidents by a factor of 1.5.

9.6 VEHICLE-ONLY ACCIDENTS

The best model without factors was:

$$A = 0.131\ SL\ QT^{0.820} \exp(0.653\ PTSL^{0.20}) \quad (9.15)$$

The best model with factors was:

$$A = 0.103\ SL\ QT^{0.782} \exp(0.748\ PTSL^{0.20}) \quad (9.16)$$

The only factor that had an effect was London (increase by a factor of 4.0 and the coefficient of $PTSL^{0.20}$ reduced to 0.21). The mean effect of the London factor over the range of PTSL was to increase accidents by a factor of 2.0.

9.7 PEDESTRIAN ACCIDENTS

The best model without factors was:

$$A = 0.141\ SL\ QT^{0.745}\ PTSL^{0.510} \quad (9.17)$$

The best model with factors was:

$$A = 0.180\ SL\ QT^{0.719}\ PTSL^{0.435} \quad (9.18)$$

The effect of the various factors on accidents was as follows: one-way (decrease by a factor of 0.42); 40 mph (decrease by a factor of 0.50); zebra (increase by a factor of

1.8); pelican (increase by a factor of 1.4 on two-way sections and by a factor of 3.6 on one-way sections).

Both zebra and pedestrian crossings have an effect on pedestrian accidents and hence on total accidents. The models presented so far handle the effect of a crossing by introducing a constant multiplying factor. This seems likely to be a fairly coarse approximation to reality since the strength of the multiplier would be expected to be greater on short link sections than on long ones. The extent to which these refinements can be detected depends on the quality and amount of data available for testing. The approach used for pedestrian accidents was to separate these into 'on-crossing' and 'off-crossing' accidents and to develop a model for each. The approach was not extended to the accident-flow models by accident group or to the full accident-flow-geometric models by accident group since there were in general too few accidents in each group to make such refinement worthwhile.

9.8 OFF-CROSSING PEDESTRIAN ACCIDENTS

The best model without factors was:

$$A = 0.157\ SL\ QT^{0.726}\ PTOFFSL^{0.468} \qquad (9.19)$$

where PTOFFSL is the off-crossing pedestrian density across the link section.

The best model with factors was:

$$A = 0.189\ SL\ QT^{0.708}\ PTOFFSL^{0.419} \qquad (9.20)$$

The effect of the factors on accidents was as follows: one-way (decrease by a factor of 0.49); 40 mph (decrease by a factor of 0.49); pelican (increase by a factor of 1.5 on two-way sections and by a factor of 3.2 on one-way sections).

9.9 ON-CROSSING PEDESTRIAN ACCIDENTS

The best model is given in linear form in Table 27 and was:

$$A = 0.0247\ QT^{0.855}\ PTON^{0.403} \qquad (9.21)$$

where PTON is the two-way pedestrian flow on the crossing.

None of the factors had a statistically significant effect at the 5 per cent level.

10. ACCIDENT-FLOW MODELS BY ACCIDENT GROUP AND SIDE OF LINK SECTION

10.1 INTRODUCTION

In the second stage of the modelling of accidents at the link sections, the accident frequency for each accident group was related to various functions of the vehicle and pedestrian flows, section length and main features.

The basic unit of analysis is the link side with one flow direction. The vehicle and pedestrian flows for the link side analysis are illustrated in Figure 2. QA is the vehicle flow on the link side and QB the flow in the opposite direction. PC is the pedestrian flow from the nearside and PD the flow from the offside. Each two-way link section gives two analysis units, while each one-way link section gives only one unit. Thus the total number of analysis units was 1851, 89 of which were on one-way roads.

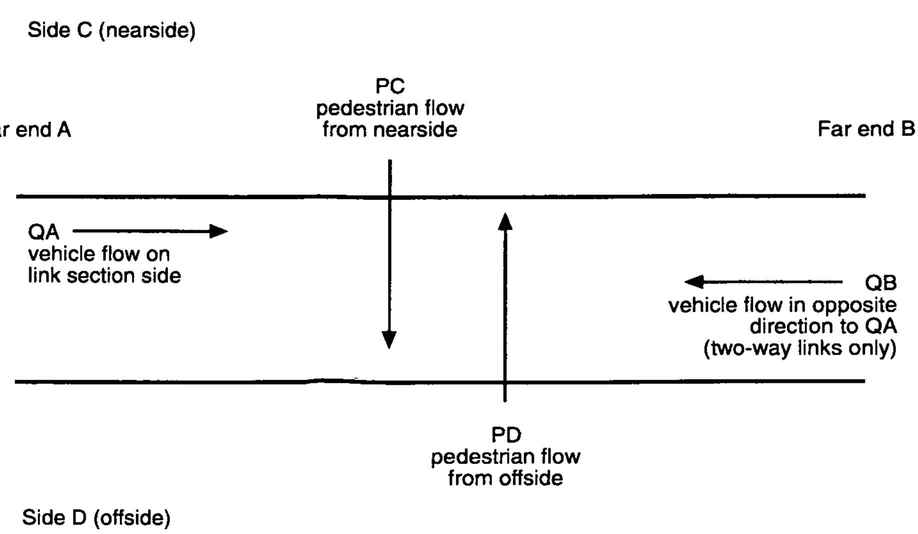


Fig. 2 Vehicle and pedestrian flows at a link section side

The variables used in testing the accident-flow models by group are given in Table 28. The factors, given in Table 25, are the same as those used in testing the total accident models.

The process of grouping the accidents has been described in Sections 5.8 and 7.3. and the numbers and percentage of accidents in each group is given in Table 9.

10.2 THE FORM OF THE MODELS

For the vehicle only accident groups, pedestrian flows as well as vehicle flows appeared in the best fitting models. They were therefore included in the form $bPTSL^{\beta}$ as in model (9.9) for the reasons explained in Section 9.2.1. The vehicle flow in the link side QA, was highly correlated with the vehicle flow from the opposite direction QB, on two-way sections and both were clearly correlated with QT, the total vehicle flow. There was little to choose between these in terms of model fitting for any of the accident groups, and since QA was the most logical form for all except the head-on and U-turn group, QA was used to represent vehicle flow throughout. Similarly, the pedestrian density from the nearside PCSL was highly correlated with pedestrian density from the offside PDSL and both were correlated with PTSL, the pedestrian density across the link section. Hence, PTSL was used for all vehicle only accident groups. The basic form of the accident model in the linear form was:

$$\log(A.YR) = \log(YR) + \log(SL) + \log(k) + \alpha\log(QA) + bPTSL^{\beta} \qquad (10.1)$$

For the pedestrian accident groups, QA was again selected to represent the vehicle flows. PCSL was the most logical pedestrian density to use in the model for the pedestrian from nearside accident group and PDSL was similarly logical for the pedestrian from offside accident group. However, models using PTSL fitted equally well, and for the sake of consistency this variable was chosen in the most suitable model for all the pedestrian accident groups. The basic form of the model was the same as model (9.7) and in the linear form was:

$$\log(A.YR) = \log(YR) + \log(SL) + \log(k) + \alpha\log(QA) + \beta\log(PTSL) \qquad (10.2)$$

10.3 MODELLING PROCEDURE

The modelling procedures were similar to those for the total accident-flow models. The most suitable flow models without factors were developed first, and then models with factors including interactions between factors and between factors and variables were tested. For the same reasons as those set down in Section 9.4, the models presented in this

TABLE 28

Explanatory variables

Variable name	Description
k	Constant term
YR	Years (offset variable)
SL	Link section length (km) (offset variable)
QA	Vehicle flow on link side (thousands of vehicles per day)
QB	Vehicle flow from opposite direction (thousands of vehicles per day)
QT	Total vehicle flow QA+QB
PC	Pedestrian flow from nearside across link (thousands of pedestrians per 12hr period)
PD	Pedestrian flow from offside across link (thousands of pedestrians per 12hr period)
PT	Total pedestrian flow PC+PD
PCSL	Pedestrian density from nearside PC/SL (thousands of pedestrians per km per 12hrs)
PDSL	Pedestrian density from offside PD/SL (thousands of pedestrians per km per 12hrs)
PTSL	Pedestrian density across link PT/SL (thousands of pedestrians per km per 12hrs)

section are likely to include associative as well as causal factors.

Table 29 provides an overall summary of the variables and factors that appeared in the models. The level of significance at which variable and factor appears in the models is also indicated. The model formulae are contained in Table 30.

10.4 SINGLE VEHICLE ACCIDENTS

The best model without factors was:

$$A = 0.0824\ SL\ QA^{0.573} \exp(0.093\ PTSL^{0.6}) \quad (10.3)$$

where A is the accident frequency *on the link section side,* QA is the vehicle flow on the link side, PTSL is the two-way pedestrian flow density and SL is the section length.

The best model with factors was:

$$A = 0.0759\ SL\ QA^{0.542} \exp(0.053\ PTSL^{0.6}) \quad (10.4)$$

The effect of factors on accidents was as follows: one-way (decrease by a factor of 0.62 but the coefficient of $PTSL^{0.6}$ increased to 0.134); London (increase by a factor of 2.1). The mean effect of the one-way factor over the range of $PTSL^{0.6}$ was to increase accidents by a factor of 1.30.

10.5 REAR SHUNT AND LANE CHANGING ACCIDENTS

The best model without factors was:

$$A = 0.00647\ SL\ QA^{1.455} \exp(0.893\ PTSL^{0.2}) \quad (10.5)$$

TABLE 29

Variables and factors in the best accident-flow models by accident group

Explanatory variables and factors	Accident groups: Single veh.	Rear end shunt	Head-On	Park ing	Private drive	Other veh.	Near-side ped.	Off-side ped.	Other ped.
Vehicle flow:									
LQA	++	++	++	+	++	++	++	++	++
Pedestrian density:									
$PTSL^{\beta}$	++	++			++				
LPTSL							++	++	++
Features & geometry:									
ONEWAY	1-(#)			++	1-		1-(#)	2-	+
SP40						2-	2-		
LONDON	++	++	++	++	+				
ZEB		++					+	+	
PEL							++	1-	1-(#)
Interactions:									
$PTSL^{\beta}$.ONEWAY	++								
$PTSL^{\beta}$.LONDON		2-							
LQA.SP40							+		
PEL.ONEWAY							++		++
LPTSL.PEL								++	

L prefix indicates log form of variable e.g. LQA = log (QA)
++/+ Statistically significant at 1%/5% level (increasing effect on accidents)
2-/1- Statistically significant at 1%/5% level (decreasing effect on accidents)
Variable not statistically significant at 5% level but included with interaction term

TABLE 30

Accident-flow models[1] by accident group and side of link section

Model	Model terms[2]	Parameter values	Exp[3]	s.e.[4]	Deviance	Degrees of freedom	Scale factor
Single vehicle accidents (235)							
Null	Lk	-1.276	0.279	0.083	1041	1850	1.63
Without factors	Lk	-2.496	0.082	0.213	941	1847[5]	1.31
	LQA	0.573		0.111			
	$PTSL^{0.6}$	0.093		0.013			
With factors	Lk	-2.578	0.076	0.221	909	1844[5]	1.31
	LQA	0.542		0.113			
	$PTSL^{0.6}$	0.053		0.023			
	ONEWAY	-0.476	0.621	0.454			
	LONDON	0.743	2.102	0.157			
	$PTSL^{0.6}$.ONEWAY	0.081		0.033			
Rear shunt and lane changing accidents (253)							
Null	Lk	-1.202	0.301	0.080	1134	1850	1.60
Without factors	Lk	-5.041	0.006	0.273	833	1847[5]	1.00
	LQA	1.455		0.106			
	$PTSL^{0.2}$	0.893		0.111			
With factors	Lk	-5.313	0.005	0.289	799	1844[5]	1.00
	LQA	1.410		0.106			
	$PTSL^{0.2}$	1.019		0.132			
	LONDON	1.581	4.860	0.392			
	ZEB	1.100	3.004	0.255			
	$PTSL^{0.2}$.LONDON	-0.823		0.271			
Head-on and U-turn accidents (two-way traffic only, 125)							
Null	Lk	-1.865	0.155	0.097	655	1761	1.21
Without factors	Lk	-2.801	0.061	0.265	634	1760	1.22
	LQA	0.581		0.141			
With factors	Lk	-3.109	0.045	0.259	599	1759	1.10
	LQA	0.539		0.133			
	LONDON	1.081	2.948	0.185			
Parking and parked vehicle accidents (145)							
Null	Lk	-1.758	0.172	0.096	745	1850	1.35
Without factors	Lk	-3.798	0.022	0.523	721	1847[5]	1.27
	LQA	0.331		0.129			
	$PTSL^{0.1}$	1.402		0.447			
With factors	Lk	-2.535	0.079	0.238	699	1847	1.36
	LQA	0.265		0.128			
	ONEWAY	0.917	2.502	0.330			
	LONDON	0.921	2.512	0.195			

TABLE 30: CONTINUED

Model	Model terms[2]	Parameter values	Exp[3]	s.e.[4]	Deviance	Degrees of freedom	Scale factor
Private drive accidents (108)							
Null	Lk	-2.052	0.128	0.115	644	1850	1.51
Without factors	Lk	-5.360	0.005	0.628	577	1847[5]	1.22
	LQA	1.037		0.168			
	$PTSL^{0.1}$	1.361		0.490			
With factors	Lk	-5.747	0.003	0.707	561	1845[5]	1.29
	LQA	1.118		0.184			
	$PTSL^{0.1}$	1.457		0.550			
	ONEWAY	-1.343	0.261	0.679			
	LONDON	0.575	1.777	0.227			
Other vehicle accidents (31)							
Null	Lk	-3.299	0.037	0.210	262	1850	1.45
Without factors	Lk	-7.170	0.001	1.101	246	1847[5]	1.22
	LQA(not sig)	0.466		0.281			
	$PTSL^{0.1}$	2.795		0.907			
With factors	Lk	-4.118	0.016	0.509	238	1848	1.04
	LQA	0.672		0.265			
	SP40	-4.270	0.014	1.591			
Nearside pedestrian accidents (397)							
Null	Lk	-0.751	0.472	0.075	1685	1850	2.23
Without factors	Lk	-2.707	0.067	0.179	1169	1848	1.15
	LQA	0.743		0.087			
	LPTSL	0.530		0.032			
With factors	Lk	-2.450	0.086	0.190	1124	1842	1.13
	LQA	0.710		0.097			
	LPTSL	0.426		0.041			
	ONEWAY	-0.754	0.470	0.283			
	SP40	-2.598	0.074	0.965			
	ZEB	0.601	1.823	0.252			
	PEL	0.455	1.576	0.170			
	LQA.SP40	0.807		0.397			
	PEL.ONEWAY	1.006		0.364			

The best model with factors was:

$$A = 0.00493\ SL\ QA^{1.410} \exp(1.019\ PTSL^{0.2}) \quad (10.6)$$

The effect of factors on accidents was as follows: London (increase by a factor of 4.9 but the coefficient of $PTSL^{0.2}$ decreased to 0.196); zebra (increase by a factor of 3.0). The mean effect of the London factor over the range of $PTSL^{0.2}$ was to increase accident risk by a factor of 1.5.

10.6 HEAD-ON AND U-TURN ACCIDENTS

For these accidents, the data set was restricted to the 1762 two-way link sections.

TABLE 30: CONTINUED

Model	Model terms[2]	Parameter values	Exp[3]	s.e.[4]	Deviance	Degrees of freedom	Scale factor
Offside pedestrian accidents (207)							
Null	Lk	-1.403	0.246	0.092	1051	1850	1.78
Without factors	Lk	-2.843	0.058	0.226	834	1848	1.19
	LQA	0.495		0.116			
	LPTSL	0.509		0.046			
With factors	Lk	-2.790	0.061	0.236	809	1844	1.16
	LQA	0.510		0.125			
	LPTSL	0.429		0.054			
	ONEWAY	-0.947	0.388	0.327			
	ZEB	0.859	2.361	0.332			
	PEL	-0.655	0.519	0.550			
	LPTSL.PEL	0.356		0.140			
Other pedestrian accidents (89)							
Null	Lk	-2.244	0.106	0.126	575	1850	1.52
Without factors	Lk	-4.475	0.011	0.365	443	1848	1.00
	LQA	0.848		0.175			
	LPTSL	0.559		0.063			
With factors	Lk	-4.372	0.013	0.380	425	1845	1.00
	LQA	0.832		0.185			
	LPTSL	0.546		0.074			
	ONEWAY	0.250	1.284	0.353			
	PEL	-1.849	0.157	0.727			
	PEL.ONEWAY	2.223		0.839			

1. Offset variable is log(YR) + log(SL) for all models
2. L prefix indicates log form of variable e.g. LQA = log (QA)
3. Exp column gives exponential values of contents of factors
4. Standard error of estimate. The values of the standard errors quoted *have been scaled by the square root of the scale factor.*
5. The number of degrees of freedom has been reduced by 1 because the exponent of PTSL has been empirically determined using the value that gave the lowest scaled deviance

( ) Figures in brackets are the numbers of accidents in each group

The best model without factors was:

$$A = 0.0607 \text{ SL QA}^{0.581} \quad (10.7)$$

The best model with factors was:

$$A = 0.0446 \text{ SL QA}^{0.539} \quad (10.8)$$

The only factor that had an effect on accident risk was London where risk was increased by a factor of 2.9.

10.7 PARKED AND PARKING VEHICLE ACCIDENTS

The best model without factors was:

$$A = 0.0224 \text{ SL QA}^{0.331} \exp(1.402 \text{ PTSL}^{0.1}) \quad (10.9)$$

The best model with factors was:

$$A = 0.0793 \text{ SL QA}^{0.265} \quad (10.10)$$

The effect of factors on accidents was as follows: one-way (increase by a factor of 2.5); London (increase by a factor of 2.5). It should be noted that the inclusion of factors eliminated pedestrian density from the model.

10.8 PRIVATE DRIVE VEHICLE ACCIDENTS

The best model without factors was:

$$A = 0.00470\ SL\ QA^{1.037} \exp(1.361\ PTSL^{0.1}) \qquad (10.11)$$

The best model with factors was:

$$A = 0.00319\ SL\ QA^{1.118} \exp(1.457\ PTSL^{0.1}) \qquad (10.12)$$

The effect of factors on accidents was as follows: one-way (decrease by a factor of 0.26); London (increase by a factor of 1.8).

10.9 OTHER VEHICLE ACCIDENTS

The best model without factors was:

$$A = 0.000769\ SL\ QA^{0.466} \exp(2.795\ PTSL^{0.1}) \qquad (10.13)$$

QA was not significant at the 5 per cent level but there are logical reasons for including a vehicle flow.

The best model with factors was:

$$A = 0.0163\ SL\ QA^{0.672} \qquad (10.14)$$

The only factor that had an effect on accident risk was 40 mph speed limit (decrease in risk by a factor of 0.014). In this case speed limit is almost certainly acting as a proxy for other more directly related variables.

10.10 PEDESTRIANS FROM NEARSIDE ACCIDENTS

The best model without factors was:

$$A = 0.0667\ SL\ QA^{0.743}\ PTSL^{0.530} \qquad (10.15)$$

The best model with factors was:

$$A = 0.0863\ SL\ QA^{0.710}\ PTSL^{0.426} \qquad (10.16)$$

The effect of the factors on accidents was as follows: one-way (decrease by a factor of 0.47 on one-way sections without a pelican crossing); 40 mph speed limit (decrease by a factor of 0.074 but the exponent of QA increases to 1.517); zebra (increase by a factor of 1.8); pelican (increase by a factor 1.6 on two-way sections and 4.3 on one-way sections). The mean effect of the 40 mph speed limit over the range of QA was to decrease risk by a factor of 0.47.

10.11 PEDESTRIANS FROM OFFSIDE ACCIDENTS

The best model without factors was:

$$A = 0.0583\ SL\ QA^{0.495}\ PTSL^{0.509} \qquad (10.17)$$

The best model with factors was:

$$A = 0.0614\ SL\ QA^{0.510}\ PTSL^{0.429} \qquad (10.18)$$

The effect of factors on accidents was as follows: one-way (decrease by a factor of 0.39); zebra (increase by a factor of 2.4); pelican (decrease by a factor of 0.52 but the exponent of PTSL increases to 0.785). The mean effect of the pelican factor over the range of PTSL was to increase accident risk by a factor of 1.70.

10.12 OTHER PEDESTRIAN ACCIDENTS

The best model without factors was:

$$A = 0.0113\ SL\ QA^{0.848}\ PTSL^{0.559} \qquad (10.19)$$

The best model with factors was:

$$A = 0.0126\ SL\ QA^{0.832}\ PTSL^{0.546} \qquad (10.20)$$

The effect of factors on accidents was as follows: one way (increase by a factor of 1.3 without a pelican crossing); pelican (decrease by a factor of 0.16 on two-way sections and increase by a factor of 1.45 on one-way sections).

11. ACCIDENT-FLOW-GEOMETRY MODELS BY ACCIDENT GROUP AND SIDE OF LINK SECTION

11.1 INTRODUCTION

In the third stage of the modelling of accidents at link sections, the accident-flow models, developed in stage two, for each main type of accident were extended by the inclusion of geometric, flow proportion and other site variables.

As before the basic unit of analysis was the link side in one flow direction, giving a total of 1851 units, 89 of which were on one-way roads.

11.2 THE FORM OF THE MODELS

In order to be able to examine the effects of the various variables of flow proportions, geometric and other site characteristics, both of a discrete and continuous form, it is necessary to extend the basic models for vehicle only accident groups - model (10.1), and for pedestrian accident groups - model (10.2), presented in Section 10.2.

The simplest forms of these extended models are, for vehicle only accident groups:

$$A = k.SL.QA^{\alpha} \exp(bPTSL^{\beta}) \exp(\Sigma b_i G_i + \Sigma d_{ij} D_{ij}) \quad (11.1)$$

and for pedestrian accident groups:

$$A = k.SL.QA^{\alpha} PTSL^{\beta} \exp(\Sigma b_i G_i + \Sigma d_{ij} D_{ij}) \quad (11.2)$$

where A is the accident frequency (per year per link direction)

SL is the section length

QA is the vehicle flow on the link side

PTSL is the pedestrian density

G_i are the continuous variables of flow proportions, geometric and section variables

D_{ij} for j = 2,h are dummy variables (taking only the values 0 and 1) representing the 2nd and higher levels up to h of each discrete factor.

$k, \alpha, \beta, b, b_i, d_{ij}$ are parameters to be estimated.

The transformed linear forms of the models used in the fitting procedure are, for vehicle only accident groups:

$$\log(A.YR) = \log(YR) + \log(SL) + \log(k) + \alpha\log(QA) + bPTSL^{\beta} + \Sigma b_i G_i + \Sigma d_{ij} D_{ij} \quad (11.3)$$

and for the pedestrian accident groups:

$$\log(A.YR) = \log(YR) + \log(SL) + \log(k) + \alpha\log(QA) + \beta\log(PTSL) + \Sigma b_i G_i + \Sigma d_{ij} D_{ij} \quad (11.4)$$

where, as before log (YR) and log (SL) are offset variables.

11.3 FLOW FUNCTIONS AND OTHER VARIABLES AND FACTORS

The accident-flow models presented in Section 11 were used in their form without features to form the basis of the full analysis presented in this section.

A wide range of geometric and other features were measured at each link section and from these and the traffic and pedestrian flow, a large number of explanatory variables were derived. These were in the form of both continuous variables and discrete variables, known as factors, and were of the following types:

(i) Site features, such as speed limit, presence of pedestrian crossing, one/two way, adjacent junction type, land use, bus stops

(ii) Geometric variables, such as road widths, number of lanes, gradient, visibility

(iii) Road markings

(iv) Parking regulations and occupancy

(v) Traffic signing

(vi) Vehicle flow proportions by vehicle type

(vii) Pedestrian flow proportions by sex and age group

The average speed of vehicles and the driver/rider sex and age variables were available only for a reduced number of link sections and were therefore excluded from the analysis.

A full list of all the explanatory variables and factors used in the analysis is given in Appendix A. Some of the variables and factors are only relevant when the data is restricted to two-way link sections. These variables and factors were tested in the model for head-on accidents which had this restriction.

Some of the factors in the models have levels that are only represented by a few link sections and hence the estimates obtained for their effects on accidents are likely to be less reliable than those in which the number of link sections is more evenly spread across the levels.

This is particularly true for the factors ZEB and PEL. Most of the zebra and pelican crossings on the links were located near junctions. Table 3 shows that zebra crossings were present on: 11 of the 881 two-way link sections and 3 of the 89 one-way link sections. Pelican crossings were present on 30 of the 881 two-way link sections and 8 of the 89 one-way link sections.

Resolving the true effect of these two factors has been further complicated by the tendency for the crossings to be located close to the ends of the link sections and for link sections with crossings to have higher vehicle flows and higher pedestrian densities than link sections without crossings.

The number of link sections in this study with zebra and pelican crossings is sufficient to give a general indication of their relationship with accidents but insufficient to resolve the relative safety performance of zebra and pelican crossings or to reliably assess their performance on one-way links.

11.4 MODELLING PROCEDURE

For each accident group, the first step in the modelling procedure was to take the most suitable accident-flow without factor model and to test the effect of individually trying each of the flow proportion, section feature, geometric and land use variables at the 5 per cent level of statistical significance. This formed a pool of variables and factors that were worthy of further consideration. The pool is likely to contain all those that have a causal effect on accident risk, but also those that are merely associated with the causal ones, together with others which appear only by chance. The aim of the analysis is, of course, to identify the causal variables and factors from the remainder.

Regression analysis is a powerful tool for identifying the determining variables and factors, but if used alone it inevitably produces alternative models with different variables that fit the data equally well. For this reason, a range of criteria for the acceptance or rejection of the variables and factors was used:

(i) the level of statistical significance. This was the dominant criterion. No variables or factors were accepted at less than the 5 per cent level, whilst none were rejected at the 1 per cent level or better without very careful consideration;

(ii) the stability of the model. If variables or factors are associated with each other, then introducing one will tend to strongly affect the model parameters for the other. Since causal rather than associative variables are sought, such instability was carefully investigated and often resulted in the elimination of the offending variable.

(iii) the comprehensibility of the effect. It is desirable that the effect of a variable or factor is understandable in terms of simple logic, common sense and traffic engineering judgement.

(iv) the size of the effect. Variables that had a large effect on accident risk in relation to their range were preferred to those that had a small effect.

(v) ease of measurement. It was recognised that engineers would be less inclined to measure variables that were difficult to measure than those that were easy to measure and hence the former were preferred.

(vi) consistency. Efforts were made to include variables in a form that was consistent within this study and with other similar published studies.

The models were developed using a form of forward selection procedure on the pool of variables. Variables and two-level factors were sequentially added to the models if the deviance drop when they were added was greater than 3.8 times the scale factor (5 per cent significance for a scale factor of 1). The variable or factor giving the highest deviance drop was added first. At each stage the contributions of the existing terms in the model was checked and terms were dropped if the deviance increase when they were dropped was less than 3.8 times the scale factor. The process was repeated until no more terms could be added or dropped.

The pool of possible variables was then expanded by individually trying all of the original variables and factors against the model fitted by the forward selection procedure. Any variables or factors that were significant at the 5 per cent level were added to the pool. The forward selection procedure was repeated using the revised pool of variables.

At this stage, the variables and factors were reviewed according to the selection criteria set out above. Some were rejected and this allowed the testing of alternate variables and factors from the pool. This was continued until the model which best satisfied the criteria was identified. This was regarded as the most suitable model for the accident group.

As a final check to ensure that no important variables or factors had been overlooked, all the original variables and factors were tried against the preferred 'full' model. The effect on accident risk of the variables and factors in the full models is summarised in Table 31. The level of statistical significance at which each variable and factor appears in the models is also indicated. Appendix B gives details of the measurement of the variables and factors that appear in the full models. The models are given in Table 32.

11.5 SINGLE VEHICLE ACCIDENTS

A total of 34 variables and factors gave a scaled deviance drop of greater than 3.8 when tested individually against model (10.3) and were therefore included in the pool for further testing.

The flow and length function of the best full model was:

$$A = 0.0822\ SL\ QA^{0.363} \exp(0.045\ PTSL^{0.60}) \qquad (11.5)$$

TABLE 31

Variables and factors in the best accident-flow-geometry models

Explanatory variables and factors	Accident groups Single veh.	Rear end shunt	Head-On	Park ing	Private drive	Other veh.	Near-side ped.	Off-side ped.	Other ped.
Vehicle flow:									
LQA	++	++	++	+	++		++	++	++
PQAPSV	+		+						
PQATW					++				
L(QA.PQAPSV)						+			
Pedestrian density:									
$PTSL^{\beta}$	++	++				+			
LPTSL							++	++	++
Features & geometry:									
ONEWAY				+	1-				
LONDON	++	++	++	++			+		+
ADJUNB		+					+		
ADJUN					++				+
GRAD									+
VISBA							++	++	
NACCESSC					++				
NBUSTC	++								
PRESBMK			+						
PRESBBY			1-						
NREFUGE	+								
ZEB		++							
CROSS (Zebra or pelican)							++	+	
EXTCROSA							++		
POCALL	1-			+(#)					
PLAND1 Shopping/recreation/shops & flats							++		++
PLAND11 Sport/Open space					2-			2-	
PLAND13 Garage/car park/Railway station					++				

++/2- Statistically significant at 1% level (increasing/decreasing effect on accidents)
+/1- Statistically significant at 5% level (increasing/decreasing effect on accidents)
Deviance drop does not quite make value for 5% significance but variable included as it is a key variable and is statistically significant if LONDON is excluded from model.

TABLE 32

Accident-flow-geometry models by accident group and side of link section

Model	Model terms	Parameter value	s.e.[1]	Deviance difference[2]	Multiplicative effect at: Min.	Mean	Max.	Deviance	Degrees of freedom	Scale factor
Single vehicle accidents (235)										
Null	Lk	-1.276	0.083					1041	1850	1.63
Full	Lk	-2.499	0.215					868	1842[3]	1.11
	LQA	0.363	0.106	13.3						
	$PTSL^{0.6}$	0.045	0.017	7.3						
	NBUSTC	0.0289	0.0053	26.1	0.9	1	3.7			
	LONDON	0.806	0.150	29.9	1		2.2			
	POCALL	-1.135	0.446	8.0	1.2	1	0.4			
	PQAPSV	7.49	2.82	7.2	0.9	1	2.6			
	NREFUGE	0.027	0.012	5.1	1.0	1	3.8			
Rear shunt and lane changing accidents (253)										
Null	Lk	-1.202	0.080					1134	1850	1.60
Full	Lk	-5.052	0.275					804	1844[3]	1.0
	LQA	1.404	0.106	194.2						
	$PTSL^{0.2}$	0.783	0.117	39.8						
	LONDON	0.441	0.133	10.4	1		1.6			
	ZEB	0.924	0.246	11.4	1		2.6			
	ADJUNB	0.312	0.139	4.7	1		1.4			
Head-on and U-turn accidents(two-way traffic only, 125)										
Null	Lk	-1.865	0.097					655	1761	1.21
Full	Lk	-3.292	0.273					579	1756	1.07
	LQA	0.519	0.133	16.7						
	LONDON	0.995	0.189	27.3	1		2.7			
	PQAPSV	10.2	3.99	5.7	0.8	1	3.8			
	PRESBBY	-1.206	0.557	6.5	1		0.3			
	PRESBMK	0.558	0.229	5.7	1		1.7			
Parking and parked vehicle accidents (145)										
Null	Lk	-1.758	0.095					745	1850	1.35
Full	Lk	-2.720	0.267					695	1846	1.36
	LQA	0.326	0.135	8.2						
	LONDON	0.834	0.202	21.7	1		2.3			
	ONEWAY	0.831	0.334	6.9	1		2.3			
	POCALL	0.769	0.429	3.9	0.9	1	1.9			

where A is the accident frequency *on the link section side*, QA is the vehicle flow on the link side, PTSL is the two-way pedestrian flow density and SL is the section length.

Accidents increased with the following: number of bus stops on the nearside per kilometre with or without markings (NBUSTC); sections within London (LONDON); proportion of public service vehicles in flow QA (PQAPSV); number of pedestrian refuges per kilometre without zebra or pelican crossing (NREFUGE). Accidents were reduced with the proportion of both sides of the road occupied by parked vehicles (POCALL).

TABLE 32: CONTINUED

Model	Model terms	Parameter value	s.e.[1]	Deviance difference[2]	Multiplicative effect at: Min.	Mean	Max.	Deviance	Degrees of freedom	Scale factor
Private drive accidents (108)										
Null	Lk	-2.052	0.116					644	1850	1.51
Full	Lk	-5.237	0.483					491	1843	1.24
	LQA	1.311	0.186	71.5						
	PLAND13	2.439	0.505	20.5	0.9	1	10.8			
	PLAND11	-2.890	0.737	27.3	1.4	1	0.1			
	ADJUN	0.829	0.226	16.9	1		2.3			
	NACCESSC	0.0101	0.003	9.9	0.8	1	3.6			
	PQATW	9.03	2.99	9.2	0.7	1	6.7			
	ONEWAY	-1.388	0.659	8.1	1		0.3			
Other vehicle accidents (31)										
Null	Lk	-3.299	0.044					262	1850	1.45
Full	LK	-5.03	1.34					244	1847[3]	1.25
	L(QA.PQAPSV)	0.347	0.171	5.4						
	$PTSL^{0.1}$	2.316	0.969	6.6						
Nearside pedestrian accidents (397)										
Null	Lk	-0.751	0.705					1685	1850	2.23
Full	Lk	-3.187	0.248					1084	1842	1.12
	LQA	0.533	0.092	40						
	LPTSL	0.384	0.038	123						
	PLAND1	0.627	0.152	19	0.9	1	2.2			
	VISBA	0.0034	0.001	15	0.6	1	1.2			
	CROSS	0.649	0.145	22	1		1.9			
	EXTCROSA	0.678	0.210	10	1	2.0				
	LONDON	0.269	0.115	6	1		1.3			
	ADJUNB	0.277	0.116	6	1		1.3			
Offside pedestrian accidents (207)										
Null	Lk	-1.403	0.092					1051	1850	1.78
Full	LK	-3.239	0.339					800	1845	1.28
	LQA	0.443	0.129	15.6						
	LPTSL	0.414	0.052	90.5						
	PLAND11	-1.449	0.497	13.0	1.2	1	0.3			
	VISBA	0.0038	0.001	10.4	0.5	1	1.2			
	CROSS	0.493	0.208	6.8	1		1.6			

11.6 REAR SHUNT AND LANE CHANGING ACCIDENTS

A total of 24 variables and factors gave a scaled deviance drop of greater than 3.8 when tested individually against model (10.5) and were therefore included in the pool for further testing.

The flow and length function of the best full model was:

$$A = 0.00640 \ SL \ QA^{1.404} \exp(0.783 \ PTSL^{0.20}) \quad (11.6)$$

Accidents increased with the following: sections within London (LONDON); the presence of a zebra crossing

TABLE 32: CONTINUED

Model	Model terms	Parameter value	s.e.[1]	Deviance difference[2]	Multiplicative effect at: Min.	Mean	Max.	Deviance	Degrees of freedom	Scale factor
Other pedestrian accidents (89)										
Null	Lk	-2.244	0.131					575	1850	1.52
Full	Lk	-4.830	0.391					417	1844	1.0
	LQA	0.728	0.180	17.4						
	LPTSL	0.452	0.071	45.2						
	PLAND1	0.893	0.288	9.4	0.8	1	2.0			
	GRAD	0.115	0.044	6.8	0.3	1	3.2			
	ADJUN	0.517	0.216	5.7	1		1.7			
	LONDON	0.506	0.219	5.0	1		1.7			

1. Standard error of estimate.The values of the standard errors quoted *have been scaled by the square root of the scale factor.*
2. The difference in scaled deviance when the term is dropped from the model.The statistical significance of a term may be judged by comparing the deviance difference with the critical values of the chisquare distribution multiplied by the scale factor.
3. The number of degrees of freedom has been reduced by 1 because the exponent of PTSL has been empirically determined using the value that gave the lowest scale deviance

(ZEB); a major rather than an internal minor junction at the end towards which vehicles are travelling (ADJUNB).

11.7 HEAD-ON AND U-TURN ACCIDENTS

For these accidents, the data set was restricted to the 1762 two-way link sections.

A total of 19 variables and factors gave a scaled deviance drop of greater than 3.8 when tested individually against model (10.7) and were therefore included in the pool for further testing.

The flow and length function of the best full model was:

$$A = 0.0372\ SL\ QA^{0.519} \qquad (11.7)$$

Accidents increased with the following: sections within London (LONDON); proportion of public service vehicles in flow QA (PQAPSV); presence of bus markings on either side of the road (PRESBMK). Accidents were reduced with the presence of bus bays on either side of the road (PRESBBY).

11.8 PARKED AND PARKING VEHICLE ACCIDENTS

A total of 16 variables and factors gave a scaled deviance drop greater than 3.8 when tested individually against model (10.9) and were therefore included in the pool for further testing.

The flow and length function of the best full model was:

$$A = 0.0658\ SL\ QA^{0.326} \qquad (11.8)$$

Accidents increased with the following: sections within London (LONDON); one-way sections (ONEWAY); the proportion of both sides of the road occupied by parked vehicles (POCALL).

11.9 PRIVATE DRIVE VEHICLE ACCIDENTS

A total of 21 variables and factors gave a scaled deviance drop greater than 3.8 when tested individually against model (10.11) and were therefore included in the pool for further testing.

The flow and length function of the best full model was:

$$A = 0.00532\ SL\ QA^{1.311} \qquad (11.9)$$

Accidents increased with the following: presence of petrol station, car park or railway station (PLAND13); major junction rather than internal minor junction at either end of the link section (ADJUN); number of nearside accesses per kilometre (NACCESSC); proportion of two wheeled vehicles in flow QA (PQATW). Accidents decreased with the proportion of sport or open space frontage (PLAND11) and on one-way sections (ONEWAY).

11.10 OTHER VEHICLE ACCIDENTS

A total of 12 variables and factors gave a scaled deviance drop greater than 3.8 when tested individually against model (10.13) and were therefore included in the pool for further testing.

The flow and length function of the best flow model was:

$$A = 0.00654\ SL\ (QA.PQAPSV)^{0.347}\ \exp(2.316\ PTSL^{0.10}) \qquad (11.10)$$

where PQAPSV is the proportion of public service vehicles within the vehicle flow QA. No other variables or factors appeared in the model.

11.11 PEDESTRIAN FROM NEARSIDE ACCIDENTS

A total of 40 variables and factors gave a scaled deviance drop greater than 3.8 when tested individually against model (10.15) and were therefore included in the pool for further testing.

The flow and length functions of the best full model was:

$$A = 0.0413\ SL\ QA^{0.533}\ PTSL^{0.384} \qquad (11.11)$$

Accidents increased with the following: shopping, recreational or shop and flat frontage (PLAND1); visibility in the opposite direction of vehicle travel (VISBA); presence of a zebra or pelican crossing on the link section (CROSS); presence of a zebra or pelican crossing within 25 metres of the link section at the end from which vehicles in flow QA are travelling (EXTCROSA); section within London (LONDON); a major rather than an internal minor junction at the end to which vehicles in flow QA are travelling (ADJUNB).

11.12 PEDESTRIAN FROM OFFSIDE ACCIDENTS

A total of 39 variables and factors gave a scaled deviance drop greater than 3.8 when tested individually against model (10.17) and were therefore included in the pool for further testing.

The flow and length function of the best full model was:

$$A = 0.0392\ SL\ QA^{0.443}\ PTSL^{0.414} \qquad (11.12)$$

Accidents increased with the following: visibility in the opposite direction of vehicle travel (VISBA); presence of a zebra or pelican crossing on the section (CROSS). Accidents reduced with the proportion of sport or open space frontage (PLAND11).

11.13 OTHER PEDESTRIAN ACCIDENTS

A total of 14 variables and factors gave a scaled deviance drop greater than 3.8 when tested individually against model (10.19) and were therefore included in the pool for further testing.

The flow and length functions of the best full model was:

$$A = 0.00799\ SL\ QA^{0.728}\ PTSL^{0.452} \qquad (11.13)$$

Accidents increased with the following: shopping, recreational or shop and flat frontage (PLAND1); uphill gradient in the direction of vehicle travel (GRAD); major junction rather than internal minor junction at either end of the link section (ADJUN); section within London (LONDON).

11.14 EXPLANATORY VARIABLES AND THEIR EFFECTS

In assessing the usefulness of the significant variables in the model it is helpful to have an indication of their sensitivity over the range of the data. To do this the model is expressed in a multiplicative form in which each continuous variable is related to its mean value over all link sections. Thus, for example, if $\overline{G}_i$ is the mean value of variables G_i, the basic form of the extended model (equation 11.2) may be written as:

$$A = K.SL.QA^{\alpha}.PTSL^{\beta}.\Pi\exp(b_i(G_i - \overline{G}_i)).\Pi\exp(d_{ij}D_{ij}) \qquad (11.14)$$

where $K = k.\Pi\exp(b_{ii}\overline{G}_i)$

Now, when all the continuous variables are at their mean values (ie $G_i = \overline{G}_i$) and all the factors are at their first level (ie all $D_{ij}=O$) all the exponent terms become unity, so K is the accident frequency for the particular type of accident when the vehicle flow, pedestrian density and link section length terms are also unity (that is, QA is 1.0 thousand vehicles, PTSL is 1.0 thousand pedestrians per kilometre and SL is 1.0 kilometre. At values of the G_i different from the mean, each term $\exp(b_i(G_i - \overline{G}_i))$ is a multiplier which modifies the mean accident frequency. Setting G_i to its minimum and maximum values over the observed data gives the range of the multiplier and a good indication of the variable's sensitivity.

In a similar way for the factors, the value of $\exp(d_{ij})$ is a multiplier of the constant K and shows the average effect on the accident frequency for the 2nd and higher levels of the factor F_i compared with the 1st level.

Table 32 gives the multiplicative effect of each variable or factor in the full models.

11.15 VARIABLES AND FACTORS INCLUDED IN THE FULL MODELS

Accident risk was directly proportional to the length of the section (SL) for all accident groups.

The total vehicle flow along the side of the link section (QA) affected accidents for all groups except 'other vehicle' accidents.

The proportion of public service vehicles in the flow QA (PQAPSV) increased accident risk for single vehicle accidents and for head-on and U-turn accidents. The proportion of two-wheeled vehicles in the flow QA (PQATW) increased accident risk for private drive accidents.

For 'other vehicle' accidents the product of vehicle flow and the proportion of public service vehicles in the flow (QA.PQAPSV) was associated with increased accidents.

The two-way pedestrian flow density (PTSL) was associated with increased risk for all groups except head-on and U-turn, parking and parked vehicle, and private drive vehicle accidents.

One-way sections (ONEWAY) were associated with increased risk for parking and parked vehicles accidents but reduced risk for private drive accidents.

Link sections in London (LONDON) were associated with increased risk for single vehicle accidents, rear shunt, lane changing accidents, head-on and U-turn accidents, parking and parked vehicle accidents, nearside pedestrian accidents, and for other pedestrian accidents.

A major rather than an internal minor junction at the end of the section to which vehicles in the flow QA were travelling (ADJUNB) was associated with increased risk for rear shunt and lane changing accidents and for nearside pedestrian accidents. A major rather than an internal minor junction at either end of the link section (ADJUN) was associated with increased risk for private drive accidents and for other pedestrian accidents. An uphill gradient (GRAD) was associated with increased risk for other pedestrian accidents. An increase in the visibility in the opposite direction of vehicle travel in flow QA (VISBA) was associated with an increase in accident risk for nearside and offside pedestrian accidents.

The number of nearside accesses per kilometre (NACCESSC) was associated with increased risk for private drive accidents.

The number of bus stops on the nearside per kilometre (NBUSTC) was associated with increased risk for single vehicle accidents. The presence of bus markings on either side of the road (PRESBMK) was associated with increased risk for head-on and U-turn accidents, whilst the presence of bus bays (PRESBBY) on either side of the road reduced risk for the same accident group.

The number of refuges per kilometre, without a zebra or pelican crossing (NREFUGE) was associated with increased risk for single vehicle accidents. Zebra crossings (ZEB) were associated with increased risk for rear shunt accidents, whilst the presence of either a zebra or a pelican crossing on the section (CROSS) was associated with increased risk for offside pedestrian accidents and for nearside pedestrian accidents. The presence of an external zebra or pelican crossing within 25 metres of a section at the end from which vehicles in the flow QA are travelling (EXTCROSA) was associated with increased risk for nearside pedestrian accidents.

The proportion of both sides of the road occupied by parked vehicles (POCALL) was associated with an increase in parking and parked vehicle accidents, but a decrease in single vehicle accidents.

The proportion of shopping, recreational and shop and flat frontage (PLAND1) was associated with increased risk for nearside pedestrian accidents and for other pedestrian accidents. The proportion of sport or open space frontage (PLAND11) was associated with reduced risk for private drive accidents, and for offside pedestrian accidents. The proportion of frontage occupied by petrol stations, car parks or railway stations (PLAND13) was associated with increased risk for private drive accidents.

11.16 AGGREGATE EFFECTS ACROSS ALL ACCIDENT GROUPS

Full accident-flow-geometry models by side of link section were also developed for total accidents, total vehicle only accidents and total pedestrian accidents. The variables and factors that were tested were limited to a subset containing those that appeared in any of the accident group models. Only statistical considerations were taken into account and the testing was performed at the 5 per cent level of statistical significance. Table 33 provides an overall summary of the variables and factors that appeared in the full models for total, vehicle and pedestrian accidents. The level of statistical significance at which each variable and factor appears in the models is also indicated. The null models, models without factors and the full models are presented in Table 34.

The full models provide a useful indication of the aggregate effect of the more important variables and factors.

For total accidents, the flow and length function of the best full model was:

$$A = 0.105\ SL\ QA^{0.608} \exp(0.946\ PTSL^{0.15}) \qquad (11.15)$$

TABLE 33

Variables and factors in the aggregate accident-flow-geometry models

Explanatory variables and factors	Total accidents	Accident groups Vehicle only accidents	Pedestrian accidents
Vehicle flow:			
LQA	++	++	++
PQAPSV	++	+	
Pedestrian density:			
$PTSL^{\beta}$	++	++	
LPTSL			++
Features & geometry:			
LONDON	++	++	+
ADJUN	+		++
GRAD			+
VISBA	++		++
NBUSTC	+	++	
NREFUGE	+		
CROSS (Zebra or pelican)	++	+	++
EXTCROSA			+
PLAND1 Shopping/recreation/shops & flats	++		++
PLAND11 Sport/Open space	1-		2-

++/2- Statistically significant at 1% level (increasing/decreasing effect on accidents)
+/1- Statistically significant at 5% level (increasing/decreasing effect on accidents)

where A is the accident frequency *on the link section side,* QA is the vehicle flow on the link side, PTSL is the two-way pedestrian flow density and SL is the section length.

Accidents increased with the following: section within London (LONDON); shopping, recreational or shop and flat frontage (PLAND1); presence of a zebra or pelican crossing on the section (CROSS); proportion of public service vehicles in flow QA (PQAPSV); visibility in the opposite direction of vehicle travel (VISBA); major junction rather than internal minor junction at either end of the link section (ADJUN); number of pedestrian refuges per kilometre - without a zebra or pelican crossing (NREFUGE); number of bus stops on the nearside per kilometre - with or without markings (NBUSTC). Accidents decreased with the proportion of sport or open space frontage (PLAND11).

For the vehicle accidents, the flow and length function of the best full model was:

$$A = 0.139\ SL\ QA^{0.698} \exp(0.347\ PTSL^{0.2}) \quad (11.16)$$

Accidents increased with the following: section within London (LONDON); number of bus stops on the nearside per kilometre - with or without markings (NBUSTC); presence of a zebra or pelican crossing on the section (CROSS); proportion of public service vehicles in flow QA (PQAPSV).

For the pedestrian accidents, the flow and length function of the best full model was:

$$A = 0.0871\ SL\ QA^{0.543}\ PTSL^{0.389} \quad (11.17)$$

Accidents increased with the following: shopping, recreational or shop and flat frontage (PLAND1); visibility in the opposite direction of vehicle travel (VISBA); presence of a zebra or pelican crossing on the section (CROSS); presence of a zebra or pelican crossing within 25 metres of the section at the end from which vehicles in flow QA are travelling (EXTCROSA); major junction rather than internal minor junction at either end of the link section (ADJUN); uphill gradient in the direction of vehicle travel (GRAD); section within London (LONDON). Accidents decreased

TABLE 34

Accident-flow-geometry models for total accidents by side of link section

Model	Model terms	Parameter value	s.e.[1]	Deviance difference[2]	Multiplicative effect at: Min.	Mean	Max.	Deviance	Degrees of freedom	Scale factor
Total Accidents										
Null	Lk	0.636	0.043					3574	1850	2.94
Without factors	Lk	-2.655	0.137					2432	1847[3]	1.58
	LQA	0.747	0.049	395						
	$PTSL^{0.15}$	1.690	0.086	570						
Full	Lk	-2.251	0.185					2218	1838[3]	1.48
	LQA	0.608	0.052	217						
	$PTSL^{0.15}$	0.946	0.118	93						
	LONDON	0.521	0.068	83	1		1.7			
	PLAND1	0.488	0.095	38	0.9	1	1.5			
	CROSS	0.399	0.092	26	1		1.5			
	PQAPSV	3.19	1.265	9	0.9	1	1.5			
	VISBA	0.0015	0.0005	14	0.8	1	1.1			
	ADJUN	0.150	0.063	8	1		1.2			
	NREFUGE	0.0156	0.0062	8	1.0	1	2.1			
	PLAND11	-0.307	0.147	7	1.0	1	0.8			
	NBUSTC	0.0058	0.0028	6	1.0	1	1.3			
Vehicle accidents[4]										
Null	Lk	0.064	0.044					2269	1850	1.82
Without factors	Lk	-2.134	0.149					1840	1847[3]	1.43
	LQA	0.797	0.061	265						
	$PTSL^{0.2}$	0.680	0.078	102						
Full	Lk	-1.972	0.156					1719	1843[3]	1.33
	LQA	0.698	0.061	189						
	$PTSL^{0.2}$	0.347	0.096	17						
	LONDON	0.745	0.082	103	1		2.1			
	NBUSTC	0.0127	0.003	16	0.9	1	1.8			
	CROSS	0.289	0.126	7	1		1.3			
	PQAPSV	3.97	1.72	7	0.9	1	1.7			

with the proportion of sport or open space frontage (PLAND11).

12. APPLICATION OF THE MODELS

Accident predictive models have been developed and presented at three levels: total accident-flow models (Section 9); accident-flow models by accident group and side of link section (Section 10); and full accident-flow-geometry models by accident group and side of link section (Section 11). The applications for which these models are suitable depends on their different characteristics.

12.1 TOTAL ACCIDENT-FLOW MODELS

The total accident-flow models treat the whole link section as a unit and separate total section accidents in a simple way into vehicle only accidents, pedestrian accidents (on and off crossing), off-crossing pedestrian accidents, and on-crossing pedestrian accidents. The models are built from

TABLE 34: CONTINUED

Model	Model terms	Parameter value	s.e.[1]	Deviance difference[2]	Multiplicative effect at: Min.	Mean	Max.	Deviance	Degrees of freedom	Scale factor
Pedestrian accidents[5]										
Null	Lk	-0.194	0.062					2465	1850	2.85
Without factors	Lk	-2.018	0.138					1605	1848	1.31
	LQA	0.678	0.069	134						
	LPTSL	0.528	0.026	607						
Full	Lk	-2.441	0.196					1492	1840	1.29
	LQA	0.543	0.075	71						
	LPTSL	0.389	0.032	211						
	PLAND1	0.512	0.125	21	0.9	1	1.5			
	VISBA	0.0029	0.0011	21	0.6	1	1.2			
	CROSS	0.489	0.118	21	1		1.6			
	PLAND11	-0.593	0.245	8	1.1	1	0.6			
	EXTCROSA	0.464	0.187	7	1		1.6			
	ADJUN	0.238	0.087	9	1		1.3			
	GRAD	0.042	0.018	6	0.7	1	1.5			
	LONDON	0.193	0.095	5	1		1.2			

Table 34 notes:
1. Standard error of estimate. The values of the standard errors quoted *have been scaled by the square root of the scale factor.*
2. The difference in scaled deviance when the term is dropped from the model. The statistical significance of a term may be judged by comparing the deviance difference with the critical values of the chisquare distribution multiplied by the scale factor.
3. The number of degrees of freedom has been reduced by 1 because the exponent of PTSL has been empirically determined using the value that gave the lowest scale deviance
4. The term PLAND1 was excluded from the subset of terms for vehicle accidents because of correlation with pedestrian flow
5. The term NACCESS1 was excluded from the subset of terms for pedestrian accidents because of correlation with pedestrian flow.

aggregate vehicle flow, pedestrian flow and pedestrian density variables and from a limited number of factors representing the main characteristics of the link sections. This restricts their application in two ways.

Firstly, the flow functions that are used at this aggregated level of modelling may not properly represent the different interaction of vehicle and pedestrian flows between accident groups, and the effect on safety of particular classes of vehicle are ignored.

Secondly and for the reasons set out in some detail in Section 10.4, these models are likely to include associative as well as causal factors. Hence, they are not reliable indicators of the features that would be suitable for use in accident remedial treatment.

In general, these models can be expected to provide reasonably good predictions of accident numbers, and do not require a detailed knowledge or measurement of the characteristics of the link section. For urban traffic management assessment, they are likely to be of most use outside of the immediate area where remedial measures are applied, for example, on untreated diversion routes. They could be equally useful in the economic appraisal of road schemes where decisions need to be taken before the detailed design of individual link sections has been worked out.

12.2 ACCIDENT-FLOW MODELS BY ACCIDENT GROUP

The accident-flow models by accident group and side of link section were developed mainly as an intermediate stage in the formation of the full accident-flow-geometry models. Nevertheless they have potential application in their own right.

These models also have the limitation that they are likely to include associative as well as causal factors and therefore are not reliable indicators of the features that affect accident risk. However, they have the advantage that the effects of the more important factors and the different flow interactions associated with individual groups of accidents can be explicitly taken into account. The models require no additional information about the link section.

The applications of those models are likely to be similar to those for the total accident-flow models but the accident predictions seem likely to be somewhat better.

12.3 FULL ACCIDENT-FLOW-GEOMETRY MODELS

The development of the accident-flow-geometry models by accident group and side of link section was the key objective of this project. Almost all plausible, measurable, physical variables and factors that might affect accident risk have been tested as far as is practicable in the models. It is therefore likely that the resulting relationships are causative (but that is not to say that the mechanisms are fully understood). The models indicate the physical variables and factors that have an effect on accident risk and which might be considered in accident remedial treatment.

The models take full account of the interactions between vehicle and pedestrian flows for each group of accidents and of the effect of vehicle class. Their only disadvantage is the amount of detailed information required to use them. The main application is likely to be in urban road design and urban traffic management appraisal where they are the only form of model that can properly evaluate accidents or link sections which are subject to remedial treatment or other direct traffic engineering measures.

13. SUMMARY AND CONCLUSIONS

A substantive study of accidents on built-up single carriageway link sections has been completed. This study was based on a national stratified sample of 970 link sections with a total length of 87 kilometres including two-way roads with 30 mph and 40 mph speed limits and one-way roads with a 30 mph speed limit. There were 1590 personal injury accidents on the link sections during the five year period from 1983 to 1988 in which the accident data was collected. Full details of the vehicle and pedestrian flows and of all other variables and factors that might have an effect on accident risk were measured.

An extensive series of accident tabulations has been prepared, a summary of which are presented in this report. These give useful insights into the characteristics of the accidents. However, since they relate to a stratified sample of link sections, they do not necessarily reflect the distribution of characteristics of the overall accident population for link sections.

Accident predictive models have been developed ranging from whole link section total accident models to full geometric models for individual accident groups. These relate accident frequency to functions of traffic and pedestrian flows and to the features and layout of the road. The aim has been to identify causal relationships rather than merely associative ones and it is considered that this has been largely achieved.

The key findings of the study were as follows:

(i) The vehicle flow function used for predicting accidents was the AADT link section flow, either total or by direction as appropriate. The pedestrian flow function was the pedestrian density (total pedestrian flow crossing the link section per unit length) crossing the road. Accident frequency was found to be directly proportional to the length of the link section.

(ii) There were more accidents involving pedestrians crossing from the nearside than from the offside.

(iii) The models indicated that the presence of a pedestrian crossing facility was associated with more pedestrian accidents in total on the section by a factor of 1.6. Thus the models predict on average more accidents on link sections with a crossing than on those without, for given vehicle and pedestrian density. However, those link sections in the sample without crossings had substantially lower pedestrian densities than those with crossings, and the error structure of the models must reflect that. So caution should be exercised in interpretation. Because the relationship between accident frequency and pedestrian density is non-linear (with index less than one) it is the case that the mean number of accidents per pedestrian crossing the road on those sections *with* pedestrian crossings was similar to the mean number on those sections without. It is clear that further work would be needed to resolve the issue of the model predictions in respect of pedestrian crossings. The usual non-accident based criteria (TA 52/87 and LTN 1/95) should therefore continue to be used for assessing the need for a crossing.

(iv) Rear shunt and lane-changing accidents increased on link sections with a zebra crossing.

(v) This study was not intended or designed to investigate speed mechanisms and relationships in depth, and speed was not measured directly. Estimates of mean vehicle speed by direction were obtained by measuring the journey times along the whole link for a small sample of vehicles in each of four periods of the day. These measurements were not available for all link sections, however, and they were not tested in the final models. Some of the physical variables in the models were correlated with speed, for example, increased visibility in the opposite direction of travel resulted in increased total, vehicle-only and pedestrian accidents. It is likely that this and some of the other variables found to affect accidents do so by modifying speeds.

(vi) A number of engineering measures were not tested in the study. These include bus lanes, cycle lanes and recent traffic calming measures such as speed humps, speed cameras and chicanes, which were rare at the time of the study. It is probable that traffic calming measures could reduce accidents by reducing speeds on link sections.

(vii) There was no difference in the predictions for a one-way link section and for one direction of a two-way link section from the full models for total, vehicle-only and pedestrian accidents. There were more parking and parked vehicle accidents but fewer private drive accidents on one-way link sections.

(viii) Other key results were: more vehicle-only and single vehicle accidents with a higher proportion of PSVs and more bus-stops; more single vehicle accidents with more refuges per kilometre; more parking and parked vehicle accidents with a higher proportion of road occupied by parked vehicles; more pedestrian accidents with shopping land-use; fewer pedestrian accidents with sport/open space land-use; increased total, vehicle-only and several accident groups on link sections in Greater London; more total and pedestrian accidents if the section is close to a major junction; more pedestrian accidents with an uphill gradient in the direction of travel; more private drive accidents with a higher proportion of two-wheeled vehicles and with more near-side accesses per kilometre.

The models are intended to be used in a wide range of applications: to identify potential design improvements, to provide accident estimates for the economic appraisal of road improvements; and in conjunction with traffic assignment models, to predict the effect on accidents of traffic management schemes, to identify casualty reducing schemes, and to optimise safety/mobility for all road users.

Alternative traffic and safety management schemes may be under consideration which involve re-distribution of traffic and the re-design of junctions and junction control to accommodate changed traffic and pedestrian flows safely. Traffic assignment models can be used to predict the changing flow patterns in a network while relationships such as those developed in the present study can be used to predict the impact on safety. In this way, alternative schemes can be compared both in terms of their traffic and safety performance.

At this stage, the research programme to develop accident models for all junction (and link) types is incomplete and therefore the results are not intended to replace the standard models used in COBA and URECA. Once models are available for the full set of junction types, the complex process of standardising on particular functions of vehicle flow will need to be undertaken in order to incorporate the results into the Department's cost-benefit appraisal programs.

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TRL were responsible for the overall planning of the study and the final statistical analysis. In addition, TRL managed the extra-mural contract and provided extensive technical input at all stages.

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APPENDIX A: VARIABLES USED IN LINK SECTION SIDE ANALYSIS

This appendix lists those explanatory variables which are used in the course of the analysis. For each accident type, however, the variables tried were only those which were considered in any way relevant to the particular accident type.

The minimum, mean and maximum values of each continuous variable over the full sample of 1851 units, (ie link section sides with one flow direction) are given; however, where a feature is present in a sub-sample only, the values relate only to that sub-sample.

For the discrete variables or factors, the number of sites with each level of the factor is given.

Vehicle flow

		Min	Mean	Max
QA	AADT Vehicle flow in direction AB (thou)	0.18	5.82	37.94
LQA	Log_e vehicle flow in direction AB	-1.69	1.49	3.64
Proportion of vehicle flow				
PQACAR	Proportion of cars in flow QA	0.40	0.81	0.94
PQATAXI	Proportion of taxis in flow QA	0.0	0.02	0.20
PQALGV	Proportion of light goods vehicles in QA	0.02	0.07	0.15
PQAHGV	Proportion of heavy goods vehicles in QA	0.0	0.03	0.10
PQAPSVC	Proportion of PSV (closed) in QA	0.0	0.02	0.15
PQAPSVO	Proportion of PSV (open) in QA	0.0	0.001	0.02
PQAMC	Proportion of motor cycles in QA	0.0	0.02	0.15
PQAPC	Proportion of pedal cycles in QA	0.0	0.02	0.10
PQAPSV	Proportion of PSV in QA (PQAPSVC+PQAPSVO)	0.0	0.02	0.15
PQATW	Proportion of two wheelers in QA (PQAMC+PQAPC)	0.0	0.04	0.25
PQAHEV	Proportion of heavy vehicles in QA (PQAHGV+PQAPSVC+PQAPSVO)	0.003	0.05	0.22
QA.PQAPSV	AADT PSV flow in direction AB (thou)	0.0	0.14	1.72
L(QA.PQAPSV)	Log_e ((QA.PQAPSV)+0.001)	-6.91	-2.76	0.54
OPENBUS	Presence of open buses on link section 1 No open buses (1660) 2 Open buses (191)			
Pedestrian flow and density				
PT	12hr two-way pedestrian flow across link section (thou)	0.004	0.579	35.794
PTSL	Two-way pedestrian density across link section (thousands of pedestrians per km)	0.01	10.40	265.15
LPTSL	Log_e of two-way pedestrian density across link section (thousands of pedestrians per km)	-5.19	1.14	5.58
Proportion of pedestrian flow				
PM15PT	Proportion of male children	0.0	0.096	0.464
PMADPT	Proportion of male adults	0.078	0.365	0.857
PM60PT	Proportion of male old persons	0.0	0.053	0.209
PF15PT	Proportion of female children	0.0	0.092	0.464
PFADPT	Proportion of female adults	0.042	0.320	0.603
PF60PT	Proportion of female old persons	0.0	0.057	0.299
PCHILDP	Proportion of children under 15 yrs	0.0	0.188	0.736
PADULTP	Proportion of adults (15 to 60 yrs)	0.21	0.686	1.0
POLDPT	Proportion of elderly people	0.0	0.11	0.46

Link variables and factors

			Min	Mean	Max
SP40	Speed limit				
	1 30 mph	(1631)			
	2 40 mph	(220)			
ONEWAY	Traffic flow				
	1 Two-way	(1762)			
	2 One-way	(89)			
LONDON	Geographical location				
	1 Outside London	(1346)			
	2 Within London	(505)			
ENDJUNA	Type of major junction at end A				
	1 Null	(180)			
	2 Signals	(683)			
	3 Priority junction	(685)			
	4 Roundabout	(303)			
ENDJUNB	Type of major junction at end B				
	1 Null	(183)			
	2 Signals	(692)			
	3 Priority junction	(680)			
	4 Roundabout	(296)			
BEND	Bendiness (degrees per km)		0.0	50.0	436.6

Link section - geometric variables and factors

			Min	Mean	Max
SL	Section length (km)		0.011	0.091	0.916
ADJUN	Type of adjacent junctions				
	1 Both internal	(1149)			
	2 Either major	(702)			
ADJUNA	Type of adjacent junction at end A				
	1 Internal	(1496)			
	2 Major	(355)			
ADJUNB	Type of adjacent junction at end B				
	1 Internal	(1492)			
	2 Major	(359)			
NEXTJUNA	Type of adjacent junction at end A				
	1 Internal	(1496)			
	2 Major - null	(33)			
	3 Major - signals	(117)			
	4 Major - priority	(146)			
	5 Major - roundabout	(59)			
NEXTJUNB	Type of adjacent junction at end B				
	1 Internal	(1492)			
	2 Major - null	(35)			
	3 Major - signals	(124)			
	4 Major - priority	(142)			
	5 Major - roundabout	(58)			
NLANEAB	No. of lanes in direction AB		1	1.145	4
	(1 (1623), 2 (199), 3 (18), 4 (11))				
NLANEBA	No. of lanes in direction BA		1	1.102	3
	(1 (1589), 2 (166), 3 (7), ... two-way only: 1762 values)				

		Min	Mean	Max
NLANE	No. of lanes in both directions (1 (0), 2 (1564), 3 (46), 4 (142), 5 (10)) two-way only)	2	2.204	5
LNWIDTHC	Average width of nearside lanes (m)	2.15	4.38	13.3
GRAD	Gradient on link section (%) (+ve uphill from A to B)	-10.0	0.035	10.0
VISAB	Visibility from centre in direction AB (m)	10	168.2	225
VISBA	Visibility from centre in direction BA (m)	10	168.2	225
WIDTHC	Half-road width in direction AB (nearside (m))	2.4	4.875	19.8
WIDTHD	Half-road width in direction BA (offside (m)) (.....................................two-way only: 1762 values)	2.4	4.658	13.3
CMWIDTH	With of centre marking (m) (.....................................two-way only: 1762 values)	0.0	0.110	4.70
TOTWIDTH	Total road width (m)	4.0	9.414	27.7
Accesses				
NPRIVC	No. of private accesses on nearside per km	0	21.0	150
NPRIVD	No. of private accesses on offside per km	0	21.0	150
NPRIV	No. of private accesses on both sides per km	0	42.1	300
NPUBC	No. of public accesses on nearside per km	0	3.0	100
NPUBD	No. of public accesses on offside per km	0	3.1	100
NPUB	No. of public accesses on both sides per km	0	6.1	163
NACCESSC	Total number of accesses on nearside per km	0	24.1	150
NACCESSD	Total number of accesses on offside per km	0	24.1	150
NACCESS	Total number of accesses on both sides per km	0	48.4	300
Bus stops, markings and bays				
NBUSTC	No. of bus stops on nearside per km (with or without markings)	0	5.1	50
NBUSTD	No. of bus stops on offside per km (with or without markings) (.....................................two-way only: 1762 values)	0	4.9	50
NBUST	No. of bus stops on both sides per km (with or without markings) (.....................................two-way only: 1762 values)	0	9.8	100
PRESBMKC	Presence of bus markings on nearside 1 No markings (1727) 2 Bus markings (124)			
PRESBMKD	Presence of bus markings on offside (two-way only: 1762 values) 1 No markings (1651) 2 Bus markings (111)			
PRESBMK	Presence of bus markings on either side (two-way only: 1762 values) 1 No markings (1596) 2 Bus markings (166)			

			Min	Mean	Max
PRESBBYC	Presence of bus bays on nearside				
	1 No bus bays	(1795)			
	2 Bus bays	(56)			
PRESBBYD	Presence of bus bays on offside (two-way only: 1762 values)				
	1 No bus bays	(1706)			
	2 Bus bays	(56)			
RESBBY	Presence of bus bays on either side (two-way only: 1762 values)				
	1 No bus bays	(1664)			
	2 Bus bays	(98)			
PBUSBYC	Proportion of nearside with bus bays		0.0	0.012	1.0
PBUSBYD	Proportion of offside with bus bays (.....................................two-way only: 1762 values)		0.0	0.013	1.0
PBUSBY	Proportion of section sides with bus bays (.....................................two-way only: 1762 values)		0.0	0.013	0.61

Lighting

LIGHT	Type of lighting (combined NS & OS)				
	1 Up to 7m high	(217)			
	2 greater than 7m high	(1634)			

Pedestrian crossing facilities and guard rails

REFUGE	No. of refuges (0 (1770), 1 (73), 2 (4), 3 (4))		0	0.050	3
NREFUGE	No. of refuges per km (without zebra or pelican crossing)		0	0.72	50
PRESREF	Presence of refuges (without zebra or pelican crossing)				
	1 No refuge	(1779)			
	2 Refuges	(72)			
PGRAILC	Proportion of nearside with guard railing		0.0	0.014	1.0
PGRAILD	Proportion of offside with guard railing		0.0	0.013	1.0
PGRAIL	Proportion of section sides with guard railing		0.0	0.013	1.0
PRESGRLC	Presence of guardrail on nearside				
	1 No guardrail	(1766)			
	2 Guardrail	(85)			
PRESGRLD	Presence of guardrail on offside				
	1 No guardrail	(1771)			
	2 Guardrail	(80)			
PRESGRL	Presence of guardrail on either side				
	1 No guardrail	(1720)			
	2 Guardrail	(131)			

INTCTYP	Internal crossing type	
	1 No crossing	(1758)
	2 Zebra	(25)
	3 Pelican	(68)
ZEB	Presence of Zebra on link section	
	1 No zebra	(1826)
	2 Zebra	(25)
PEL	Presence of Pelican on link section	
	1 No pelican	(1783)
	2 Pelican	(68)
CROSS	Presence of a crossing on link section	
	1 No crossing	(1758)
	2 Pelican or zebra	(93)
INTZEB	Internal zebra	
	1 No zebra	(1826)
	2 Zebra within 25m of either end	(16)
	3 Zebra > 25m from both ends	(9)
INTZEBA	Internal zebra at end A	
	1 No zebra	(1826)
	2 Zebra within 25m	(8)
	3 Zebra greater than 25m	(17)
INTZEBB	Internal zebra at end B	
	1 No zebra	(1826)
	2 Zebra within 25m	(10)
	3 Zebra greater than 25m	(15)
INTPEL	Internal pelican	
	1 No pelican	(1783)
	2 Pelican within 25m of either end	(53)
	3 Pelican > 25m from both ends	(15)
INTPELA	Internal pelican at end A	
	1 No pelican	(1783)
	2 Pelican within 25m	(31)
	3 Pelican greater than 25m	(37)
INTPELB	Internal pelican at end B	
	1 No pelican	(1783)
	2 Pelican within 25m	(30)
	3 Pelican greater than 25m	(38)
EXTCROSA	External crossing at end A	
	1 No crossing within 25m	(1802)
	2 Pelican or zebra	(49)
EXTCROSB	External crossing at end B	
	1 No crossing within 25m	(1801)
	2 Pelican or zebra	(50)
EXTYPA	External crossing type at end A	
	1 No crossing within 25m	(1802)
	2 Zebra	(26)
	3 Pelican	(23)
EXTYPB	External crossing type at end B	
	1 No crossing within 25m	(1801)
	2 Zebra	(28)
	3 Pelican	(22)

			Min	Mean	Max
EXTZEBA	External zebra at end A				
	1 No zebra	(1825)			
	2 Zebra within 25m	(26)			
EXTZEBB	External zebra at end B				
	1 No zebra	(1823)			
	2 Zebra within 25m	(28)			
EXTPELA	External pelican at end A				
	1 No pelican	(1828)			
	2 Pelican within 25m	(23)			
EXTPELB	External pelican at end B				
	1 No pelican	(1829)			
	2 Pelican within 25m	(22)			
INTLOL	Presence of lollipop patrol (away from pedestrian crossing)				
	1 No patrol	(1832)			
	2 Lollipop patrol	(19)			
EXTLOLA	External lollipop patrol at end A (away from pedestrian crossing)				
	1 No patrol	(1834)			
	2 Patrol within 25m of A	(17)			
EXTLOLB	External lollipop patrol at end B (away from pedestrian crossing)				
	1 No patrol	(1834)			
	2 Patrol within 25m of B	(17)			

Loading regulations

LOADC	Loading restrictions on nearside	
	1 no loading restrictions	(1424)
	2 loading restrictions	(427)
LOADD	Loading restrictions on offside	
	1 no loading restrictions	(1432)
	2 loading restrictions	(419)
LOAD	Loading restrictions on either side	
	1 none on both sides	(1358)
	2 some on either side	(453)

Parking regulations and occupancy

(i) proportion of nearside link section with:

		Min	Mean	Max
PREGDSC	Double or single solid yellow lines	0.0	0.380	1.0
PREGOTHC	Other parking regulations	0.0	0.109	1.0
PREGUNRC	Unrestricted parking	0.0	0.511	1.0
POCALLC	Proportion of nearside occupied by parked vehicles	0.0	0.175	1.0

(ii) proportion of offside link section with:

		Min	Mean	Max
PREGDSD	Double or single solid yellow lines	0.0	0.376	1.0
PREGOTHD	Other parking regulations	0.0	0.114	1.0
PREGUNRD	Unrestricted parking	0.0	0.511	1.0
POCALLD	Proportion of offside occupied by parked vehicles	0.0	0.177	1.0

		Min	Mean	Max
(iii) proportion of both sides of link section with:				
PREGDS	Double or single solid yellow lines	0.0	0.378	1.0
PREGOTH	Other parking regulations	0.0	0.111	1.0
PREUNR	Unrestricted parking	0.0	0.511	1.0
POCALL	Proportion of both sides occupied by parked vehicle	0.0	0.177	1.0

PRESDBYC	Presence of double yellow lines on nearside	
	1 No double yellow lines	(1406)
	2 Double yellow lines	(445)
PRESDBYD	Presence of double yellow lines on offside	
	1 No double yellow lines	(1413)
	2 Double yellow lines	(438)
PRESDBY	Presence of double yellow lines on either side	
	1 No double yellow lines	(1338)
	2 Double yellow lines	(513)
PRESSGYC	Presence of single yellow lines on nearside	
	1 No single yellow lines	(1393)
	2 Single yellow lines	(458)
PRESSGYD	Presence of single yellow lines on offside	
	1 No single yellow lines	(1392)
	2 Single yellow lines	(459)
PRESSGY	Presence of single yellow lines on either side	
	1 No single yellow lines	(1329)
	2 Single yellow lines	(522)
PRESDSC	Presence of double or single yellow lines on nearside	
	1 No lines	(991)
	2 Yellow lines	(860)
PRESDSD	Presence of double or single yellow lines on offside	
	1 No lines	(996)
	2 Yellow lines	(855)
PRESDS	Presence of double or single yellow lines on either side	
	1 No lines	(920)
	2 Yellow lines	(931)
PRESOTHC	Presence of other regulations on nearside	
	1 No other regulations	(1505)
	2 Other regulations	(346)
PRESOTHD	Presence of other regulations on offside	
	1 No other regulations	(1499)
	2 Other regulations	(352)
PRESOTH	Presence of other regulations on either side	
	1 No other regulations	(1408)
	2 Other regulations	(443)

		Min	Mean	Max
Parking bays				
PPARKBYC	Proportion of nearside with parking bays	0.0	0.007	1.0
PPARKBYD	Proportion of offside with parking bays	0.0	0.007	1.0
PPARKBY	Proportion of section sides with parking bays	0.0	0.007	1.0
PRESPBYC	Presence of parking bays on nearside 1 No parking bays (1821) 2 Parking bays (30)			
PRESPBYD	Presence of parking bays on offside 1 No parking bays (1820) 2 Parking bays (31)			
PRESPBY	Presence of parking bays on either side 1 No parking bays (1796) 2 Parking bays (55)			
Centre road markings				
PGHOSTNA	Proportion of section with ghost hatching (no arrows) (.....................................two-way only: 1762 values)	0.0	0.038	1.0
PGHOSTRA	Proportion of section with ghost hatching (rtn arrow) (.....................................two-way only: 1762 values)	0.0	0.005	1.0
PRMBRKN	Proportion of section with broken line (.....................................two-way only: 1762 values)	0.0	0.786	1.0
PRMNONE	Proportion of section with no line (.....................................two-way only: 1762 values)	0.0	0.136	1.0
PRMDOUB	Proportion of section with double line (.....................................two-way only: 1762 values)	0.0	0.008	1.0
PRMZIG	Proportion of section with zigzags (.....................................two-way only: 1762 values)	0.0	0.015	1.0
ARROW	No. of arrows (.....................................two-way only: 1762 values)	0	0.022	4
Traffic signs				
WSIGNC	No. of warning signs on nearside per km	0	1.2	50
DSIGNC	No. of information and direction signs on the nearside per km	0	1.7	50
TSIGNC	Total no. of signs on the nearside per km	0	3.6	50
PRESBANC	Presence of banned turn signs on nearside 1 No banned turn signs (1826) 2 Banned turn signs (25)			
PRESOBLC	Presence of obligatory signs on nearside (not no-entry or banned turn) 1 No banned turn signs (1779) 2 Banned turn signs (72)			

			Min	Mean	Max
WSIGND	No. of warning signs on offside per km (.....................................two-way only: 1762 values)		0	1.2	50
DSIGND	No. of information and direction signs on the offside per km (.....................................two-way only: 1762 values)		0	1.4	50
TSIGND	Total no. of signs on the offside per km (.....................................two-way only: 1762 values)		0	3.2	50
PRESBAND	Presence of banned turn signs on offside (two-way only: 1762 values)				
	1 No banned turn signs	(1742)			
	2 Banned turn signs	(20)			
PRESOBLD	Presence of obligatory signs on offside (not no-entry or banned turn) (two-way only: 1762 values)				
	1 No banned turn signs	(1702)			
	2 Banned turn signs	(60)			

Land Use

Proportion of both sides of the link section with the following land use:

			Min	Mean	Max
PLAND1	Shopping/Recreational/Shops & flats		0.0	0.191	1.00
PLAND2	Commercial/Industrial/Public buildings/ Offices & flats/Religious		0.0	0.120	1.00
PLAND5	Educational		0.0	0.021	1.00
PLAND7	Residential		0.0	0.528	1.00
PLAND11	Sport/Open space		0.0	0.114	1.00
PLAND13	Petrol station/car park/railway		0.0	0.023	1.00
SHOP	Dominant land use shopping				
	1 PLAND1 less than 0.5	(1459)			
	2 PLAND1 greater than 0.5	(392)			

APPENDIX B: MEASUREMENT OF VARIABLES AND FACTORS USED IN THE FULL ACCIDENT-FLOW GEOMETRY MODELS

The methods used to measure or determine the variables and factors that appear in the full models are described here in more detail to assist with the use of the model formulae.

Vehicle flow along link side (QA). Annual average daily flows (see Sections 5.5.1 to 5.5.3). Units: thousands of vehicles.

Proportion of public service vehicles in flow QA (PQAPSV). Measured from 12-hour manual classified counts (see Section 5.5.2).

Proportion of two wheeled vehicles in flow QA (PQATW). Measured from 12-hour manual classified counts (see Section 5.5.2).

Flow of public service vehicles along link side (QA.PQAPSV). Measured from 12-manual classified counts see Section 5.5.2).

Two-way pedestrian density across link section (PTSL). 12-hour pedestrian flows divided by length of link section - (see Sections 5.6.1 and 5.6.2). Units: thousands of pedestrians per kilometre.

Presence of one-way traffic flow on link section (ONEWAY). Determined by observation on site.

Location of link section within London (LONDON). Whether the link was within DTp London region.

Presence of major junction at the far end B of link section side (ADJUNB). Determined by observation on site. A major junction was defined as a junction where the link lost priority; links were bounded by a major junction at both ends. Types of major junction included traffic signals, roundabouts, gyratories, priority junctions and 'null junctions'; the latter was defined as a change of speed limit or a change to one-way traffic.

Presence of major junction at either the near or the far end of link section side (ADJUN). Determined by observation on site - see above.

Gradient on link section side (GRAD). Measured over the link section length using a levelling device (Abney level), from near boundary A to far boundary B along the footway. Uphill measurements A to B had a positive sign. One measurement was made per link section; the gradient on the opposite link section side had the opposite sign. Units: percentage gradient.

Visibility from centre of link section side towards A (VISBA). One observer stood at the centre of the link section side and determined the point at which he/she could see cars appear at the near end A of the link section side. The second observer was asked to stand adjacent to this point. The distance between observers was recorded. The observations were made from the footway unless the link section was very curved. Units: metres.

Number of private and public access per kilometre on the nearside of the link section side (NACCESSC). A count was made of the total number of private vehicle driveways and public accesses, including petrol stations and car parks, along the nearside of the link section side. The count was divided by the link section length. Separate entries and exits were counted as two accesses. Units: number of accesses per kilometre.

Number of bus stops per kilometre on the nearside of the link section side (NBUSTC). A count was made of the total number of bus stops, including those with bus markings on the carriageway or with bus bays. The count was divided by the link section length. Units: see above.

Presence of a rectangular road marking, indicating a bus stop area, on either the nearside or the offside of the carriageway within a link section (PRESBMK). Determined by observation on site.

Presence of a bus bay, where the kerb is set back from the road, on either the nearside or the offside of the carriageway within a link section (PRESBBY). Determined by observation on site.

Number of pedestrian refuges per kilometre on the link section (NREFUGE). A count was made of the number of raised-island/refuges, located in the centre of the carriageway, that were not adjacent to a zebra or pelican crossing. The count was divided by the link section length. Units: see above.

Presence of a zebra crossing within the link section (ZEB). Determined by observation on site. No link sections contained more than one zebra or pelican crossing.

Presence of a zebra or a pelican crossing within the link section (CROSS). Determined by observation on site. No link sections contained more than one zebra or pelican crossing.

Presence of an external zebra or a pelican crossing within 25m of the near end A of the link section side (EXTCROSA). Determined by observation on site. An external zebra or pelican was defined as one within an adjacent junction section.

Proportion of both sides of the carriageway on a link section that was occupied by parked vehicles (POCALL). A count was made of the number of parked vehicles along both sides of the carriageway during four survey periods spread throughout the day. The average number of cars parked along on the link section was converted to a length of parked road assuming a length of 6m per car. The length of parked road was divided by twice the link section length to give the proportion occupied by parked vehicles. The assumption of 6m was approximate and a small number of link sections had a value of parking occupancy greater than 1. These were replaced with 1. None of the link sections were observed to have vehicles parked at right angles to the kerb. Where right-angled parking does occur, parking occupancy may be estimated assuming a length of 2.2m per car.

Proportion of both sides of the carriageway on a link section with shopping, recreational (cinemas, pubs, restaurants and takeaways) or shops with flats (PLAND1). Determined by observations on site. See Appendix A for full range of land use categories.

Proportion of both sides of the carriageway on a link section with sports centres, sports grounds or open space (PLAND11). Determined by observations on site. See Appendix A for full range of land use categories.

Proportion of both sides of the carriageway on a link section with petrol stations, car parks or railway stations (PLAND13). Determined by observations on site. See Appendix A for full range of land use categories.

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