TRANSPORT RESEARCH LABORATORY

TRL REPORT 185

ACCIDENTS AT URBAN PRIORITY CROSSROADS AND STAGGERED JUNCTIONS

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Prepared for: **Road Safety Division, DOT**
Project: **Accidents at Urban Priority Crossroads (S205E/RT)**

Transport Research Foundation Group of Companies
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First Published 1996
ISSN 0968-4107

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EXECUTIVE SUMMARY

About 14,000 personal injury accidents (PIAs) are reported each year at priority crossroads and staggered junctions on urban single carriageway roads. The annual cost of these accidents amounted to about £300 million at 1990 prices. The accidents include all those within 20 metres of the junctions.

This report describes a full-scale study, undertaken on behalf of the Road Safety Division of the Department of Transport, of accidents at priority crossroads and staggered junctions 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); and four-arm single carriageway urban traffic signals (Hall, 1986). Reports from three further studies are published concurrently with this report: three-arm single carriageway priority junctions (Summersgill, Kennedy and Baynes, 1996); non-junction single carriageway roads (Summersgill and Layfield, 1996); and three-arm single-carriageway urban traffic signals (Taylor 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.

A sample of 300 junctions was identified for the study which comprised 202 crossroads, 48 left/right staggered junctions and 50 right/left staggered junctions. The sample was stratified by vehicle and pedestrian flow and care was taken to ensure that the main junction characteristics, the types of frontage land use and the geographical regions were properly represented. An in-depth data collection exercise was carried out with 12 hour vehicle and pedestrian counts and an extensive geometric survey at each site.

A total of 2917 PIAs was reported at the 300 junctions for the six year period from 1984 to 1989 inclusive. Detailed tabulations are given showing accident frequencies, severities and rates by 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 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 junction total accident models to full geometric models for individual groups of accidents.

Some of the key findings of the study were as follows:

(i) Longer stagger lengths between the minor arms resulted in fewer total, vehicle and right angle accidents (major with previous minor and major with next minor).

(ii) The models predict on average more accidents at crossroads with a facility than at those without, for given vehicle and pedestrian flow. However, those junctions in the sample without crossings had substantially lower pedestrian flows 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 flows is non-linear (with index less than one) it is the case that the mean number of accidents per pedestrian crossing the road at those crossroads with pedestrian crossings was similar to the mean number at those crossroads 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.

(iii) This study was not intended or designed to investigate speed mechanisms and relationships in depth, and only coarse measures of speed were included. Speed variables were omitted from the preferred models on the grounds of lack of ease of measurement and consistency across accident groups. Traffic calming measures such as speed humps, speed cameras and chicanes were not tested in the study.

(iv) There were physical variables that were found to have an effect on accidents which were correlated with speed, but these variables produced much stronger relationships than did speed.

(v) The presence of an island on the major road had a mixed effect depending on location within the junction and accident group.

(vi) More traffic lanes increased rear shunt and lane-changing accidents on a major arm and also increased pedestrian with vehicle entering accidents.

(vii) A stop-line on the minor arm reduced right angle (major with previous minor) accidents.

(viii) Other key results were: more single vehicle accidents on the major road with a higher proportion of PSVs; more single vehicle and vehicle-only accidents with a higher proportion of motor cyclists in the major road flow; increased total, vehicle-only and several accident groups at crossroads in Greater London.

The models are intended for a range of applications: to identify potential road 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 strategies, 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.

ACCIDENTS AT URBAN PRIORITY CROSSROADS AND STAGGERED JUNCTIONS

ABSTRACT

The Report gives the findings of a study of accident risk based on a national stratified sample of 300 urban priority crossroads and staggered junctions on single carriageway roads (2917 personal injury accidents). The study includes crossroads with and without pedestrian crossings on roads with 30 mph or 40 mph speed limits. 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 develop relationships between accident frequency and traffic flow, road features, layout, geometry, land use and other variables. The technique of generalised linear modelling was used to develop such relationships for different types of accidents.

1. INTRODUCTION

1.1 GENERAL

The Report describes a project to study accidents and accident risk at urban single carriageway priority crossroads and staggered junctions.

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). About 130,000 of the PIAs and 1308 of the fatal accidents occurred at or within 20 metres of a junction (Department of Transport, 1991). The majority of these accidents occurred at 3-arm priority junctions. However, it is estimated that about 14,000 of these junction accidents occurred at single carriageway crossroads and staggered junctions. The annual cost of these accidents amounted to about £300 million at 1990 prices.

There is clearly a need to have the fullest understanding of the characteristics of accidents at crossroads and staggered junctions 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 of accidents at four-arm priority junctions 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); and four-arm single carriageway urban traffic signals (Hall, 1986). Reports from three further studies are published concurrently with this report: three-arm single carriageway priority junctions (Summersgill, Kennedy and Baynes, 1996); non-junction single carriageway roads (Summersgill and Layfield, 1996); and three-arm single-carriageway urban traffic signals (Taylor 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 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 study was conducted by means of intra-mural work at TRL and an extra-mural contract, with the Transportation Research Group of the University of Southampton as the main contractor responsible for data collection and the development of the preliminary accident predictive models.

1.2 DISTINCTION BETWEEN CROSSROADS AND STAGGERED JUNCTIONS

Although most people have a general idea of what a crossroads is and the way in which these differ from staggered junctions, it is difficult to identify a simple definition that will distinguish all cases to everyone's satisfaction.

The reconnaissance survey showed that some junctions, particularly those of the 'scissor type' (see Figure 1), have a stagger between the centre lines of the opposite minor arms yet appear to operate as crossroads, with little movement of the steering wheel required to cross from one minor arm to the other. For the tabulations described in Sections 4, 6 and 7 of this paper, junction type was based on the subjective assessment of the surveyors as to whether the junction was operating as a crossroad, left/right or right/left staggered junction.

In the accident predictive models a more objective definition of junction type was used. Staggered junctions were defined as junctions where the absolute value of stagger length exceeded 5 metres; right/left junctions had a stagger length greater than 5m and left/right junctions had a stagger less than minus 5 metres. Stagger length was defined as the displacement between the perpendiculars from the centre lines of the opposite minor arms (see Figure 1). Junction type, stagger length, the absolute value of stagger length, and the angle between adjacent arms were all tested as explanatory variables in the full accident-flow-geometry models. A further alternative definition of stagger, measured along the centre line of the major road between the extended centre lines of the minor arms, was tested but this did not fit the data so well.

The distinction between staggered junctions and separate T-junctions (with opposite minor arms) is also difficult to determine. For the purposes of this study, staggered junctions were limited to junctions where the absolute value of stagger length does not exceed 20 metres. This is the same definition as was used in earlier studies of urban links and T-junctions. It was based on the assumption that a 4-arm junction with a stagger greater than 20 metres effectively operates as a pair of T-junctions. The safety characteristics of such a junction are therefore also likely to be similar to a those of a pair of T-junctions.

2. STUDY APPROACH

The main objectives of the study were:

(i) to investigate the characteristics of accidents at crossroads and staggered junctions 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: junction type; 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 junctions. 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.

3. THE RECONNAISSANCE SURVEY

The reconnaissance involved a limited survey of flows, features and geometrics at 1000 crossroads and staggered junctions throughout Great Britain. The survey started in the first week of October 1989 and finished at the end of February 1990. Nearly all significant urban areas in Great Britain were visited; the exceptions were Cornwall, parts of South Devon, Mid and North Wales and Northumberland.

At the end of the exercise a total of 1003 junctions had been surveyed. The 1003 junctions were then used as a base from which 300 junctions were selected for the main surveys of traffic, geometry and accidents.

3.1 SELECTION OF JUNCTIONS

The junctions selected for the reconnaissance survey had to conform to the following conditions:

(a) have four arms, all single carriageway, with two-way traffic

(b) the junction operates under priority control, with the minor arms on the opposite sides of the major road and having a give-way or stop line across their entries

(c) the stagger between the centre lines of the opposite minor arms does not exceed 20m

(d) the speed limit on each arm is 30 or 40 mph. The junction speed limit is that of the major arms

(e) all arms are lit

(f) the junction should be in an urban area but not be in an internal part of a housing or industrial estate

(g) there is not more than one sample junction on the same stretch of road between major junctions, unless this is done to increase the number of sample junctions that have characteristics that are needed but are relatively difficult to find

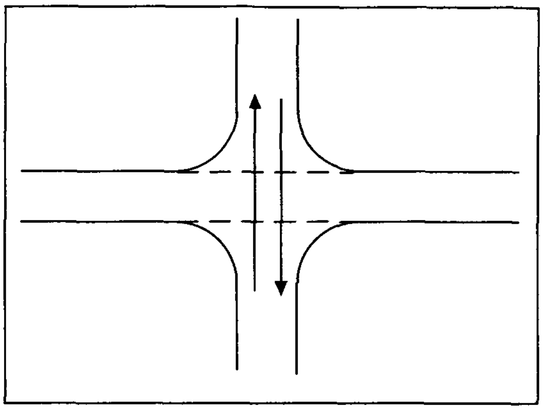
(h) junctions which look new or appear to have been modified should be excluded (six years of unmodified operation is desirable in order to provide a sufficient number of accidents)

(i) there are no banned turns

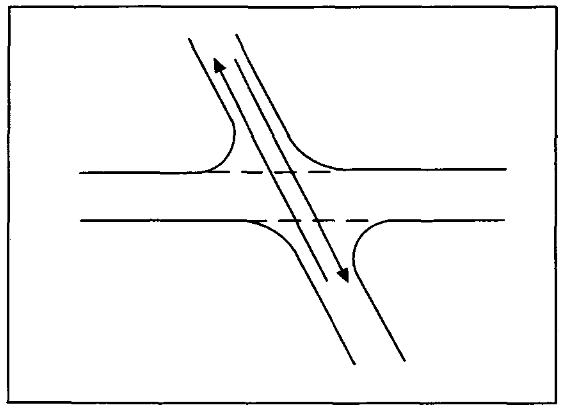
(j) there are no arms with no-through roads

(k) there are no junctions with significant accesses (eg petrol stations) within 40m of the junction

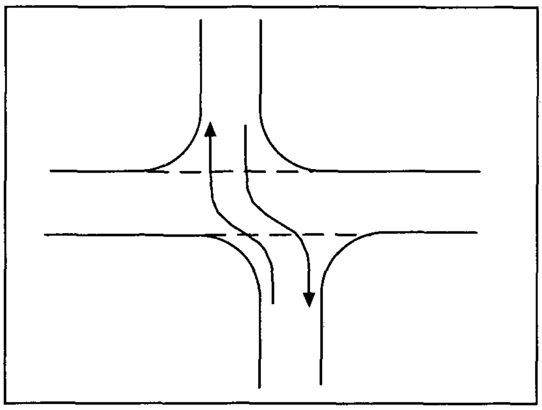
(l) there are no roads with bus lanes



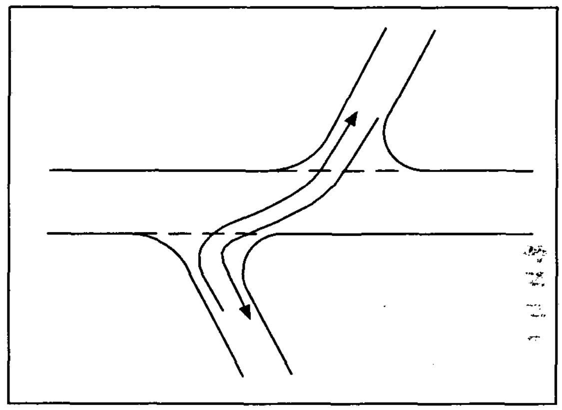
Conventional crossroads



Scissor type crossroads



Left/right staggered junction



Right/left staggered junction

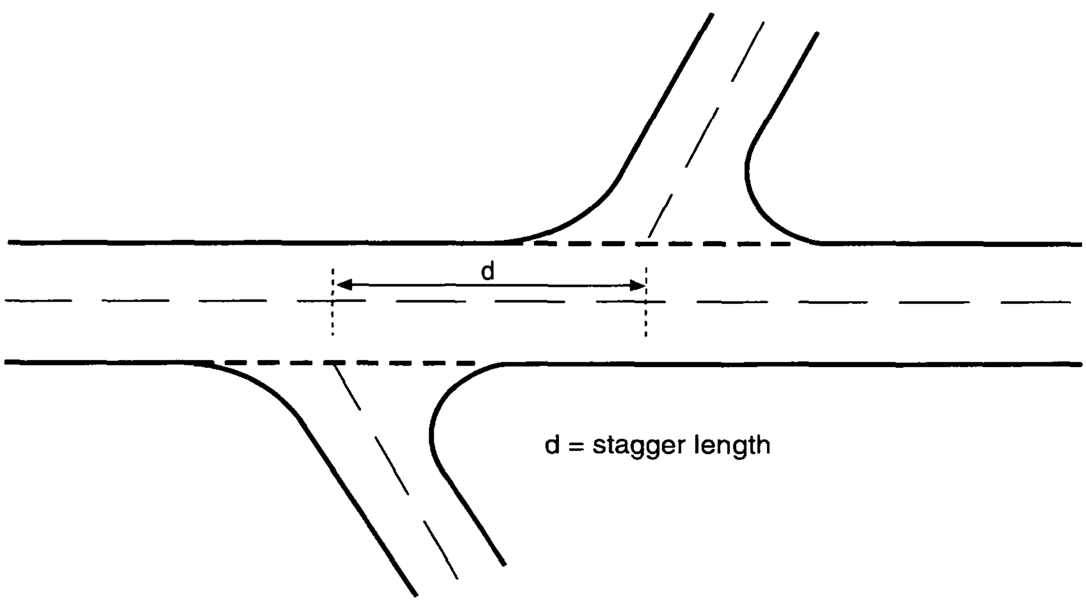


Figure 1 Illustration of crossroads and staggered junctions

Within these general guidelines targets were set for particular features:

(a) twenty-five percent of junctions in Greater London, the remaining junctions evenly spread across the other regions

(b) two-thirds of the junctions to be crossroads, one-sixth left/right staggered junctions and one-sixth right/left staggered junctions

(c) twenty-five percent of the junctions to have a 40 mph speed limit

(d) the sample to be stratified by major arm vehicle inflow in the ranges:

0 - 10,000, 10,001 - 20,000, >20,000 (AADT)

(e) the sample to be stratified by minor arm vehicle inflow in the ranges:

0 - 4,000, 4,001 - 8,000, >8,000 (AADT)

(f) the sample to be stratified by the sum of pedestrian movements across all arms of the junction in the ranges:

0 - 100, 101 - 500, >500 (pedestrians per hour)

(g) the sample to be stratified by the proportion of minor road inflow that crosses the major road in the ranges:

0 - 0.25, >0.25 - 0.5, >0.5

(h) junctions with the following features were sought:

(i) Pelican crossing facility on major arm

(ii) Zebra crossing facility on major arm

(iii) Traffic islands and hatched markings

(iv) Pedestrian guard rail

(v) Bus stops and bus bays

(vi) Frontage development of varying type

(vii) Additional traffic lanes

Approximately equal numbers of junctions were required for each of the 81 combinations of the flow stratification levels, that is 12 to 13 junctions per combination. Hence the teams were instructed to look for junctions with a wide range of vehicle and pedestrian flow.

3.2 DATA COLLECTION

The data collected at each site consisted of the following:

(i) a plan of the junction showing layout and features was drawn

(ii) photographs were taken of the junction showing details of all the arms

(iii) site data were collected to complement the plan data indicating for example, stagger length, road widths, banned turns and gradients

(iv) a 15-minute count of major road inflow

(v) separate 15-minute counts of minor road left and right and minor road ahead inflows

(vi) a 15-minute count of pedestrians crossing any of the junction arms within 20m.

4. SAMPLE SELECTION

4.1 REQUIREMENTS FOR THE FINAL 300 SITE SAMPLE

The targets for percentages by region, junction type and speed limit were the same for the selection of the 300 site sample as that used for the reconnaissance survey. The minor flow and pedestrian flow ranges were reset before the selection of the 300 site sample because of the shortage of sites with higher flows. These changes aided selection by spreading the sites across the flow strata, adding more sites to the higher flow bands.

The minor arm vehicle inflow was stratified in the ranges: 0 - 2,500, 2,501 - 5,000, >5,000 (AADT).

Pedestrian flow was stratified in the ranges: 0 - 150, 151 - 350, >350 (pedestrians per hour).

The above changes should not be interpreted as a weakness of the study. The initial targets were deliberately set to be highly demanding. The aim was to encourage the contractor to use the reconnaissance exercise to seek out scarce but important junctions with high vehicle and pedestrian flows. Such sites have a strong influence in establishing the flow functions in the accident predictive models.

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 junctions with higher flows and is not likely to be representative of the national population of roads in relation to many other characteristics.

The estimates of flow used in the stratification were derived from the short period counts taken at the site (typically 15 minutes per count) during the reconnaissance survey. Factors were used to convert the 15-minute vehicle counts to AADTs and the 15-minute pedestrian counts to 12-hour flows. The factors were derived from the profiles of vehicle and pedestrian flow measured in the study of four-arm traffic signals (Hall,1986).

Further requirements for the final 300 site sample were:

(a) The final sample should include junctions with all features or characteristics that are reasonably well represented within the reconnaissance sample, and especially those that seem likely to have an effect on safety.

(b) Each characteristic to be represented by at least 15 junctions so that the magnitude and statistical significance of any safety effects can be properly evaluated.

(c) A characteristic should not be over represented in the sample so that it dominates it.

(d) As well as the 300 junctions being evenly distributed across the flow bands, subsets with a particular characteristic should also be distributed across the flow bands even though some characteristics are naturally associated with certain flow levels.

(e) Correlations between particular features should be avoided. For example not all junctions with guard rails should be at 40 mph sites in the West Midlands.

Before the site selection began, photographs of all junctions were carefully examined and any relevant characteristics revealed in the photographs that were not specifically recorded as part of the reconnaissance survey were noted.

4.2 UNCOMMON JUNCTION FEATURES EXCLUDED FROM THE SAMPLE

The following features occurred at only a few junctions within the 1003 site reconnaissance survey. These junctions were excluded from the final 300 site sample because the safety effects of these features could not be properly resolved given the small number of junctions having a particular feature; their removal reduced a possible source of variation within the sample and will assist the assessment of the safety effects of the more common features.

(a) Parking bays

(b) Bus bays on minor arm

(c) Pedestrian crossing on major arm located between staggered minor arms

(d) Pedestrian crossing on minor arm

(e) Unusually large traffic islands

(f) Narrowed junctions (by kerbing or hatching)

(g) Taxi ranks

(h) Major arms with school zigzags

(i) Yellow box markings

(j) KEEP CLEAR road markings

(k) Ghost hatching through major road with no space for turning traffic

(l) Continuous/broken and double continuous centre road markings on major arms

(m) 3 exit or entry lanes on major arms

(n) Left-turn entry lane on major arms

(o) Unadopted minor arm

(p) Stop markings without a sign

(q) Single short broken markings across minor arms

(r) Zig-zag centre road markings on minor arms

(s) 2 exit lanes on minor arms

4.3 SAMPLE SELECTION PROCESS

The process of selecting the sample from the remaining junctions was an iterative one; starting off by choosing junctions with high desirability in terms of flow, speed limit, proportion of minor road flow going ahead, number of entry lanes on minor arms, and presence of pedestrian crossing, island or ghost hatching. This produced an excess of sites and so those junctions with flow bands and layout codes that were well represented were reduced in number.

The distribution of particular junction characteristics across the flow bands was checked and junctions were substituted as required. Cross tabulations were studied for layout, stagger and land use with respect to flow to ensure that no artificial correlations had been created. Eventually a point was reached in the selection process where it was not possible to improve the flow distribution of a particular characteristic without inflicting greater damage to the distribution of other important characteristics.

Checks were made with the Local Authorities to ensure that no major changes in junction operation, layout or traffic flow had recently occurred or were imminent at the 300 junctions that had been selected.

The flow distribution of the junctions selected for the main survey is shown in Table 1. The junctions are well distributed across the lower and medium bands but are less frequent in the higher bands; 26 per cent of junctions are in the high major road flow band, 19 per cent in the high minor road flow band, 16 per cent in the high pedestrian flow band and 52 per cent in the 'high proportion crossing from the minor road' band. Junctions falling within all three high flow bands: high major flow, high minor flow and high pedestrian flow, are not well represented.

However, since the reconnaissance survey targeted high flow sites and almost all of the junctions with high flows were included in the 300 sample, the sample distribution is likely to be biased towards the higher flow sites compared with the national population of such junctions.

Table 2 shows the number of junctions in the 300 site sample by type and DOT region. Twenty-six per cent of the junctions were in London, the remaining seventy-four per cent were spread across the other 10 regions of Great Britain.

The regional distribution is less even than had been hoped but some of the variation is a reflection on the differences in the size of the 'built-up' areas in the regions. While an effort was made to achieve an even distribution junctions across the regions, it was not the most important criterion for site selection; the distributions of traffic flow and site features had greater priority.

Sixty-seven percent of the sample sites were cross roads, sixteen per cent left/right staggered junctions and seventeen per cent right/left staggered junctions. The distribution of staggered junctions is representative of the population surveyed.

Twenty-two per cent of the junctions have a 40 mph speed limit on the major road and seventy-eight percent a 30 mph limit. The sample fell slightly short of the target of twenty-five per cent of the sample to be 40 mph junctions. Urban priority crossroads and staggered junctions with a 40 mph limit were generally difficult to find except in the Yorkshire and Humberside region.

5. THE MAIN SURVEY

5.1 TRAFFIC SURVEY

Data were collected at each of the 300 junctions selected for the main surveys. The main survey of vehicle and pedestrian flow, vehicle queuing, parking occupancy, and vehicle speed was carried out on weekdays (not on early closing, market days, bank holidays or school holidays) during June, September, October and November in 1990 and February, March and April in 1991.

The traffic survey at each junction consisted of one day of 12-hour continuous (7am to 7pm) counts, with counts recorded every 30 minutes. The counts included a vehicle-turning count on each arm classified by vehicle type, and a pedestrian count across each arm (within 20m of the junction) and across the junction centre classified by sex and estimated age. The pedestrian count included those using a pelican or zebra crossing provided the crossing was within 27.5m of the junction. The maximum queue length, the parking occupancy and parking activity on each arm were recorded at 30 minute intervals.

In addition, four 15-minute measurements were made on the same day during the morning and afternoon peak and off-peak periods of: vehicle speed, parking occupancy on each arm within 100m of the junction, sex and estimated age of drivers of light vehicles on the minor arms, and the number of pedestrians crossing on and off a zebra or pelican crossing.

Vehicle speed was measured as spot speeds of approaching vehicles at the centre of the junction on the major arms and at a point 100m back from the give-way line on the minor arms.

A comprehensive traffic survey manual and forms were designed for the collection of the data. The traffic surveys were subcontracted to local authorities and traffic survey agencies. The traffic survey data were checked for completeness, consistency and correct orientation of junction arms before entry into the traffic survey database.

Each classified 12-hour vehicle turning count was converted to an annual average daily total (AADT) for the year in which they were measured (1990 or 1991) using factors supplied by the DOT. The factors were broken down by: road class, day of week, month of year and road user type.

The AADTs were then adjusted to allow for broad changes in traffic flow in built-up areas between the years when the accidents occurred (1984 to 1989) and the years when the flows were measured. The factors used were supplied by the DOT and were broken down by: year, class of road and road user type.

5.2 GEOMETRIC SURVEY

The main survey of geometric data took place in October and November 1990. The geometric survey consisted of a site visit to each junction. During the site visit, a comprehensive record was made of all the main junction dimensions, road markings, layout, features, gradients, sight distances and land use. A comprehensive survey manual was designed for the collection of the data and tested at a number of local junctions. To improve consistency in the collection of the data, the geometric survey was carried out by two teams of two people. Consistency between the teams was checked at the start of the survey using local junctions. After the surveys were completed the teams discussed all aspects of the data collected to ensure complete consistency had been achieved.

Plans of the junctions were also used to measure for each arm: the radius of curvature of the centre line at the sharpest bend on the approach, the distance from the junction to the start of the sharpest bend, the length of the sharpest bend, and the radius of curvature of the entry kerbline. The angle

TABLE 1

Stratification of 300 junctions selected from the reconnaissance survey

Low pedestrian flow: 0-150 pedestrians per hour

Minor road AADT	Crossing proportion	Major road AADT 0-10000	10001-20000	>20000
0-2501	0-0.25	3	1	1
	>0.25-0.50	3	11	4
	>0.50	9	27	18
2501-5000	0-0.25	8	12	1
	>0.25-0.50	3	10	4
	>0.50	3	14	10
>5000	0-0.25	7	6	2
	>0.25-0.50	8	7	0
	>0.50	0	5	2

Medium pedestrian flow: 151-350 pedestrians per hour

Minor road AADT	Crossing proportion	Major road AADT 0-10000	10001-20000	>20000
0-2500	0-0.25	0	1	0
	>0.25-0.50	1	10	0
	>0.50	0	11	8
2501-5000	0-0.25	2	1	0
	>0.25-0.50	1	8	4
	>0.50	0	4	8
>5000	0-0.25	1	4	1
	0.25-0.50	0	3	1
	>0.50	0	3	0

High pedestrian flow: >350 pedestrians per hour

Minor road AADT	Crossing proportion	Major road AADT 0-10000	10001-20000	>20000
0-2500	0-0.25	0	1	0
	>0.25-0.50	0	1	2
	>0.50	2	6	4
2501-5000	0-0.25	0	2	0
	>0.25-0.50	0	3	1
	>0.50	0	13	6
>5000	0-0.25	2	1	0
	>0.25-0.50	0	2	0
	>0.50	0	2	1

TABLE 2

Number of junctions by region and type of junction

DOT region	Junction Type							
	Cross roads		Left/right stagger		Right/left stagger		Total	
	30mph	40mph	30mph	40mph	30mph	40mph	no.	%
London	51	4	13	0	10	0	78	26%
South East	19	6	2	1	5	1	34	11%
South West	14	1	0	0	1	0	16	5%
Eastern	4	1	3	0	1	2	11	4%
East Midlands	6	2	4	2	2	3	19	6%
West Midlands	15	7	8	2	2	3	37	12%
Yorks & Humb.	17	12	5	2	2	5	43	14%
North West	13	5	0	0	2	0	20	7%
Northern	8	1	1	0	6	3	19	6%
Wales	5	0	3	1	1	1	11	4%
Scotland	9	2	0	0	1	0	12	4%
Total	161	41	39	8	33	18	300	
Percentage	54%	14%	13%	3%	11%	6%		100%

of the minor arm with the next major arm (clockwise) was measured at 20 metres from the give-way line and at the give-way line.

5.3 ACCIDENT RECORDS

In order to identify the accidents at the junctions, accident reference numbers, plain language descriptions and basic accident details such as date and time were obtained from the local authorities for all personal injury accidents that occurred at the junctions within the six year period 1984 to 1989. The plain language descriptions and basic details were used to code the accidents according to the accident type and arm of association at the junctions. The codings were independently checked and any errors corrected.

Full accident details, as recorded on the STATS 19 forms, were also required for these accidents but the local authorities were not able to supply these in a form for direct input into the accident database. The STATS 19 details were therefore obtained from the TRL national accident computer records by matching the relevant accident reference numbers.

There were a number of junctions where physical alteration had occurred between 1 January 1984 and 31 December 1989 so that the stable accident study period had to be reduced from the full six years. 11 junctions had study periods beginning after January 1984, 4 junctions had study periods ending before December 1989 and for 13 junctions the study period was split into two, with one study period prior to the alteration and the other after the alteration.

5.4 DATA PROCESSING AND VERIFICATION

All of the data used to develop accident predictive relations was stored in a series of databases constructed using dBaseIV. The computer files were structured similarly to the data on the survey forms to aid the task.

As a result of the split period junctions, 13 'new' sites were created and the relevant information entered for all the data files. For the traffic count files, the 13 'new' sites had the same base data as the 'original' sites since the junction alterations were relatively minor and were unlikely to have affected traffic flow. However, the resulting AADT flows differed slightly because of differences in the factors used to take account of annual trends. For the junction layout, feature and geometric files, there were small differences between the 'new' and 'original' sites. The accidents relating to the 13 junctions were reassigned to the 'new' or 'original' sites.

Once the data had been entered into the databases an extensive programme of checking was initiated to ensure that the data were accurate. The traffic survey data were checked for extreme values and for consistency between each half hour turning movement count and the overall average half hour flow for that turning movement. For data from the geometric survey, a range check was carried out on each measured variable and, where possible, logic checks were made between related variables.

The full STATS 19 accident data were used to amend the accident coding of those accidents where insufficient detail had been received from the local authorities. Accident type, arm of association and vehicle correspondence were amended if necessary.

6. JUNCTION CHARACTERISTICS

The basic characteristics of the crossroads and staggered junctions that were used in the analysis are set out in this Section of the paper.

6.1 NUMBER OF JUNCTIONS

Table 3 gives the numbers of junctions by main features, junction type and speed limit. It can be seen that all the main categories are reasonably well represented. In total there were 300 junctions of which 13 had split accident survey periods as a result of minor layout changes. This gave a total of 313 different junctions for analysis. Of these 313 junctions, 15 per cent had a pelican crossing, 17 per cent had a zebra crossing, 25 per cent had pedestrian islands without pedestrian crossings or ghost hatching, 9 percent had islands and hatching, 7 per cent had hatching without pedestrian crossings or islands and 28 per cent had no junction features. All the zebras and pelicans were located on the major arms of the junctions and no junction had more than one pedestrian crossing.

Staggered junctions formed 32 per cent of the total. The main features were well represented at the 30 mph sites. Junctions with 40 mph speed limits formed 22 per cent of the total. About 60 per cent of the 40 mph junctions had no features; only 10 percent had pelican or zebra crossings.

6.2 VEHICLE AND PEDESTRIAN FLOW

Table 4 shows the range of total vehicle inflow per 24 hour day by junction classification.

The total vehicle inflow is the sum of the entry flows on the major and minor arms. The total vehicle inflows at the 30 mph junctions were similar to those at the 40 mph junctions. For 30 mph crossroads, the vehicle inflow per day ranged from about 3,400 to 31,000 with a mean value of about 13,400. For 40 mph crossroads the vehicle flow varied from 1,600 to about 30,000, with a mean value of 15,100.

The mean vehicle flows at staggered junctions were similar to those at crossroads.

There were only small differences in the mean vehicle flows at junctions with pelican and zebra crossings compared to no crossing sites. The mean vehicle flow at pelicans was, in general, about two to three thousand higher than the mean vehicle flow at no crossing sites.

Table 5 shows the range of total pedestrian flow in a 12-hour day. The total pedestrian flow is the sum of the flows of pedestrians crossing the major arms, the minor arms and the junction centre. There were large differences in pedestrian flow across the different junction categories. The mean pedestrian flow at 30 mph crossroads (1980) was about five times the mean pedestrian flow at 40 mph crossroads (410). The mean pedestrian flow at 30 mph

TABLE 3

Numbers of junctions by main features

Junction features	Crossroads		Left/right stagger		Right/left stagger		Total
	30mph	40mph	30mph	40mph	30mph	40mph	
Pelican crossing[1]	31	2	8	0	5	1	47
Zebra crossing[2]	31	4	9	0	8	0	52
Islands alone	50	7	8	1	9	3	78
Islands and hatching	15	1	4	1	2	4	27
Hatching alone	10	5	3	0	2	1	21
No junction features	32	24	8	7	8	9	88
All junctions	169	43	40	9	34	18	313[3]

1 includes junctions with pelicans and islands (kerbed or hatched)
2 includes junctions with zebras and islands (kerbed or hatched)
3 junction total 313 includes 13 'new' sites created by splitting the accident observation period at 13 junctions where minor layout or geometric alterations had been made (see Section 5.4).

TABLE 4

Total vehicle flow by junction classification (thousands of vehicles per day)

Junction features	Flow level	Crossroads 30mph	Crossroads 40mph	Left/right stagger 30mph	Left/right stagger 40mph	Right/left stagger 30mph	Right/left stagger 40mph
Pelican crossing	Min	11.11	----	11.56	----	13.18	----
	Mean	17.58	----	18.25	----	18.11	----
	Max	24.02	----	23.88	----	24.84	----
Zebra crossing	Min	7.53	----	9.81	----	8.58	----
	Mean	14.04	----	15.93	----	15.35	----
	Max	28.95	----	21.21	----	22.10	----
No crossing	Min	3.39	1.60	4.46	9.30	6.76	4.96
	Mean	13.41	15.10	16.87	14.61	16.32	13.86
	Max	26.67	29.73	31.09	26.20	30.90	24.92
All sites	Min	3.39	1.60	4.46	9.30	6.76	4.96
	Mean	14.49	15.70	16.90	14.60	16.55	14.31
	Max	28.95	29.73	31.09	26.20	30.90	24.92

TABLE 5

Total pedestrian flow by junction classification (thousands of pedestrians per 12-hours)

Junction features	Flow level	Crossroads 30mph	Crossroads 40mph	Left/right stagger 30mph	Left/right stagger 40mph	Right/left stagger 30mph	Right/left stagger 40mph
Pelican crossing	Min	1.00	----	0.86	----	1.41	----
	Mean	3.44	----	2.61	----	5.80	----
	Max	10.77	----	7.33	----	12.54	----
Zebra crossing	Min	0.43	----	1.10	----	0.43	----
	Mean	2.33	----	2.23	----	2.48	----
	Max	4.57	----	4.18	----	6.11	----
No crossing	Min	0.12	0.05	0.09	0.11	0.23	0.10
	Mean	1.34	0.34	0.85	0.30	2.53	0.43
	Max	8.34	0.81	3.94	0.60	14.86	1.41
All sites	Min	0.12	0.05	0.07	0.11	0.23	0.10
	Mean	1.98	0.41	1.51	0.29	3.08	0.46
	Max	10.77	1.76	7.33	0.60	14.86	1.41

right/left staggered junctions (3080) was higher than that at 30 mph crossroads (1980) and 30 mph left/right staggered junctions (1510). The mean pedestrian flow at 30 mph crossroads with pelicans (3440) was higher than those with zebras (2330) or with no pedestrian crossings (1340).

For those arms of the junctions with pedestrian crossings, the mean percentage of pedestrians using the crossing to cross the major arm, during the periods sampled, was 93 per cent for pelicans and 95 per cent for zebras. For pelicans the percentage using the crossing ranged from 75 to 100 per cent; for zebras the percentage using the crossing ranged from 53 to 100 per cent.

6.3 NUMBERS OF ACCIDENTS

Table 6 gives the numbers of injury accidents by main features, junction type and speed limit. There were 2917 accidents in total and these were distributed across the main features in a manner similar to the number of junctions.

Table 7 presents the number of accidents by accident type and junction arm. 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. A more detailed breakdown of accidents by accident type, junction arm and vehicle manoeuvre is given in Appendix B.

There were about 50 per cent more vehicle-only accidents on the major arms (1379) compared to the minor arms (906). For major arm accidents (1915 PIAs) the main vehicle-only accident groups were right angle (26 per cent), right turn with opposite ahead (14 per cent) and rear shunt (13 per cent). For minor arm accidents (1002 PIAs) the main vehicle-only accident groups were right angle (41 per cent), right turn with previous ahead (21 per cent), right turn with next ahead (11 per cent) and left turn with previous ahead (6 per cent).

Many more pedestrian accidents occurred on the major arms (536) compared to the minor arms (96). For major arm accidents, the percentage of accidents involving pedestrians and vehicles entering the junction (10 per cent) was slightly lower than the percentage of accidents involving pedestrians and vehicles exiting the junction (13 per cent). About 14 per cent of major arm accidents involved pedestrians crossing from the nearside and about 9 per cent from the offside.

7. ACCIDENT TABULATIONS

7.1 INTRODUCTION

One of the main aims of the study was to investigate the characteristics of a sample of priority crossroads and staggered 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 was 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 frequencies 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 frequency: the average number of accidents per junction per year over the six year period 1984 - 1989;

(ii) average accident rate: the average number of accidents per 100 million vehicles entering the junction over the six-year period 1984 - 1989.

TABLE 6

Numbers of accidents during 6 years by main features

Junction features	Crossroads		Left/right stagger		Right/left stagger		Total
	30mph	40mph	30mph	40mph	30mph	40mph	
Pelican crossing[1]	408	31	76	0	61	8	584
Zebra crossing[2]	404	28	117	0	86	0	635
Islands alone	494	63	71	5	72	18	723
Islands and hatching	157	4	13	5	18	15	212
Hatching alone	66	40	8	0	16	5	135
No junction features	258	168	59	40	56	47	628
All junctions	1787	334	344	50	309	93	2917

1 includes junctions with pelicans and islands (kerbed or hatched)
2 includes junctions with zebras and islands (kerbed or hatched)

TABLE 7

Accidents by group and type

Group	Type	Major arm No. of accs per six years	Major arm Per cent	Minor arm No. of accs per six years	Minor arm Per cent
Single vehicle	On approach and exit	41	2.1	9	0.9
	Hit object off carriageway	26	1.4	2	0.2
	Hit object in carriageway	16	0.8	0	0.0
	Passenger falling inside PSV	28	1.5	2	0.2
	Passenger falling off PSV	14	0.7	1	0.1
	Other PSV	2	0.1	1	0.1
	Other single vehicle	6	0.3	6	0.6
	Total	133	6.9	21	2.1
Rear shunts and lane changing	Rear shunt on approach or centre	203	10.6	20	2.0
	Rear shunt on exit	46	2.4	3	0.3
	Changing lanes	8	0.4	1	0.1
	Side collision entry	14	0.7	2	0.2
	Side collision exit	7	0.4	1	0.1
	Total	278	14.5	27	2.7
Right angle	Right angle	492	25.7	410	40.9
Right turn	Right turn with next ahead	1	0.1	12	1.2
	Right turn with opposite right	1	0.1	4	0.4
	Right turn with own ahead	47	2.5	0	0.0
	Right turn with next ahead	3	0.2	105	10.5
	Right turn with opposite ahead	270	14.1	18	1.8
	Right turn with previous ahead	11	0.6	209	20.9
	Right turn with opposite left	1	0.1	5	0.5
	Right turn with previous left	3	0.2	6	0.6
	Total	337	17.6	359	35.8
Left turn	Left turn with own ahead	24	1.3	2	0.2
	Left turn with previous ahead	5	0.3	61	6.1
	Other left turn	10	0.5	9	0.9
	Total	39	2.0	72	7.2
Head-on and U-turn	Head-on	31	1.6	4	0.4
	U-turn	10	0.5	1	0.1
	Total	41	2.1	5	0.5
Parked/parking vehicle hit	Parked vehicle hit	33	1.7	8	0.8
	Parking	13	0.7	1	0.1
	Total	46	2.4	9	0.9
Other vehicle accidents	Private drive	10	0.5	2	0.2
	Reversing	3	0.2	1	0.1
	Total	13	0.7	3	0.3
Total vehicle-only accidents		1379	72.0	906	90.4

TABLE 7 (CONTINUED)

Group	Type	Major arm No. of accs per six years	Major arm Per cent	Minor arm No. of accs per six years	Minor arm Per cent
Pedestrian vehicle entering	Pedestrian from nearside kerb	124	6.5	17	1.7
	Pedestrian from offside kerb	68	3.6	6	0.6
	Pedestrian direction unknown	5	0.3	0	0.0
	Total	197	10.3	23	2.3
Pedestrian vehicle exiting	Pedestrian from nearside kerb	142	7.4	26	2.6
	Pedestrian from offside kerb	98	5.1	25	2.5
	Pedestrian direction unknown	2	0.1	1	0.1
	Total	242	12.6	52	5.2
Pedestrian position of collision in junction unknown	Pedestrian from nearside	22	1.1	1	0.1
	Pedestrian from offside	21	1.1	1	0.1
	Pedestrian direction unknown	3	0.2	0	0.0
	Total	46	2.4	2	0.2
Other pedestrian	Pedestrian crossing centre	8	0.4	0	0.0
	Reversing vehicle hits pedestrian	11	0.6	5	0.5
	Pedestrian in carriageway (not crossing)	11	0.6	5	0.5
	Pedestrian hit on footway	7	0.4	4	0.4
	Pedestrian at private drive	1	0.1	0	0.0
	Pedal cyclist crossing arm	11	0.6	2	0.2
	Other pedestrian	2	0.1	3	0.3
	Total	51	2.7	19	1.9
Total pedestrian only accidents		536	28.0	96	9.6
Total accidents		1915	100.0	1002	100.0

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 entering the junction.

(iv) average pedestrian involvement rate: the average number of pedestrians involved in accidents per 100 million pedestrians crossing the arms of the junction. The pedestrian flows used in calculating the pedestrian involvement rates in this paper are simply the 12-hour (7am - 7pm) counts times the number of junction 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 SEVERITY

Table 8 shows the severity of the accidents for the different types of junction. Accident severity, defined as the percentage of injury accidents that involve fatal or serious injury, was 22.7 per cent across all junctions. This is similar to a mean severity on built-up roads in GB in 1989 of 20.1 per cent (Department of Transport, 1990).

The lowest accident severity was at 30 mph right/left staggered junctions (18.8 per cent) and the highest severity was at 40 mph left/right staggered junctions (30.0 per cent).

The overall accident severity at the crossroads (22.4 per cent) was similar to that at the staggered junctions (23.6 per cent).

For vehicle-only accidents, the severity of injury (19.5 per cent) was lower than for pedestrian accidents (34.3 per cent); the higher level of severity in pedestrian accidents reflecting the vulnerability of pedestrians to injury following a collision with a vehicle.

TABLE 8

Accident severity

Type of junction		Fatal	Serious	Slight	Total	Percentage fatal & serious
			Number of accidents			
Cross roads	30 mph	15	377	1395	1787	21.9 (1.0)
	40 mph	9	74	251	334	24.9 (2.4)
Left/right stagger	30 mph	3	86	255	344	25.9 (2.3)
	40 mph	1	14	35	50	30.0 (6.5)
Right/left stagger	30 mph	2	56	251	309	18.9 (2.2)
	40 mph	0	26	67	93	28.0 (4.6)
Crossroads		24	451	1646	2121	22.4 (0.9)
Staggered junction		6	182	608	796	23.6 (1.5)
30 mph		20	519	1901	2440	22.1 (0.8)
40 mph		10	114	353	477	26.0 (2.0)
All junctions:						
Vehicle-only accidents		11	435	1839	2285	19.5 (0.8)
Pedestrian accidents		19	198	415	632	34.3 (1.9)
Total accidents		30	633	2254	2917	22.7 (0.8)

( ) All figures in brackets are standard errors of the mean values

The overall accident severity at the 40 mph junctions (26.0 per cent) was slightly higher than the severity at the 30 mph junctions (22.1 per cent). In each case the accident severity of 40 mph junctions was about 5 per cent above the severity of the corresponding 30 mph junctions. The difference in accident severity at the 40 mph and 30 mph junctions was statistically significant at the 5 per cent level. The difference in severity of injury between 30 mph and 40 mph junctions was much greater for pedestrians accidents (33.1 and 44.8 per cent respectively) than for vehicle-only accidents (18.8 and 22.9 per cent respectively).

The accident severity at the priority crossroads and staggered junctions was similar to that found in the study of priority T-junctions. At 40 mph T-junctions the accident severity was 24.2 per cent and at 30 mph T-junctions it was 22.4 per cent (Summersgill, Kennedy and Baynes, 1996).

7.3 ACCIDENT FREQUENCY

Table 9 gives the number and average frequency of the accidents at the 300 junctions. Accident frequencies are heavily dependent on traffic and pedestrian flows, features, and geometric variables and therefore it is not possible to properly assess accident risk between junctions without taking all these factors into account. Differences in accident frequencies may reflect differences in accident risk but this cannot be determined without a full analysis (Sections 8, 9, 10 and 11).

The average accident frequency for the 300 site sample of crossroads and staggered junctions was 1.64 PIA per junction-year. As has been stated in Section 7.1, this value will be influenced by the sample bias towards sites with higher vehicle and pedestrian flows and particular junction characteristics and it is likely that the accident average frequency for the national population of crossroads and staggered junctions will be lower than this.

The 30 mph crossroads had the highest average accident frequency (1.88 PIA per year) and the 40 mph staggered junctions the lowest average accident frequency (0.93 PIA per year). There was little difference in average accident frequencies between left/right staggered junctions and right/left staggered junctions.

The average accident frequency for all crossroads (1.78 PIA per year) was higher than that for all staggered junctions (1.37 PIA per year). The accident frequency for all 30 mph junctions (1.77 PIA per year) was higher than that for all 40 mph junctions (1.20 PIA per year).

The average accident frequency (1.64 PIA per year) for the 300 site sample of crossroads and staggered junctions was higher than the average accident frequency (0.85 PIA per

TABLE 9

Number and frequency of accidents

Type of junction		No. of sites	Site years	No. of accidents	Accidents per site year
Cross roads	30 mph	161	951.3	1787	1.88 (0.04)
	40 mph	41	242.2	334	1.38 (0.08)
Left/right stagger	30 mph	39	230.6	344	1.49 (0.08)
	40 mph	8	52.2	50	0.96 (0.14)
Right/left stagger	30 mph	33	197.0	309	1.57 (0.09)
	40 mph	18	102.2	93	0.91 (0.09)
Crossroads		202	1193.5	2121	1.78 (0.04)
Staggered junctions		98	582.2	796	1.37 (0.05)
30 mph		233	1378.9	2440	1.77 (0.04)
40 mph		67	396.8	477	1.20 (0.05)
All junctions		300	1775.7	2917	1.64 (0.03)

( ) All figures in brackets are standard errors of the mean values

year) for the 300 site sample of T-junctions and lower than the average accident frequency (2.65 PIA per year) for the 177 site sample of 30 mph four-arm urban traffic signals (Hall, 1986).

Table 10 gives an indication of the effects of the main features of crossroad and staggered junctions on accident frequency.

In general those junctions with a pedestrian crossing on the major arm had higher average accident frequencies than other junctions. For 30 mph junctions, the average accident frequency at junctions with a pelican (2.08) or a zebra (2.17) was about 50 per cent higher than that at junctions with no junction features (1.37). Junctions with islands (on the major or minor arms) had a higher average accident frequency (1.72) than the no feature sites (1.37). Junctions with hatching alone (on the major or minor arms) had a

TABLE 10

Accidents by main junction features

Junction features	Number of junctions		Number of accidents		Accidents per year per site	
	30mph	40mph	30mph	40mph	30mph	40mph
Pelican crossing[1]	44	3	545	39	2.08	2.36
Zebra crossing[2]	48	4	607	28	2.17	1.20
Islands alone	67	11	637	86	1.72	1.30
Islands and hatching	21	6	188	24	1.62	0.79
Hatching alone	15	6	90	45	1.12	1.54
No junction features	48	40	373	255	1.37	1.10
All junctions	243	70	2440	477	1.77	1.20

1 includes junctions with pelicans and islands (kerbed or hatched)
2 includes junctions with zebras and islands (kerbed or hatched)

lower average accident frequency (1.12) than the no feature sites.

The differences in accident frequency at the 40 mph junctions are less reliable because of the small number of junctions and few accidents. The accident frequencies at those 40 mph junction types that were well represented in the sample were less than at the corresponding 30 mph junctions.

7.4 ACCIDENT RATES

Table 11 shows the average 24 hour vehicle inflow to the junctions, the average 12-hour pedestrian flow across the junction arms and the accident rate per 10^8 vehicles entering a junction.

The average vehicle flows are very similar at around 15,000 vehicles for each of the different types of junction. The lack of variation in average vehicle flow means that the distribution of accident rate across the crossroads and staggered junctions is very similar to that for accident frequency.

The average accident rate at staggered junctions (23.2 PIA per 10^8 vehicles) was less than the average accident rate at crossroads (33.0). The average accident rate for left/right staggered junctions was similar to the average accident rate for right/left staggered junctions.

As has been stated in Section 6.2, there were large differences in the average 12-hour flow of pedestrians at 30 mph and at 40 mph junctions. The lower pedestrian flows result in a smaller proportion of pedestrian accidents at 40 mph junctions and contribute towards the lower overall accident rates at these sites.

The overall accident rate of 31.9 PIA per 10^8 vehicles for 30 mph priority crossroads and staggered junctions was similar to the value of 34.4 accidents per 10^8 vehicles found for 30 mph urban four-arm traffic signals and about twice the value of 15.1 accidents per 10^8 vehicles found for a 300 site sample of priority T-junctions.

	Accident frequency	Accident rate
Urban traffic signals (30 mph)	2.65	34.4
Priority crossroads (30 mph)	1.77	31.9
Priority T-junction (30 mph)	0.89	15.1

Similarities in the average accident rate per total vehicle inflow at urban traffic signals and priority cross roads should not be regarded as definite evidence of similar safety performance as it is likely that the proportion of traffic on the minor arms is higher at urban traffic signals and hence there will be more traffic interactions at these sites.

Accident predictive models for urban 4-arm junctions, that include vehicle flow interactions, and compare traffic signals and priority junctions, are given in Section 9.7.

TABLE 11

Vehicle flow, pedestrian flow and accident rate

Type of junction		No. of sites	Average 24 hour vehicle flow	Average 12 hour pedestrian flow	Accidents per 100 million vehicles
Cross roads	30 mph	161	14491	1977	35.5 (0.84)
	40 mph	41	15700	405	24.0 (1.31)
Left/right stagger	30 mph	39	16898	1511	24.2 (1.31)
	40 mph	8	14599	292	18.0 (2.55)
Right/left stagger	30 mph	33	16549	3078	26.0 (1.48)
	40 mph	18	14311	456	17.4 (1.80)
Crossroads		202	14737	1658	33.0 (0.72)
Staggered junction		98	16118	1745	23.2 (0.82)
30 mph		233	15188	2056	31.9 (0.65)
40 mph		67	15197	403	21.7 (0.99)
All junctions		300	15190	1687	29.6 (0.55)

( ) All figures in brackets are standard errors of the mean values

Table 12 compares the accident severity, frequency and rate between regions. Accident frequency was much higher in London (2.32 accidents per junction per year) than the overall average accident frequency (1.64). London also had the highest accident rate (37.4 accidents per 100 million vehicles) compared to an average of 29.6. The accident severity in London (22.6 per cent fatal and serious) was similar to the overall average severity (22.7).

Accident frequencies were lower than the overall average in Wales (0.88), Eastern (1.17), Northern (1.26), Yorks and Humberside (1.28) and East Midlands (1.40). These regions also had lower accident rates than the overall average: Wales (17.9), Eastern (23.5), Northern (25.3), Yorks and Humberside (22.0) and East Midlands (23.9). The estimates of frequencies and rates for Eastern and Wales are less reliable as they are based on fewer sites and hence fewer accidents than the other regions.

7.5 ACCIDENT GROUPS

Table 13 shows the number and percentage of accidents by accident group for crossroads and staggered junctions. Left/right and right/left staggered junctions have been grouped together to avoid percentages based on small accident numbers.

An accident was defined as a vehicle accident if the primary cause or first impact did not involve a pedestrian. Thus some of the vehicle accidents may contain pedestrian casualties, in particular, the category 'single vehicle' contain accidents in which bus passengers were injured. Some vehicle drivers/riders were injured in pedestrian accidents and a small number of the pedestrian accidents involve a pedestrian but do not have a pedestrian casualty.

The categories of accident that formed the highest proportion of accidents were right angle (31 per cent), right turn minor (12 per cent), right turn major (12 per cent) rear end shunt and lane changing (11 percent) and pedestrian nearside on major (11 per cent).

The proportion of total accidents that were classified as vehicle accidents was similar for crossroads and for staggered junctions at about 75 per cent for 30 mph junctions and 85 per cent for 40 mph junctions. As might be expected, staggered junctions had a higher proportion of 'right turn minor' and a lower proportion of 'right angle' than crossroads. 30 mph staggered junctions had a higher proportion of 'rear end shunt and lane changing' than 30 mph crossroads.

The 40 mph junctions had a smaller proportion of the total accidents classified as pedestrian accidents than the 30 mph junctions. The pedestrian accident category 'offside on major' had similar proportions (about 6 per cent) across the different types of junction but for the other categories of pedestrian accidents the proportion at 40 mph junctions was generally about half that at the corresponding 30 mph junctions.

Table 14 presents average accident severity by accident group. For vehicle-only accidents, the severities of rear shunt and lane changing accidents (10.8 per cent fatal or serious) and left turn from major (12.8) were relatively low, whilst the severities of right turn from major (24.0) and

TABLE 12

Vehicle flow, pedestrian flow and accident rate

Region	Number of accidents	Accident severity % fatal & serious		Accident frequency per jn year		Accident rate per 100 million vehicles	
London	1082	22.6	(1.3)	2.32	(0.07)	37.4	(1.1)
South East	313	25.6	(2.5)	1.57	(0.09)	29.7	(1.7)
South West	133	15.0	(3.1)	1.40	(0.12)	31.3	(2.7)
Eastern	77	35.1	(5.4)	1.17	(0.13)	23.5	(2.7)
East Midlands	157	24.2	(3.4)	1.40	(0.11)	23.9	(1.9)
West Midlands	340	25.6	(2.4)	1.56	(0.08)	27.4	(1.5)
Yorks & Humb	324	19.1	(2.2)	1.28	(0.07)	22.0	(1.2)
North West	195	17.9	(2.7)	1.65	(0.12)	33.7	(2.4)
Northern	141	20.6	(3.4)	1.26	(0.11)	25.3	(2.1)
Wales	58	24.1	(5.6)	0.88	(0.12)	17.9	(2.4)
Scotland	97	27.8	(4.5)	1.38	(0.14)	30.2	(3.1)
Total	2917	22.7	(0.8)	1.64	(0.03)	29.6	(0.5)

( ) All figures in brackets are standard errors of the mean values

TABLE 13

Number of accidents by accident group

Accident group	Crossroads				Staggered junctions			
	30 mph		40 mph		30 mph		40 mph	
	no.	%	no.	%	no.	%	no.	%
Vehicle accidents:								
Single vehicle	95	5.3	9	2.7	47	7.2	3	2.1
Rear end shunt & lane changing	144	8.1	44	13.2	95	14.5	22	15.4
Right angle	650	36.4	121	36.2	103	15.8	28	19.6
Right turn major	184	10.3	54	16.2	76	11.6	23	16.1
Right turn minor	186	10.4	38	11.4	100	15.3	35	24.5
Left turn major	23	1.3	3	1.0	11	1.7	2	1.4
Left turn minor	48	2.7	7	2.1	14	2.1	3	2.1
Head on & U turn	29	1.6	7	2.1	7	1.1	3	2.1
Parked & parking	34	1.9	1	0.3	16	2.5	4	2.8
Reversing & private drive	9	0.5	3	0.9	4	0.6	0	0.0
Total vehicle	1402	78.2	287	85.9	473	72.4	123	86.0
Pedestrian accidents:								
Offside on major	121	6.8	18	5.4	40	6.1	9	6.3
Nearside on major	187	10.5	21	6.3	91	13.9	9	6.3
Offside on minor	13	0.7	5	1.5	15	2.3	0	0.0
Nearside on minor	30	1.7	0	0.0	15	2.3	1	0.7
Other pedestrian	34	1.9	3	0.9	19	2.9	1	0.7
Total pedestrian	385	21.5	47	14.1	180	27.6	20	14.0
All types	178	100.0	334	100.0	653	100.0	143	100.0

parked/parking were relatively high (23.6). For pedestrian accidents, the severity of accidents involving pedestrians crossing the major arms (about 37 per cent fatal or serious) was higher than for pedestrians crossing the minor arms (about 22 per cent fatal or serious).

7.6 ROAD USER INVOLVEMENT

7.6.1 Accidents by class of user involved

Table 15 shows the percentage of all accidents that involve road users from a particular class including pedestrians. It is important to note that in general, a single accident will involve more than one user class.

The proportions of vehicle accidents that involved pedal cyclists (17 per cent) and motor cyclists (27 per cent) were much higher than the proportion of these types of vehicle in the total flow (2 per cent for both pedal cyclists and motor cyclists). The proportions of vehicle accidents that involved light goods vehicles (10 per cent), heavy goods vehicles (3 per cent) and public service vehicles (5 per cent) were generally similar to or slightly higher than the proportions of these types of vehicles in the total flow (8, 4 and 2 per cent respectively).

The proportion of pedestrian accidents involving motor cyclists (9 per cent) was about four times the proportion of motor cyclists in the total flow. The proportions of pedestrian accidents involving pedal cyclists (3 per cent), light goods vehicles (5 per cent), heavy goods vehicles (1 per cent) and public service vehicles (2 per cent) were generally similar to or slightly less than their respective proportions in the total flow.

Table 15 also shows the distribution of accidents for each user class between the various accident groups.

TABLE 14

Accident severity by accident group

Accident group	Number of accidents: Fatal	Serious	Slight	Total	Accident severity % fatal & serious	
Vehicle:						
Single vehicle	0	30	124	154	19.5	(3.2)
Rear shunt & lane chg.	2	31	272	305	10.8	(1.8)
Right angle	6	179	717	902	20.5	(1.3)
Right turn from major	2	79	256	337	24.0	(2.3)
Right turn from minor	1	79	279	359	22.3	(2.2)
Left turn from major	0	5	34	39	12.8	(5.4)
Left turn from minor	0	11	61	72	15.3	(4.2)
Head-on and U-turn	0	7	39	46	15.2	(5.3)
Parked vehicle	0	13	42	55	23.6	(5.7)
Revers. & Private drive	0	1	15	16	6.3	(6.1)
Total vehicle	11	435	1799	2285	19.5	(0.8)
Pedestrian:						
Offside on major	6	67	115	188	38.8	(3.6)
Nearside on major	12	99	197	308	36.0	(2.7)
Offside on minor	0	7	26	33	21.2	(7.1)
Nearside on minor	0	11	35	46	23.9	(6.3)
Other pedestrian	1	14	42	57	26.3	(5.8)
Total pedestrian	19	198	415	632	34.3	(1.9)
Total	30	633	2254	2917	22.7	(0.8)

( ) All figures in brackets are standard errors of the mean values

The percentage of accidents involving cars or taxis that were 'pedestrian' (20 per cent) was substantially higher than for other classes of vehicle. All vehicle classes except public service vehicles had a similar involvement in right angle accidents at about 35 per cent. The distribution of accidents for public service vehicles is distorted by the high involvement in single vehicle accidents caused by injury to passengers falling within the vehicles.

For accidents involving pedal cyclists, the distribution of vehicle accidents was similar to that for cars except for 'right turn from major' (20 per cent), 'left turn from major' (5 per cent) and 'left turn from minor' 6 per cent) which were substantially higher than the percentage for cars (12 per cent, 1 per cent and 3 per cent respectively). For accidents involving motor cycles, 'right turn from major' (20 per cent) and 'right turn from minor' (20 per cent) were higher than the respective percentages for cars (12 per cent and 13 per cent).

The percentage of accidents involving heavy goods vehicles that were 'rear shunt or lane changing' (21 per cent) was higher and the percentage for 'right turn from major' (5 per cent) was lower than the respective percentages for cars (11 and 12 per cent). However, the number of accidents involving HGVs was small (75) and the 95 per cent confidence limits for the percentages of the above HGV accident groups are relatively large at 9 and 5 per cent respectively.

7.6.2 Accident involvement rates

Table 16 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 motorcycle classes. Pedal cycles account for 7 per cent of involvements, motor cycles 12 per cent of involvements, public service vehicles 2 per cent and pedestrians 11 per cent.

Table 16 also shows the accident involvement rates for the junctions by road user class and accident group. The involvement rates for pedal cyclists and motor cyclists were higher than those for cars. For total accidents, the

TABLE 15

Accidents by class of user involved and accident group

	Accidents involving a:							All accidents
	Pedal cycle	Motor cycle	Car & taxi	LGV	HGV	PSV	Pedest -rian	
Number of accidents (percentage of total)								
Vehicle:	381 (16.7)	606 (26.5)	2101 (90.1)	225 (9.8)	66 (2.8)	117 (5.1)	17 (0.7)	2285 (100.0)
Pedestrian:	19 (3.0)	54 (8.5)	519 (82.1)	33 (5.2)	9 (1.4)	15 (2.4)	632 (100)	632 (100.0)
Total:	400 (13.7)	660 (22.6)	2620 (89.8)	258 (8.8)	75 (2.6)	132 (4.5)	649 (22.2)	2917 (100.0)
Percentage by accident group								
Vehicle:								
Single vehicle	2	4	3	2	1	39	0	5.3
Rear shunt & lane chg.	10	8	11	12	21	7	1	10.5
Right angle	33	32	33	36	35	21	1	30.9
Right turn from major	20	20	12	12	5	2	0	11.6
Right turn from minor	14	20	13	14	11	8	0	12.3
Left turn from major	5	1	1	1	0	2	0	1.3
Left turn from minor	6	3	3	2	4	2	0	2.5
Head-on and U-turn	1	2	2	3	5	3	0	1.6
Parked vehicle	4	1	2	5	4	4	1	1.9
Revers. & Private drive	0	1	1	1	1	1	0	0.5
Total vehicle	95	92	80	87	88	89	3	78.3
Pedestrian:								
Offside on major	1	2	6	3	1	1	29	6.4
Nearside on major	3	4	10	6	7	5	48	10.6
Offside on minor	0	0	1	0	0	2	5	1.1
Nearside on minor	1	1	1	1	1	2	7	1.6
Other pedestrian	0	0	2	3	3	2	9	2.0
Total pedestrian	5	8	20	13	12	11	97	21.7
Total	100	100	100	100	100	100	100	100.0

involvement rate for pedestrians appears to be similar to the involvement rate for cars & taxis. However, they are not directly comparable (see Table 16 note 1).

Vehicle accidents: For vehicle accidents, the ratios of the rates for individual classes of vehicles to the rate for cars & taxis (1.0) was as follows: pedal cyclists (4.2), motor cyclists (8.2), light goods vehicles (0.7), heavy goods vehicles (0.5), and public service vehicles (1.7). About 85 per cent of the pedal cyclists and motor cyclists that were involved in right angle or turning accidents were travelling straight ahead on the major road and hit by turning traffic.

Pedestrian accidents: For pedestrian accidents, the ratios of the rates for individual classes of vehicles to the rate for cars & taxis (1.0) was as follows: pedal cyclists (1.3), motor cyclists (4.5), light goods vehicles (0.6), heavy goods vehicles (0.4), and public service vehicles (1.3).

TABLE 16

Vehicles and pedestrians involved in accidents and involvement rates[1] by accident group

	Accidents involving a:						
	Pedal cycle	Motor cycle	Car & taxi	LGV	HGV	PSV	Pedest -rian[2]
Number of involvements	403	667	3817	270	80	133	669
(percentage of total)	6.7	11.0	63.2	4.5	1.3	2.2	11.1
Involvement rate by accident group							
Single vehicle	4.1	15.9	0.9	0.5	0.3	29.1	0.2
	(0.20)	(0.62)	(0.01)	(0.03)	(0.03)	(2.5)	(0.01)
Rear shunt & lane	18.6	30.7	6.5	3.9	4.6	5.1	0.4
changing	(0.93)	(1.2)	(0.11)	(0.24)	(0.51)	(0.44)	(0.02)
Right angle	60.8	115.0	17.3	12.2	7.6	16.0	0.4
	(3.03)	(4.5)	(0.28)	(0.74)	(0.85)	(1.4)	(0.02)
Right turn from major	37.2	71.7	5.6	4.6	1.1	1.7	0.1
	(1.85)	(2.8)	(0.09)	(0.28)	(0.12)	(0.15)	(0.00)
Right turn from minor	25.9	70.6	6.4	4.9	2.4	6.3	0.1
	(1.29)	(2.7)	(0.10)	(0.30)	(0.27)	(0.55)	(0.00)
Left turn from major	9.5	5.5	0.6	0.3	0.0	1.1	0.0
	(0.47)	(0.21)	(0.01)	(0.02)	(0.0)	(0.10)	(0.00)
Left turn from minor	10.4	9.9	1.2	0.6	0.8	1.7	0.0
	(0.52)	(0.38)	(0.02)	(0.04)	(0.09)	(0.15)	(0.00)
Head-on and U-turn	0.9	6.6	0.9	1.0	1.4	2.9	0.1
	(0.04)	(0.26)	(0.01)	(0.06)	(0.16)	(0.25)	(0.00)
Parked vehicle	6.8	4.9	1.0	1.8	0.8	2.9	0.6
	(0.34)	(0.19)	(0.02)	(0.11)	(0.09)	(0.25)	(0.02)
Revers. & Private drive	0.0	4.9	0.2	0.3	0.3	0.6	0.0
	(0.0)	(0.19)	(0.0)	(0.02)	(0.03)	(0.05)	(0.00)
TOTAL VEHICLE	174.4	335.6	40.6	30.0	19.2	67.4	1.7
	(8.7)	(13.0)	(0.66)	(1.83)	(2.2)	(5.84)	(0.07)
Pedestrian offside on major	1.8	8.8	2.0	1.0	0.3	0.6	17.5
	(0.09)	(0.34)	(0.03)	(0.06)	(0.03)	(0.05)	(0.68)
Pedestrian nearside on major	5.4	15.3	3.2	1.9	1.4	3.4	29.0
	(0.27)	(0.59)	(0.05)	(0.12)	(0.16)	(0.29)	(1.1)
Pedestrian offside on minor	0.5	1.1	0.3	0.1	0.0	1.7	3.1
	(0.02)	(0.04)	(0.0)	(0.01)	(0.00)	(0.15)	(0.12)
Pedestrian nearside on minor	0.9	3.3	0.5	0.3	0.3	1.1	4.2
	(0.04)	(0.13)	(0.01)	(0.02)	(0.03)	(0.10)	(0.16)
Other pedestrian	0.0	1.1	0.6	0.9	0.5	1.7	5.7
	(0.0)	(0.04)	(0.01)	(0.05)	(0.06)	(0.15)	(0.22)
TOTAL PEDESTRIAN	8.6	29.6	6.6	4.2	2.4	8.6	59.4
	(0.43)	(1.2)	(0.11)	(0.26)	(0.27)	(0.75)	(2.3)
TOTAL	183.0	365.2	47.2	34.2	21.7	76.0	61.2
	(9.1)	(14.1)	(0.76)	(2.1)	(2.4)	(6.6)	(2.4)

( ) All figures in brackets are standard errors of the mean values

TABLE 16 (CONTINUED)

	Accidents involving a:						
	Pedal cycle	Motor cycle	Car & taxi	LGV	HGV	PSV	Pedest -rian[2]
Involvement rate:							
All crossroads	209.1 (12.2)	364.1 (17.0)	53.8 (1.0)	40.6 (2.8)	26.1 (3.3)	74.1 (8.0)	63.5 (3.0)
All left/right staggered junctions	135.4 (17.4)	339.9 (33.5)	34.8 (1.6)	21.0 (4.0)	14.7 (4.7)	100.1 (18.9)	76.7 (7.6)
All right/left staggered junctions	140.8 (19.7)	398.9 (38.7)	35.4 (1.6)	22.4 (4.0)	13.3 (4.4)	61.6 (14.1)	45.3 (4.4)
All 30mph junctions	177.0 (9.4)	358.2 (15.0)	49.7 (0.89)	36.0 (2.4)	19.7 (2.8)	78.8 (7.3)	57.7 (2.9)
All 40mph junctions	250.2 (37.3)	411.1 (41.3)	39.0 (1.5)	27.9 (4.0)	25.6 (4.6)	59.6 (15.4)	121.6 (14.3)
TOTAL	183.0 (9.1)	365.1 (14.1)	47.2 (0.76)	34.2 (2.1)	21.7 (2.4)	76.0 (6.6)	61.1 (2.4)

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 a junction. The pedestrian flows used in calculating the pedestrian involvement rates are simply the 12-hour (7 am - 7 pm) counts times the number of junction 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 The number of pedestrian involvements was generally taken from the number of pedestrian casualties. A few pedestrians were injured in secondary collisions associated with non-pedestrian accidents. Some pedestrian accidents did not involve injury to pedestrians. For these cases, the number of pedestrian involvements was taken as one.

30 mph and 40 mph junctions: For cars and taxis, light goods vehicles and public service vehicles, the accident involvement rates at 40 mph junctions were about 20 per cent lower than those at 30 mph junctions. For vulnerable road users: pedal cycles, motor cycles and pedestrians, the accident involvement rates at 40 mph junctions were higher than those at 30 mph junctions by 41, 14 and 110 per cent respectively.

Crossroads/staggered junctions: For pedal cyclists, cars & taxis, light goods vehicles and heavy goods vehicles, the accident involvement rates at staggered junctions were generally about 35 per cent lower than the rates at crossroads. For motor cyclists, public service vehicles and pedestrians the rates were similar at staggered junctions and crossroads. The accident involvement rates at left/right staggered junctions were generally similar to the equivalent rates at right/left staggered junctions.

7.7 ACCIDENTS BY NUMBERS OF CASUALTIES

Table 17 shows the number of casualties in vehicle and pedestrian accidents at the different types of junction.

The average number of casualties in vehicle accidents at 30 mph crossroads (1.28) was lower than at 40 mph crossroads (1.41). This pattern was repeated for pedestrian accidents but with lower average numbers (1.05 and 1.11). The average numbers of casualties in accidents at staggered junctions were very similar to those for crossroads.

Over all junctions, 84 per cent of the accidents involved only one casualty and the average number of casualties per accident was 1.24. This is similar to National values for built up roads in 1989 (84.5 per cent and 1.22 casualties per accident) (Department of Transport, 1990).

TABLE 17

Number of casualties by main type of accident

Accident type	Average number of casualties					
	Crossroads		Left/right stagger		Right /left stagger	
	30mph	40mph	30mph	40mph	30mph	40mph
Total vehicle	1.28	1.41	1.23	1.42	1.23	1.29
Total pedestrian	1.05	1.11	1.08	1.14	1.08	1.08
All types	1.24	1.37	1.19	1.38	1.18	1.26

Table 18 gives the number of casualties by accident group. Head-on and U-turn had the highest number of casualties per accident (1.50) followed by right angle accidents (1.39), right turn from minor (1.26), left turn from minor (1.25) and right turn from major (1.24). Other accident groups had less than the average number of casualties per accident (1.24).

7.8 ACCIDENTS BY THE NUMBER OF VEHICLES INVOLVED

Table 19 shows the distribution of accidents by the numbers of vehicles involved in accidents. Over all the study junctions, 25 percent of accidents involved only one

TABLE 18

Number of casualties by accident group

Accident group	Number of accidents	Average number of casualties			
		Fatal	Serious	Slight	Total
Vehicle:					
Single vehicle	154	0.000	0.214	0.916	1.130
Rear shunt & lane chg.	305	0.007	0.111	1.082	1.200
Right angle	902	0.008	0.238	1.142	1.388
Right turn from major	337	0.006	0.237	1.000	1.243
Right turn from minor	359	0.003	0.242	1.019	1.265
Left turn from major	39	0.000	0.128	0.897	1.026
Left turn from minor	72	0.000	0.153	1.097	1.250
Head-on and U-turn	46	0.000	0.174	1.326	1.500
Parked vehicle	55	0.000	0.309	0.909	1.218
Revers. & Private drive	16	0.000	0.125	1.063	1.188
Total vehicle	2285	0.005	0.215	1.070	1.291
Pedestrian:					
Offside on major	188	0.032	0.362	0.660	1.053
Nearside on major	308	0.039	0.331	0.705	1.075
Offside on minor	33	0.000	0.212	0.818	1.030
Nearside on minor	46	0.000	0.261	0.783	1.043
Other pedestrian	57	0.018	0.246	0.842	1.105
Total pedestrian	632	0.030	0.321	0.715	1.066
Total	2917	0.011	0.238	0.993	1.242

TABLE 19

Distribution of accidents by number of vehicles involved

Type of junction		No. of accidents	Percentage by number of vehicles 1	2	3	4	5
Crossroads	30 mph	1787	25.3	66.8	7.1	0.7	0.1
	40 mph	334	15.3	71.0	10.5	2.4	0.9
Left/right stagger	30 mph	344	31.1	59.0	8.4	1.5	0.0
	40 mph	50	16.0	72.0	12.0	0.0	0.0
Right/left stagger	30 mph	309	34.0	57.3	7.4	1.3	0.0
	40 mph	93	16.1	74.2	9.7	0.0	0.0
Total	30 mph	2440	27.2	64.5	7.3	0.9	0.1
	40 mph	477	15.5	71.7	10.5	1.7	0.6

vehicle. For 30 mph junctions, staggered junctions had a higher proportion of accidents involving only one vehicle (about 32 per cent) than crossroads (25 per cent). This is probably due to the higher proportion of accidents classified as pedestrian at 30 mph staggered junctions (see Table 13).

7.9 ACCIDENTS BY TIME PERIOD

Table 20 shows that the percentage of accidents in each year are very similar with a slightly lower percentage in 1985 and slightly higher percentages in 1988 and 1989. None of the differences are statistically significant.

The accident ratio for national statistics for 1984 to 1989 shows less variation than the accident ratio for the sample of 300 junctions and indicates a fairly constant level of accidents in built-up areas across the period.

Table 21 shows that the distribution of the accident ratio across the months for the sample of 300 junctions generally follows the distribution of the casualty ratio for the national statistics. The general pattern is fewer casualties at the beginning of the year and more casualties towards the end of the year. The largest discrepancies between the distributions occur in August and November. The 300 site sample

TABLE 20

Accidents by year 1984 to 1989

	1984	1985	1986	1987	1988	1989
Number of accidents	466	446	488	469	529	519
Percentage of total accidents	16.0	15.3	16.7	16.1	18.1	17.8
Accident frequency per junction year	1.55	1.49	1.63	1.56	1.76	1.73
Accident ratio[1]	0.96	0.92	1.00	0.96	1.09	1.07
National statistics[2]: accident ratio[1] for built-up roads	1.03	1.00	1.00	0.96	0.98	1.03

1. Accident ratio = $\frac{\text{Number of accidents for specific year}}{\text{Average number of accidents over 84-89}}$

2. Department of Transport, Road Accidents Great Britain 1990, Table 3, accidents on built-up roads

TABLE 21

Accidents by month over the years 1984 to 1989

Month	Number of accidents	Percentage of total accidents	Accident ratio[1]	National statistics[2]: casualty ratio
January	228	7.8	0.94	0.87
February	229	7.9	0.94	0.81
March	215	7.4	0.88	0.93
April	202	6.9	0.83	0.90
May	233	8.0	0.96	1.01
June	240	8.2	0.99	1.01
July	245	8.4	1.01	1.07
August	210	7.2	0.86	1.07
September	225	7.7	0.93	1.02
October	292	10.0	1.20	1.14
November	327	11.2	1.35	1.14
December	271	9.3	1.11	1.04

1. Accident ratio = $\frac{\text{Number of accidents for specific month}}{\text{Average number of accidents for all months}}$

2. Department of Transport, Road Accidents Great Britain 1985 to 1990, Table 27, casualties on all roads

has a smaller ratio value in August and a larger value in November than the national statistics.

Table 22 gives the proportion of accidents across individual days of the week and compares the accident ratio at the study junctions with the national ratio for driver involvement. The distributions of the two ratios are similar with low ratios on Sundays and high ratios on Fridays.

The study junctions had slightly fewer accidents on Sunday than would have been expected from the national statistics but this may be due to the fact that the national statistics relate to driver involvement on all roads while the study is concerned with accidents at junctions in built-up areas.

Table 23 shows the percentage of accidents by time of day for Saturday and Sunday and for Monday to Friday.

TABLE 22

Accidents by day of week over the years 1984 to 1989

Month	Number of accidents	Accident of total accidents	Percentage ratio[1]	National statistics[2]: driver ratio
Monday	414	14.2	0.99	0.97
Tuesday	434	14.9	1.04	0.96
Wednesday	439	15.0	1.05	0.98
Thursday	455	15.6	1.09	1.05
Friday	490	16.8	1.18	1.21
Saturday	410	14.1	0.98	1.03
Sunday	275	9.4	0.66	0.80

1. Accident ratio = $\frac{\text{Number of accidents for specific day of week}}{\text{Average number of accidents for all days}}$

2. Department of Transport, Road Accidents Great Britain 1985 to 1990, Table 35, drivers involved in accidents on all roads

TABLE 23

Accidents by time of day and day of week over the years 1985 to 1990

Time period	Saturday and Sunday Percentage of: Accidents	Saturday and Sunday Percentage of: Casualties (National statistics[1])	Monday to Friday Percentage of: Accidents	Monday to Friday Percentage of: Casualties National statistics[1])
00-02h	6.0	7.5	1.5	2.2
02-04h	3.8	3.8	0.5	0.9
04-06h	1.2	1.2	0.7	0.8
06-08h	1.8	2.1	5.5	5.6
08-10h	6.3	4.9	15.8	12.4
10-12h	9.3	10.2	9.0	8.9
12-14h	14.9	12.9	9.4	10.9
14-16h	13.6	14.4	12.8	12.3
16-18h	13.1	13.4	18.1	17.5
18-20h	11.4	10.9	12.1	11.8
20-22h	9.5	8.5	7.7	8.5
22-24h	9.2	10.2	6.9	8.3

1. Department of Transport, Road Accidents in Great Britain 1985 to 1990, Table 28, casualties on all roads

The distribution of accidents by time of day at the study junctions was similar to the national distribution in the numbers of casualties.

7.10 ACCIDENTS BY LIGHT, WEATHER AND ROAD SURFACE CONDITIONS

Table 24 shows that the percentage of accidents occurring in rain, in snow or fog, on a wet surface or one covered with snow or ice, on a lit or unlit road at night were similar to the percentages of accidents occurring in these conditions nationally on built-up roads during the same period.

8. REGRESSION ANALYSIS

8.1 METHOD

The objective of the analysis is to relate the accident frequency (the average number of accidents per year) at the junctions to a range of 'explanatory variables', thus providing a model for examining the effect of vehicle and pedestrian flow and junction 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 these 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 junctions. 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, vehicle-only and pedestrian accident frequencies at the junctions to various functions of the traffic and pedestrian flows (Section 9);

(ii) relating accident frequency for each main accident group to various functions of the traffic flow (Section 10);

TABLE 24

Percentage of accidents by weather, road surface and lighting over the year 1985 to 1990

Junction type		No. of accidents	Percentage by condition				
			Weather		Road surface		Lighting
			Rain	Snow or fog	Wet	Snow or ice	Dark, lights[1] lit
Crossroads	30 mph	1787	18.0	1.2	33.5	1.1	31.3
	40 mph	334	16.8	2.4	38.6	3.0	28.7
Left/right stagger	30 mph	344	16.6	1.8	34.3	2.0	28.5
	40 mph	50	22.0	4.0	42.0	2.0	20.0
Right/left stagger	30 mph	309	15.2	1.6	32.4	1.0	26.9
	40 mph	93	12.9	2.2	29.0	4.3	23.7
Total	30 mph	2440	17.5	1.3	33.4	1.2	30.3
	40 mph	477	16.6	2.5	37.1	3.1	26.8
National statistics for built-up roads[2]		1129269	15.4	1.3	31.6	1.8	26.3

1. The category 'Dark - lights unlit' was 0.3 percent or less for all junction types.
2. Department of Transport, Road Accidents in Great Britain 1985 to 1990, Tables 14, 15 and 16, Accidents on built-up roads.

(iii) extending the best accident-flow models of (ii) to include the geometric variables and factors (Section 11).

At each of the first two stages, differences in accident frequency between the junctions were examined in terms of whether the junction was a crossroads or a staggered junction, whether the speed limit was 30 mph or 40 mph, whether the junction 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 aim only to produce models that are 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 plausible, measurable, physical variables and factors were 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.

8.2 SIGNIFICANCE TESTING

The aim of the modelling is 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 is fitted in a step-by-step procedure, starting with the 'null' model, which simply fits the mean value of the dependent variable. At each step, the statistic calculated is the 'scaled deviance' which gives 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 becomes the better is the fit of the model 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 junctions 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, for some of the groups the mean number of accidents per junction 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 paper.

A quasi-likelihood method has been used to take account of over-dispersion in the presence of low mean values. The procedure is as follows. Each model is 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 is 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 provides a revised estimate of the scale factor (s). The model parameters themselves are unchanged, but both the scaled deviance and the standard errors of the parameters are 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 paper the standard errors have already been scaled by the standard errors given.**

9. TOTAL ACCIDENT-FLOW MODELS

9.1 INTRODUCTION

The first stage of the modelling was to relate the total accident frequency at crossroads and staggered junctions to various functions of the vehicle and pedestrian flows. The basic unit of analysis here is *the whole junction*. The models given in Sections 9.4 to 9.6 predict accident frequency at the whole junction.

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

The same procedure was then carried out for vehicle-only accidents and pedestrian accidents.

9.2 THE FORM OF THE MODELS

9.2.1 Vehicle and pedestrian flows

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 *at the junction* (accidents per year),

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

k and 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 junction 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 junction.

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 junctions, 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.

In model (9.4), Q_a will generally represent a function of the individual vehicle flows (measured in thousands of vehicles per 24 hours), and Q_b a function of the individual pedestrian flows (measured in terms of thousands of pedestrians per 12-hour period).

The basic vehicle and pedestrian flows at a typical crossroads or staggered junction are illustrated in Figure 2. An extensive range of vehicle and pedestrian flow functions were tested in the total accident-flow models; the more important of these are defined in Table 25 and their minimum, mean and maximum values are given in Table 26.

Vehicle-only accidents do not involve pedestrians in the primary collision, and pedestrian flow may appear in vehicle-only 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 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 junction 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 which has the linear form:

$$\log(A.YR) = \log(YR) + \log(k) + \alpha \log(Q_a) + b\,(Q_b)^{\beta} \qquad (9.5)$$

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

9.2.2 Factors

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

$$\log(A.YR) = \log(YR) + \log(k) + \text{other terms} + \gamma D \qquad (9.6)$$

where D is the dummy variable relating to the second level of the factor and γ 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:

$$\log(A.YR) = \log(YR) + \log(k) + \text{other terms} + \alpha \log(Q_a) + \gamma D + \delta \log(Q_a)\,D \qquad (9.7)$$

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

The factors tested are given in Table 27.

9.3 MODELLING PROCEDURE

The first stage in the modelling process was to identify well fitting logical models including only the key vehicle flows and pedestrian flows. None of the factors representing junction categories or physical features were tested at this stage. The most suitable accident-flow models without factors are presented in Table 28.

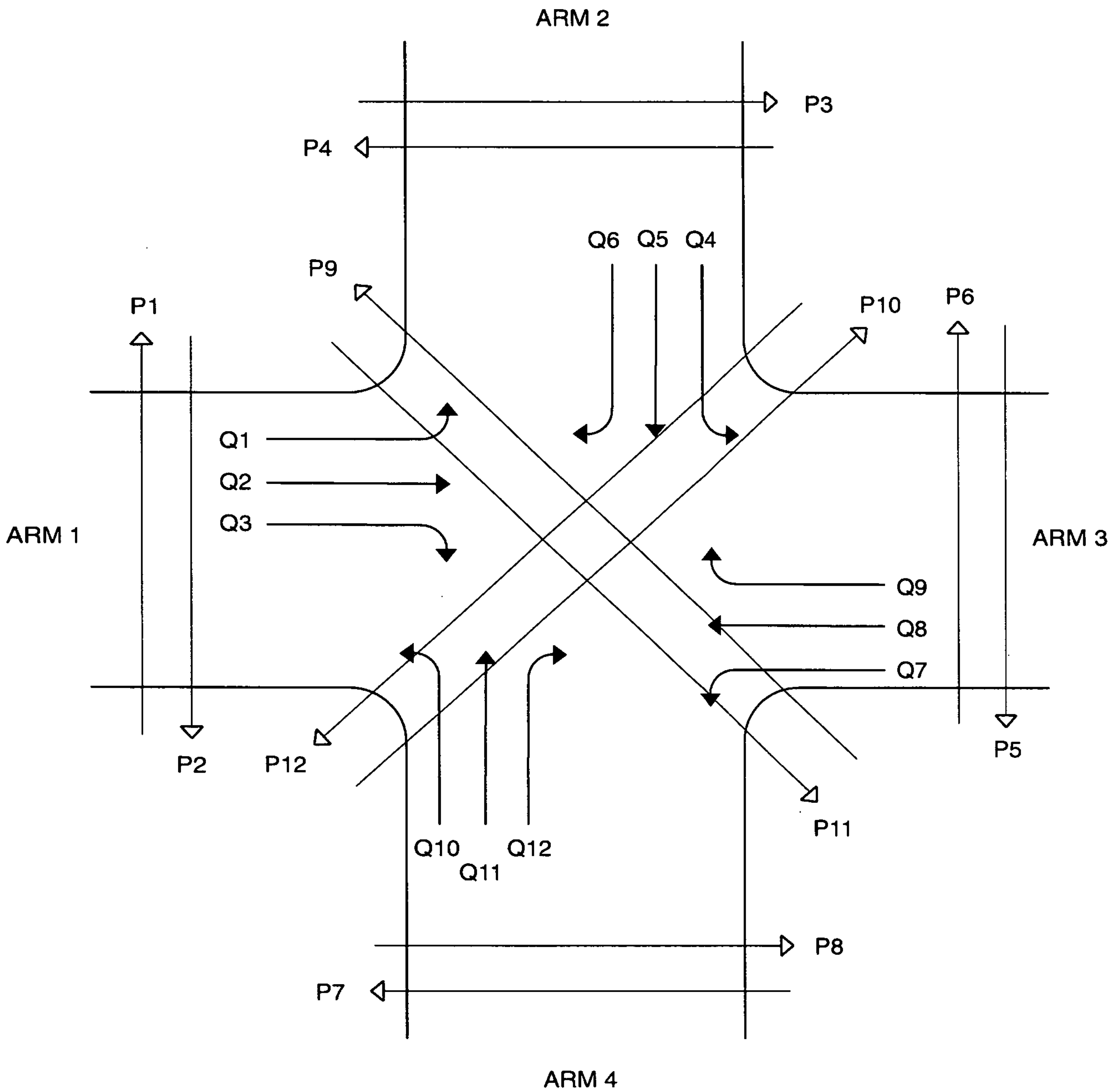


Figure 2 Vehicle and pedestrian flows at a priority crossroads or staggered junction

TABLE 25

Vehicle and pedestrian flow functions for total junction accident models

Vehicle flow functions:		
Major road inflow	QMA	= Q1+Q2+Q3+Q7+Q8+Q9
Minor road inflow	QMI	= Q4+Q5+Q6+Q10+Q11+Q12
Total junction inflow	QT	= QMA + QMI
Cross product flow	QC	= QMA.QMI
Crossing flow products	QX	= QH+QROA+QROI+QRVA+QRVI+QRR
where:		
Right angle products	QH	= (Q2+Q8).(Q5+Q11)
Right turn from major with opposite ahead products	QROA	= Q3.Q8 + Q9.Q2
Right turn from minor with opposite ahead products	QROI	= Q6.Q11 + Q12.Q5
Right turn from major with previous ahead products	QRVA	= Q3.Q11 + Q9.Q5
Right turn from minor with previous ahead products	QRVI	= Q6.Q2 + Q12.Q8
Right turn with right turn	QRR	= Q3.Q6 + Q3.Q9 + Q3.Q12 + Q6.Q9 + Q6.Q12 + Q9.Q12
Merging flow products	QMG	= QMGA + QMGI
where:		
Merging major flow products	QMGA	= Q6.Q8 + Q12.Q2 + Q4.Q2 + Q10.Q8
Merging minor flow products	QMGI	= Q3.Q5 + Q9.Q11 + Q1.Q11 + Q7.Q5
Diverging flow products	QD	= QDA + QDI
where:		
Diverging major flow prod.	QDA	= Q2(Q1+Q3) + Q8(Q7+Q9)
Diverging minor flow prod.	QDI	= Q5(Q4+Q6) + Q11(Q10+Q12)
Encounter products	QN	= QX + QMG + QD
Proportion of minor road inflow going straight ahead	PQMIS	= (Q5+Q11)/QMI
Proportion of minor road inflow making a right turn	PQMIR	= (Q6+Q12)/QMI
Pedestrian flow functions:		
Pedestrian flow across major arms	PTA	= P1+P2+P5+P6
Pedestrian flow across minor arms	PTI	= P3+P4+P7+P8
Pedestrian flow across junction centre	PX	= P9+P10+P11+P12
Total pedestrian flow	PT	= PTA+PTI+PX

TABLE 25 (CONTINUED)

Vehicle and pedestrian flow functions:

Sum of vehicle and pedestrian flows	QPT = QT + PT
Product of vehicle and pedestrian flows	QPU = QT.PT
Sum of products of vehicle inflow and pedestrian flow	QPV = QPVA + QPVI
where:	
Sum of products of vehicle inflow and pedestrian flow on major arms	QPVA = (Q1+Q2+Q3).(P1+P2) + (Q7+Q8+Q9).(P5+P6)
Sum of products of vehicle inflow and pedestrian flow on minor arms	QPVI = (Q4+Q5+Q6).(P3+P4) + (Q10+Q11+Q12).(P7+P8)
Sum of products of two-way vehicle flow and pedestrian flow	QPW = QPWA + QPWI
where:	
Sum of products of two-way vehicle flow and pedestrian flow on major arms	QPWA = (Q1+Q2+Q3+Q6+Q8+Q10).(P1+P2) + (Q7+Q8+Q9+Q12+Q2+Q4).(P5+P6)
Sum of products of two-way vehicle flow and pedestrian flow on minor arms	QPWI = (Q4+Q5+Q6+Q9+Q11+Q1).(P3+P4) + (Q10+Q11+Q12+Q3+Q5+Q7).(P7+P8)
Product of ahead vehicle flow on major and pedestrian crossing flow on major	QPSA = (Q2+Q8).(P1+P2+P5+P6)
Sum of crossing flow product and vehicle-pedestrian product on major arms	QPXV = QX + QPVA

Note: The vehicle flows Q1 to Q12 and the pedestrian flows P1 to P12 are all in thousands and are illustrated in Figure 2.

TABLE 26

Ranges for whole junction vehicle and pedestrian flow functions (313 units)

Flow Function	Min	Mean	Max
QMA	0.610	12.650	29.220
QMI	0.212	2.543	7.512
QT	1.600	15.190	31.090
QC	0.610	30.420	125.840
QX	0.320	16.330	68.740
QH	0.025	6.514	44.383
QROA	0.041	4.958	31.451
QROI	0.0002	0.279	3.386
QRVA	0.0003	0.488	6.181
QTVI	0.009	3.201	14.804
QRR	0.0057	0.887	6.796
QMG	0.340	14.250	55.530
QMGA	0.260	13.360	55.300
QMGI	0.0008	0.896	9.211
QD	0.170	10.290	43.700
QDA	0.050	9.458	43.502
QDI	0.0007	0.835	7.064
QN	0.830	40.870	146.960
PQMIS	0.003	0.282	0.746
PQMIR	0.030	0.275	0.801
PTA	0.011	0.604	4.124
PTI	0.015	1.018	14.014
PX	0.000	0.017	0.299
PT	0.045	1.638	14.864
QPT	1.750	16.830	35.170
QPU	0.240	26.990	301.830
QPV	0.056	5.276	40.959
QPVA	0.021	4.122	37.932
QPVI	0.007	1.154	15.667
QPW	0.110	10.530	80.470
QPWA	0.044	8.177	72.686
QPWI	0.011	2.355	38.873
QPSA	0.013	7.043	68.981
QPXV	0.339	20.451	78.168

TABLE 27

Factors for junction features (313 units)

Symbol	Description		Number
STJ	Staggered junction[1]	1 = crossroads	187
		2 = staggered jn	126
JTP	Junction type	1 = crossroads	187
		2 = left/right stgr.	66
		3 = right/left stgr.	60
SP	Speed limit	1 = 30 mph	243
		2 = 40 mph	70
LON	Sites within the DOT	1 = not in London	234
	London region	2 = in London	79
ZEB	Zebra on major	1 = absent	275
	(without island)	2 = present	38
ZIB	Zebra on major	1 = absent	299
	(with island)	2 = present	14
ZEBA	Zebra on major	1 = absent	261
	(with or without island)	2 = present	52
PEL	Pelican on major	1 = absent	267
	(without island)	2 = present	46
PIL	Pelican on major	1 = absent	312
	(with island)	2 = present	1
PELA	Pelican on major	1 = absent	266
	(with / without island)	2 = present	47
PZC	Pelican or zebra on major	1 = absent	214
	(with / without island)	2 = present	99
ISA	Island on major	1 = absent	247
	(no pelican or zebra)	2 = present	66
ISI	Island on minor	1 = absent	274
	(no pelican or zebra)	2 = present	39
HCHA	Hatching on both major	1 = absent	292
	arms but no island	2 = present	21
HCHI	Hatching on one or both	1 = absent	308
	minor arms only	2 = present	5

1 STJ - a junction was considered to be staggered if the absolute value of the displacement of the perpendiculars from the centre lines of the minor arms was greater than 5m (see Fig 1).

TABLE 28

Total accident-flow models

Model	Model terms[1]	Parameter value	s.e.[2]	Exp.[3]	Deviance	Degrees of freedom	Scale factor
Total accidents (2917)							
Null	Lk	0.496	0.040	1.642	1379.	312	4.52
Without factors	Lk	-1.212	0.277	0.298	1206.	311	4.03
	LQT	0.634	0.100				
	Lk	-1.559	0.221	0.210	1028.	311	3.40
	LQN	0.567	0.059				
	Lk	-1.184	0.179	0.306	1010.	311	3.32
	LQC	0.511	0.051				
	Lk	-1.110	0.204	0.330	1008.	310	3.33
	LQMA	0.473	0.073				
	LQMI	0.534	0.060				
	Lk	-1.057	0.144	0.347	923.0	311	3.03
	LQX	0.578	0.050				
	Lk	-2.346	0.259	0.096	863.5	308	2.84
	LQMA	0.722	0.076				
	LQMI	0.454	0.061				
	PQMIS	1.498	0.216				
	PQMIR	0.899	0.231				
	Lk	-1.506	0.284	0.222	1138.	309[4]	3.90
	LQT	0.570	0.101				
	$PTA^{0.3}$	0.585	0.140				
	Lk	-1.836	0.231	0.159	976.6	309[4]	3.30
	LQN	0.531	0.058				
	$PTA^{0.3}$	0.510	0.129				
	Lk	-1.495	0.191	0.224	956.7	309[4]	3.20
	LQC	0.478	0.050				
	$PTA^{0.3}$	0.522	0.127				
	Lk	-1.389	0.213	0.249	953.0	308[4]	3.19
	LQMA	0.420	0.073				
	LQMI	0.511	0.054				
	$PTA^{0.3}$	0.535	0.129				
	Lk	-1.366	0.162	0.255	876.9	311	2.90
	LQPXV	0.634	0.051				
	Lk	-1.404	0.164	0.246	869.8	309[4]	2.87
	LQX	0.551	0.049				
	$PTA^{0.3}$	0.526	0.122				

TABLE 28 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Exp.[3]	Deviance	Degrees of freedom	Scale factor
Total accidents (2917)							
Null	Lk	0.496	0.040	1.642	1379.	312	4.52
Without factors cont.	Lk	-2.715	0.264	0.066	796.0	306[4]	2.65
	LQMA	0.680	0.077				
	LQMI	0.414	0.059				
	PQMIS	1.605	0.213				
	PQMIR	0.859	0.227				
	$PTA^{0.3}$	0.608	0.120				
With factors	Lk	-1.305	0.168	0.271	704.2	305[4]	2.29
	LQX	0.608	0.059				
	$PTA^{0.7}$	0.149	0.070				
	STJ	-0.291	0.059	0.748			
	LON	0.350	0.059	1.419			
	PZC	0.682	0.265	1.978			
	LQX.PZC	-0.185	0.089				
	Lk	-2.111	0.237	0.121	685.7	304[4]	2.22
	LQMA	0.615	0.072				
	LQMI	0.452	0.055				
	PQMIS	1.268	0.203				
	PQMIR	0.553	0.216				
	$PTA^{0.7}$	0.282	0.055				
	STJ	-0.268	0.060	0.765			
	LON	0.317	0.061	1.373			

At the second stage, factors were added to these models and tested for statistical significance. The most suitable accident-flow models with factors are also presented in Table 28. 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 or pedestrian flow.

The sample of sites in the study was stratified to provide a good range of: vehicle flows on the major and minor arms; pedestrian flows across the junction arms and the proportion of minor arm inflow that crosses the junction. In addition, sites were included to provide a good range of particular characteristics such as geographic location, junction type, speed limit and pedestrian crossing facility. The use of a stratified sample in the accident predictive models provides greater knowledge about the effect of the variables on which the stratification has been made. The disadvantage is that the distribution of flows and characteristics in the sample differs from the national population and it is necessary to include all the stratified variables, if statistically significant, in the predictive models to provide an unbiased estimate of accident frequency. The accident-flow models with factors presented in Table 28 include the stratified variables where relevant.

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 a 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 almost all measurable, physical variables and factors are tested, as in the case of the full models presented in Section 11,

TABLE 28 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Exp.[3]	Deviance	Degrees of freedom	Scale factor
Vehicle-only accidents (2285)							
Null	Lk	0.252	0.043	1.287	1279.	312	4.14
Without factors	Lk	-1.442	0.303	0.236	1145.	311	3.81
	LQT	0.629	0.109				
	Lk	-0.868	0.190	0.420	1123	311	3.76
	LQMG	0.438	0.070				
	Lk	-0.694	0.133	0.500	1042	311	3.49
	LQD	0.435	0.056				
	Lk	-1.993	0.246	0.136	957.2	311	3.17
	LQN	0.618	0.064				
	Lk	-1.647	0.195	0.193	921.5	311	2.99
	LQC	0.575	0.055				
	Lk	-1.413	0.216	0.243	907.1	310	2.90
	LQMA	0.453	0.077				
	LQMI	0.652	0.066				
	Lk	-0.361	0.073	0.697	890.0	311	2.85
	LQH	0.393	0.035				
	Lk	-1.529	0.158	0.217	829.3	311	2.68
	LQX	0.658	0.054				
	Lk	-2.756	0.275	0.064	768.3	308	2.47
	LQMA	0.743	0.082				
	LQMI	0.545	0.066				
	PQMIS	1.678	0.226				
	PQMIR	0.796	0.246				
With factors	Lk	-1.473	0.143	0.229	705.7	309	2.18
	LQX	0.648	0.050				
	STJ	-0.345	0.066	0.708			
	LON	0.324	0.064	1.383			
	Lk	-2.445	0.260	0.087	667.6	306	2.09
	LQMA	0.683	0.078				
	LQMI	0.589	0.062				
	PQMIS	1.339	0.217				
	PQMIR	0.521	0.236				
	STJ	-0.317	0.067	0.728			
	LON	0.303	0.068	1.354			

TABLE 28 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Exp.[3]	Deviance	Degrees of freedom	Scale factor
Pedestrian accidents (632)							
Null	Lk	-1.033	0.061	0.356	712.9	312	2.35
Without factors	Lk	-0.887	0.057	0.412	600.5	311	1.95
	LPTI	0.334	0.045				
	Lk	-1.137	0.058	0.321	554.8	311	1.74
	LPT	0.460	0.050				
	Lk	-2.084	0.407	0.124	544.9	310	1.71
	LQT	0.354	0.149				
	LPT	0.429	0.051				
	Lk	-1.717	0.250	0.180	544.5	310	1.70
	LQC	0.180	0.075				
	LPT	0.442	0.050				
	Lk	-1.976	0.322	0.139	542.3	310	1.69
	LQN	0.235	0.088				
	LPT	0.432	0.051				
	Lk	-1.721	0.211	0.179	539.7	310	1.67
	LQX	0.224	0.076				
	LPT	0.443	0.049				
	Lk	-1.846	0.302	0.158	544.5	310	1.71
	LQMA	0.288	0.119				
	LPT	0.425	0.050				
	Lk	-0.649	0.054	0.523	510.2	311	1.56
	LPTA	0.533	0.050				
	Lk	-1.199	0.244	0.301	501.7	310	1.52
	LQC	0.166	0.072				
	LPTA	0.514	0.049				
	Lk	-1.179	0.205	0.308	498.7	310	1.50
	LQX	0.197	0.072				
	LPTA	0.514	0.049				
	Lk	-1.502	0.316	0.223	498.4	310	1.50
	LQN	0.232	0.085				
	LPTA	0.506	0.049				
	Lk	-1.767	0.394	0.171	497.4	310	1.50
	LQT	0.407	0.141				
	LPTA	0.504	0.049				
	Lk	-1.538	0.077	0.215	496.7	311	1.49
	LQPVA	0.469	0.042				
	Lk	-1.534	0.295	0.216	495.3	310	1.50
	LQMA	0.346	0.113				
	LPTA	0.501	0.049				

TABLE 28 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Exp.[3]	Deviance	Degrees of freedom	Scale factor
Pedestrian accidents (632)							
Null	Lk	-1.033	0.061	0.356	712.9	312	2.35
With factors	Lk	-1.706	0.288	0.182	435.6	307	1.37
	LQMA	0.231	0.114				
	LPTA	0.359	0.061				
	LON	0.352	0.103	1.422			
	ZEBA	0.650	0.130	1.916			
	PELA	0.400	0.155	1.492			
	Lk	-1.560	0.205	0.210	434.3	307	1.36
	LQX	0.154	0.068				
	LPTA	0.353	0.061				
	LON	0.359	0.101	1.432			
	ZEBA	0.673	0.128	1.960			
	PELA	0.457	0.148	1.579			
	Lk	-1.746	0.084	0.174	436.4	308	1.36
	LQPVA	0.331	0.054				
	LON	0.328	0.100	1.388			
	ZEBA	0.675	0.222	1.964			
	PELA	0.403	0.153	1.496			

Notes:

1. L prefix indicates log form of variable e.g. LQT = log (QT)
2. Standard error of estimate. The values of the standard errors quoted *have been scaled by the square root of the scale factor.*
3. Exp column gives exponential values of constants and factors
4. The number of degrees of freedom has been reduced by 1 because the exponent of PTA has been empirically determined using the value that gave the lowest scaled deviance

( ) Figures in brackets are the number of accidents

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.

9.4 TOTAL JUNCTION ACCIDENTS

All of the vehicle and pedestrian functions shown in Table 25 gave statistically significant relationships when tested using the model forms 9.1 or 9.2.

Models based on simple vehicle flows do not provide a best fit but they are published for many types of junction and can be useful if a rough estimate of the safety of crossroads and staggered priority junctions is required.

Functions which represented the interaction of the individual vehicle streams, the sum of the encounter products QN, the cross-product QC, the product of the major road inflow QMA with the minor road inflow QMI and the crossing flow products QX, fitted the data a good deal better than the total inflow QT. The best fitting vehicle flow function was major road inflow combined with minor road inflow and the proportions of minor road inflow travelling straight ahead and making a right turn (ie QMA with QMI, PQMIS and PQMIR). The models are given in linear form in Table 28 and were:

$$A = 0.298\ QT^{0.634} \qquad (9.8)$$

$$A = 0.210\ QN^{0.567} \qquad (9.9)$$

$$A = 0.306\ QC^{0.511} \qquad (9.10)$$

$$A = 0.330\ QMA^{0.473}\ QMI^{0.534} \qquad (9.11)$$

$$A = 0.347\ QX^{0.578} \quad (9.12)$$

$$A = 0.0957\ QMA^{0.722}\ QMI^{0.454}\ \exp(1.498\ PQMIS + 0.899\ PQMIR) \quad (9.13)$$

where A is the accident frequency *at the whole junction* (accidents per year).

Models which included the product of a vehicle flow function and a pedestrian flow function fitted the data better than the corresponding vehicle-only function; the vehicle flow function was the stronger component. Examples of these models are given in linear form in Table 28. The best fitting model contained the functions QMA, QMI, PQMIS, PQMIR and PTA^{β}.

Single term combined vehicle and pedestrian flow functions were also tried and the best of these was LQPXV (the sum of the crossing flow products and major arm-vehicle pedestrian products). The scaled deviance obtained (876.9) was not as low as that for QX and PTA^{β} (scaled deviance difference 7.1). However, as two fewer degrees of freedom were used, it may be considered to be an equally good model. Neither of these models fitted the data as well as the model containing QMA, QMI, PQMIS, PQMIR and PTA^{β} which, although it used 3 more degrees of freedom than the model containing QX and PTA^{β}, had a much lower scaled deviance (scaled deviance difference 73.8). This model also had the advantage that it did not require a knowledge of turning movements on the major arm.

The preferred model without factors is given in linear form in Table 28 and was:

$$A = 0.0662\ QMA^{0.680}\ QMI^{0.414}\ \exp(1.605\ PQMIS + 0.859\ PQMIR)\ \exp(0.608\ PTA^{0.3}) \quad (9.14)$$

where A is the accident frequency *at the whole junction,* QMA is the sum of the inflow on the major arms, QMI is the sum of the inflow on the minor arms, PQMIS and PQMIR are the proportions of minor road inflow travelling straight ahead and turning right and PTA is the two-way pedestrian flow across the major arms.

The flow function of the best fitting model with factors was:

$$A = 0.121\ QMA^{0.615}\ QMI^{0.452}\ \exp(1.268\ PQMIS + 0.553\ PQMIR)\ \exp(0.282\ PTA^{0.7}) \quad (9.15)$$

The effect of the factors was as follows: STJ (staggered junction) decreased accidents by a factor of 0.77; LON (in London) increased accidents by a factor of 1.4. Right/left staggered junctions had fewer accidents than left/right staggered junctions, but the difference between two types of staggered junction was small and not statistically significant at the 5 per cent level.

9.5 VEHICLE-ONLY ACCIDENTS

The vehicle flow functions were tested first; those that involved the product of flows (eg QN, QC and QX) gave a better fit than simple inflow functions like QT. The models are given in linear form in Table 28 and were:

$$A = 0.236\ QT^{0.629} \quad (9.16)$$

$$A = 0.136\ QN^{0.618} \quad (9.17)$$

$$A = 0.193\ QC^{0.575} \quad (9.18)$$

$$A = 0.243\ QMA^{0.453}\ QMI^{0.652} \quad (9.19)$$

$$A = 0.217\ QX^{0.658} \quad (9.20)$$

$$A = 0.0635\ QMA^{0.743}\ QMI^{0.545}\ \exp(1.678\ PQMIS + 0.796\ PQMIR) \quad (9.21)$$

where A is the accident frequency *at the whole junction* (accidents per year).

The best fitting flow function was the inflow from the major arms combined with the inflow from the minor arms and the proportions of minor arm traffic travelling straight ahead and making a right turn (ie QMA with QMI, PQMIS and PQMIR). None of the pedestrian flow functions in any of the forms PT, PTA, exp (PT^{β}) or exp(PTA^{β}) were found to be statistically significant.

The best model without factors is given in linear form in Table 28 and was:

$$A = 0.0635\ QMA^{0.743}\ QMI^{0.545}\ \exp(1.678\ PQMIS + 0.796\ PQMIR) \quad (9.22)$$

The flow function of the best fitting model with factors was:

$$A = 0.0867\ QMA^{0.683}\ QMI^{0.589}\ \exp(1.339\ PQMIS + 0.521\ PQMIR) \quad (9.23)$$

The effect of the factors was as follows: STJ (staggered junction) decreased accidents by a factor of 0.73; LON (in London) increased accidents by a factor of 1.4. Right/left staggered junctions had fewer accidents than left/right staggered junctions, but the difference between two types of staggered junction was small and not statistically significant at the 5 per cent level.

9.6 PEDESTRIAN ACCIDENTS

Over 70 different pedestrian and vehicle flow functions were tested and those that involved pedestrian flow gave a much better fit than those that involved only vehicle flow. The models containing the more important functions are given in linear form in Table 28 and were:

$$A = 0.124\ QT^{0.354}\ PT^{0.429} \quad (9.24)$$

$$A = 0.139\ QN^{0.235}\ PT^{0.432} \quad (9.25)$$

$$A = 0.180\ QC^{0.180}\ PT^{0.442} \quad (9.26)$$

$$A = 0.179\ QX^{0.224}\ PT^{0.443} \quad (9.27)$$

$$A = 0.158\ QMA^{0.288}\ PT^{0.425} \quad (9.28)$$

$$A = 0.171\ QT^{0.407}\ PTA^{0.504} \quad (9.29)$$

$$A = 0.223\ QN^{0.232}\ PTA^{0.506} \quad (9.30)$$

$$A = 0.301\ QC^{0.166}\ PTA^{0.514} \quad (9.31)$$

$$A = 0.308\ QX^{0.197}\ PTA^{0.514} \quad (9.32)$$

$$A = 0.216\ QMA^{0.346}\ PTA^{0.501} \quad (9.33)$$

$$A = 0.215\ QPVA^{0.469} \quad (9.34)$$

where A is the accident frequency *at the whole junction* (accidents per year).

The best fitting pedestrian flow function was PTA (pedestrian flow across the major arms). The vehicle flow functions QX, QT, and QMA were statistically significant when added to PTA but they only improved the fit slightly. The combined pedestrian and vehicle flow function QPVA was equally as good. None of the vehicle flow functions was outstandingly good; QMA was preferred on the grounds of consistency with the best models for total and vehicle-only accidents.

The preferred model without factors is given in linear form in Table 28 and was:

$$A = 0.216\ QMA^{0.346}\ PTA^{0.501} \quad (9.35)$$

The flow function of the preferred model with factors was:

$$A = 0.182\ QMA^{0.231}\ PTA^{0.359} \quad (9.36)$$

The effect of the various factors was as follows: LON (in London) increased accidents by a factor of 1.4; ZEBA (zebra crossing on major with or without pedestrian refuge) increased accidents by a factor of 1.9; PELA (pelican crossing on major with or without island) increased accidents by a factor of 1.5.

9.7 COMPARISON WITH 4-ARM TRAFFIC SIGNALS

A preliminary comparison of accident predictive models for 4-arm signalled junctions and 4-arm priority junctions was made by including accident and flow information from the 4-arm traffic signal study, (Hall, 1986), in a combined 'whole junction' database. The comparison was limited to 4-arm junctions with a 30 mph speed limit. This gave a total of 177 signalled junctions and 243 priority junctions. It has not been possible to do this comparison exhaustively. In particular the effect of pedestrian crossing facilities was not investigated.

Total accidents at 4-arm signals and priority junctions:

Models which included the product of a vehicle flow function and a pedestrian flow function fitted the data better than the corresponding vehicle-only function; the vehicle flow function was the stronger component. The best fitting model contained the functions QX and $PT^{0.3}$. The models are given in linear form in Table 29.

The preferred model without factors was:

$$A = 0.399\ QX^{0.394} \exp(0.296\ PT^{0.3}) \quad (9.37)$$

Factors LON (in London) and PRI (junction type - the presence of a 4-arm priority junction compared to 4-arm traffic signals) were tested for statistical significance.

The flow function of the preferred model with factors was:

$$A = 0.243\ QX^{0.472} \exp(0.246\ PT^{0.3}) \quad (9.38)$$

The effect of the various factors on accidents was as follows: LON increased accidents by a factor of 1.5; PRI increased accidents by a factor of 1.3.

The interaction term between QX and PRI was not statistically significant.

Vehicle accidents at 4-arm signals and priority junctions:

Four vehicle flow functions were tested (QT, QC, QX and QN). The crossing flow products, QX, gave the best fit. The models are given in linear form in Table 29.

The preferred model without factors was:

$$A = 0.391\ QX^{0.421} \quad (9.39)$$

where A is the accident frequency *at the whole junction* (accidents per year)

The flow function of the preferred model with factors was:

$$A = 0.181\ QX^{0.539} \quad (9.40)$$

TABLE 29

Whole junction accident-flow models for 30 mph, 4-arm signalled junctions and 4-arm priority crossroads (combined database)

Model	Model terms[1]	Parameter value	s.e.[2]	Exp.[3]	Deviance	Degrees of freedom	Scale factor
Total accidents (4212)							
Null	Lk	0.721	0.036	2.056	2092.	419	5.61
Without factors	Lk	-0.615	0.102	0.541	1325.	417	3.29
	LQX	0.395	0.029				
	LPT	0.105	0.029				
	Lk	-0.920	0.125	0.399	1320.	416[4]	3.28
	LQX	0.394	0.029				
	$PT^{0.3}$	0.296	0.078				
With factors	Lk	-1.154	0.163	0.315	1087.	415	2.62
	LQX	0.470	0.039				
	LPT	0.090	0.026				
	LON	0.419	0.053	1.520			
	PRI	0.258	0.076	1.294			
	Lk	-1.416	0.186	0.243	1086.	414[4]	2.62
	LQX	0.472	0.039				
	$PT^{0.3}$	0.246	0.071				
	LON	0.412	0.053	1.510			
	PRI	0.264	0.078	1.302			
Vehicle-only accidents (3137)							
Null	Lk	0.426	0.039	1.531	1803.	419	4.63
Without factors	Lk	-2.059	0.264	0.128	1440.	418	3.62
	LQT	0.878	0.091				
	Lk	-1.535	0.169	0.215	1315.	418	3.24
	LQN	0.485	0.040				
	Lk	-1.246	0.147	0.288	1310.	418	3.20
	LQC	0.441	0.036				
	Lk	-0.940	0.113	0.391	1265.	418	3.04
	LQX	0.421	0.031				
With factors	Lk	-1.711	0.188	0.181	1039.	416	2.46
	LQX	0.539	0.044				
	LON	0.429	0.060	1.536			
	PRI	0.379	0.086	1.461			

TABLE 29 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Exp.[3]	Deviance	Degrees of freedom	Scale factor
Pedestrian accidents (1075)							
Null	Lk	-0.645	0.056	0.525	1167.	419	3.32
Without factors	Lk	-1.028	0.062	0.358	862.4	418	2.10
	LPT	0.550	0.046				
	Lk	-3.232	0.341	0.039	776.2	417	1.85
	LQT	0.797	0.120				
	LPT	0.451	0.046				
	Lk	-2.523	0.221	0.080	767.0	417	1.82
	LQN	0.384	0.053				
	LPT	0.460	0.046				
	Lk	-2.188	0.188	0.112	777.2	417	1.85
	LQC	0.320	0.048				
	LPT	0.474	0.045				
	Lk	-1.970	0.148	0.139	768.1	417	1.82
	LQX	0.307	0.043				
	LPT	0.474	0.045				
With factors	Lk	-1.992	0.147	0.136	741.7	416	1.78
	LQX	0.286	0.043				
	LPT	0.447	0.044				
	LON	0.334	0.085	1.397			
	Lk	-3.838	0.608	0.022	729.5	414	1.76
	LQT	0.996	0.196				
	LPT	0.418	0.045				
	LON	0.282	0.089	1.326			
	PRI	1.944	0.741				
	LQT.PRI	-0.735	0.245				

1. L prefix indicates log form of variable e.g. LQT = log (QT)
   PRI is a factor that compares the accident frequency at 4-arm priority crossroads with 4-arm signalled junctions:
   1 = Signalled junction 177
   2 = Priority junction 243
2. Standard error of estimate. The values of the standard errors quoted *have been scaled by the square root of the scale factor.*
3. Exp column gives exponential values of constants and factors
4. The number of degrees of freedom has been reduced by 1 because the exponent of PT has been empirically determined using the value that gave the lowest scaled deviance

( ) Figures in brackets are the number of accidents

The effect of the various factors on accidents was as follows: LON increased accidents by a factor of 1.5; PRI (junction type - the presence of a 4-arm priority junction compared to 4-arm traffic signals) increased accidents by a factor of 1.5.

The interaction term between QX and PRI was not statistically significant.

Pedestrian accidents at 4-arm signals and priority junctions:

The pedestrian flow function PT and four vehicle flow functions were tested (QT, QC, QX and QN). All four vehicle flow functions were statistically significant when individually added to models containing the pedestrian flow function but none of them was outstandingly good in terms of the reduction in scaled deviance; the model with PT and QX gave the best fit. The models are given in linear form in Table 29.

The factor LON was statistically significant when added to the above models but the factor PRI was only significant when added to the model containing the flow functions PT and QT. However, the interaction term between QT and PRI was also statistically significant.

The model with the vehicle flow function QX without factors was:

$$A = 0.139\ QX^{0.307}\ PT^{0.474} \qquad (9.41)$$

The flow function of the model with vehicle flow function QX and factors was:

$$A = 0.136\ QX^{0.286}\ PT^{0.447} \qquad (9.42)$$

The effect of the various factors on accidents was as follows: LON increased accidents by a factor of 1.4; PRI gave a very small decrease in accidents that was not statistically significant.

The flow function of the model with vehicle flow function QT and factors was:

$$A = 0.0215\ QT^{0.996}\ PT^{0.418} \qquad (9.43)$$

The effect of the various factors on accidents was as follows: LON increased accidents by a factor of 1.3; PRI increased accidents by a factor of 7.0 and reduced the coefficient of QT to 0.261.

10. ACCIDENT-FLOW MODELS BY ACCIDENT GROUP AND ARM OF JUNCTION

10.1 INTRODUCTION

In the second stage of the modelling of accidents at crossroads and staggered junctions, the accident frequency for each accident group was related to various functions of the vehicle and pedestrian flows.

The basic unit of analysis was *the junction arm.* Each junction gave two major arms and two minor arms. The total number of analysis units was 626 for the major arms and 626 for the minor arms. The vehicle and pedestrian flows on the junction arms are illustrated in Figure 2. For the analysis of the accident groups on the major arms, arm 1 is the major arm, arm 3 is the opposite major arm, arm 4 is the previous minor arm and arm 2 is the next minor arm. For the analysis of accident groups on the minor arms, arm 2 is the minor arm, arm 4 is the opposite minor arm, arm 1 is the previous major arm and arm 3 is the next major arm.

The accident groups shown in Table 13 and described in Section 7.5 were modified for the accident-flow models by accident group to allow specific flow functions to be fitted to different accident types on the major and minor arms. The accident grouping for the regression analysis follows the main accident types shown in Table 7. The number and percentage of accidents in each group is given in Table 30. The terms 'next' and 'previous' when applied to arms of the junction are used in a clockwise sense.

10.2 THE FORM OF THE MODELS

10.2.1 Vehicle and pedestrian flow functions

Although a large range of vehicle and pedestrian flow functions were tested in the model development, the most logical forms generally produced the best fit to the data. The flow functions used for the accident-flow models by accident group are described in Table 31 at the end of this Section.

The flow functions for the vehicle-only accident groups will be considered first and for these the rationale was as follows. Most accident groups represent a primary collision between vehicles in one or more clearly defined streams. In this context, a stream of vehicles is one in which each vehicle is at first treated as making the same contribution to accident risk as any other. Stream flows were obtained by summing the contributing vehicle movements.

The influence on risk of vehicles in different categories was handled in the full accident-flow-geometry models described in Section 11 by the use of vehicle proportion variables.

TABLE 30

Numbers of accidents by group

Accident		Number of accidents	% of total
Vehicle-only accidents:			
VA1	Single vehicle on major arm	133	5
VA2	Rear shunt and lane changing on major arm	278	10
VA3	Right angle: major arm with previous minor	492	17
VA4	Right angle: major arm with next minor	410	14
VA5	Right turn from major arm with own ahead	47	2
VA6	Right turn from minor arm with next ahead	105	4
VA7	Right turn from major arm with opposite ahead	270	9
VA8	Right turn from minor arm with previous ahead	209	7
VA9	Other right turn from minor arm	45	2
VA10	Left turn from minor arm with previous ahead	61	2
VA11	Head-on/U-turn/Parked/Parking on major arm	87	3
VA12	Other vehicle-only accidents on major arm	72	2
VA13	Other vehicle-only accidents on minor arm	76	3
Pedestrian accidents:			
PA1	Pedestrian with vehicle entering on major arm	197	7
PA2	Pedestrian with vehicle exiting on major arm	242	8
PA3	Other pedestrian accidents on major arm	97	3
PA4	Pedestrian accidents on minor arm	96	3

Some vehicle-only accident groups involved only one stream of vehicles. In these cases, a model of the form (9.1), $A = kQ^{\alpha}$, where Q was the sum of the vehicle flows in the stream was best.

Many accident groups represent collisions between vehicles in two quite different streams. In these cases the appropriate model was of the form (9.1), $A = kQ^{\alpha}$, where both stream flows have the same exponent or of the form (9.2), $A = kQ_a^{\alpha} Q_b^{\beta}$, where the stream flows have different exponents.

In some accident groups the accident risk may be influenced by other streams of vehicles or pedestrians ('spoiling flows') that were not involved in the collisions. In these cases flow functions of the form $\exp(b\ Q_b^{\beta})$ were used for the spoiling flows. This ensured that accidents were not eliminated when the 'spoiling flow' was zero. For the pedestrian accident groups, the models were straightforward and flow functions of the form Q_b^{β} were appropriate.

10.2.2 Factors

The factors tested in these models are given in Table 32. They are similar to those used in testing the total accident models. The accident-flow models with factors presented in Section 10.4 include the variables and factors used in the stratification of the junction sample where they are statistically significant (see Section 9.3).

For the same reasons as those set down in Section 9.3, the models presented in this Section are likely to include associative as well as causal factors.

10.3 MODELLING PROCEDURE

The modelling procedures were similar to those for the total accident-flow models. For each accident type, Table 33 gives the parameter values and scaled deviances of the null model (which simply fits the mean accident frequency). Models with the most appropriate flow function were developed first; taking into account the reduction in scaled deviance, the degrees of freedom and the relevance of the flow function to the particular accident group. Then models with factors including interactions between factors and between factors and variables were tested. The best model with and without factors is given, for each accident group, in Table 33.

10.4 MODELS FOR VEHICLE-ONLY ACCIDENT GROUPS

The models given in this Section are *arm based models* and predict accident frequency for a particular accident group on *a major arm* or *a minor arm*. Thus the models will need to be applied twice when predicting accidents for the whole junction with arms 'ABCD'; firstly with major arms A,C as arm 1 and arm 3 and minor arms B,D as arm 2 and arm 4,

TABLE 31

Vehicle and pedestrian flow functions for accident-flow models by accident group

Vehicle flow functions:			
Entering flow on major arm	V1	=	Q1+Q2+Q3
Entering flow on minor arm	V2	=	Q4+Q5+Q6
Entering flow on opposite major arm	V3	=	Q7+Q8+Q9
Entering flow on opposite minor arm	V4	=	Q10+Q11+Q12
Exiting flow on major arm	V5	=	Q6+Q8+Q10
Exiting flow on minor arm	V6	=	Q1+Q9+Q11
Two-way flow on major arm	V7	=	V1+V5
Two-way flow on minor arm	V8	=	V2+V6
Total inflow on major arms	QMA	=	V1+V3
Total inflow on minor arms	QMI	=	V2+V4
Entering flow on major arm plus right turn on previous minor arm plus left turn on next minor arm	V15	=	V1+Q4+Q12
Ahead on previous and next minor arms	V25	=	Q5+Q11
Entering flow on opposite minor arm plus right turn on next major arm plus left turn on previous major arm	V39	=	V4+Q1+Q9
Ahead on minor arm plus right turn on minor arm	V56	=	Q5+Q6
Left turn and straight ahead on minor plus entering flow on opposite minor	V64	=	Q4+Q5+V4
Product of ahead on major with right turn on major arm	X23	=	Q2.Q3
Pedestrian flow functions:			
Pedestrian flow across major arm	PA	=	P1+P2
Pedestrian flow across opposite major arm	PB	=	P5+P6
Pedestrian flow across both major arms	PTA	=	PA+PB
Pedestrian flow across centre of junction	PX	=	P9+P10+P11+P12
Pedestrian flow across both major arms and centre	PTB	=	PA+PB+PX
Pedestrian flow across minor arm	PI	=	P3+P4
Pedestrian flow across opposite minor arm	PJ	=	P7+P8
Pedestrian flow across both minor arms	PTI	=	PI+PJ
Total pedestrian flow at junction	PT	=	PTA+PTI+PX

and secondly with major arms C,A as arm 1 and arm 3 and minor arms D,B as arm 2 and arm 4 respectively.

For some vehicle-only accident groups, pedestrian flow functions were statistically significant when added to models containing the relevant vehicle flow functions. For these accident groups, alternative models containing only the vehicle flow functions are also given in Table 33.

VA1 - Single vehicle accidents on the major arm

This accident group included all single vehicle (non-pedestrian) accidents occurring on the major arm approach, junction centre or exit side of the opposite major arm. There were 133 of these accidents, 4.6 per cent of the total.

The flow function V15, the sum of the entering flows plus the right turn on the previous minor plus the left turn on the next minor, was relevant and was one of the best flow functions tested. The pedestrian flow function PTB, the two-way pedestrian flow across both major arms and the centre of the junction, was also significant.

The best model without factors was:

$$A = 0.00105\ V15^{0.789} \exp(2.194\ PTB^{0.1}) \quad (10.1)$$

where A is the accident frequency.

TABLE 32

Factors for junction features tested in accident-flow models by accident group

Symbol	Description	
STJ	Staggered junction[1]	1 = crossroads 2 = staggered jn
JTP	Junction type	1 = crossroads 2 = left/right stgr. 3 = right/left stgr.
RLJ	Right-left stagger	1= crossroads or left/right stgr. 2 = right/left stgr.
SP	Speed limit on major arms at junction	1 = 30 mph 2 = 40 mph
LON	Sites within the DOT London region	1 = not in London 2 = in London
ZEB1	Zebra on major arm 1 (without island)	1 = absent 2 = present
ZEB3	Zebra on major arm 3 (without island)	1 = absent 2 = present
ZEB5	Zebra on major arms 1 or 3 (without island)	1 = absent 2 = present
ZIB1	Zebra on major arm 1 (with island)	1 = absent 2 = present
ZIB3	Zebra on major arm 3 (with island)	1 = absent 2 = present
ZIB5	Zebra on major arms 1 or 3 (with island)	1 = absent 2 = present
ZAB1	Zebra on major arm 1 (with or without island)	1 = absent 2 = present
ZAB3	Zebra on major arm 3 (with or without island)	1 = absent 2 = present
ZAB5	Zebra on major arms 1 or 3 (with or without island)	1 = absent 2 = present

The flow function for the best model with factors was:

$$A = 0.00837\ V15^{0.782} \qquad (10.2)$$

Three factors were included in this model: SP, LON and HCH1. The effect of the factors was as follows: SP (40 mph speed limit on major arms at junction) decreased accidents by a factor of 0.37; LON (in London) increased accidents by a factor of 1.6; HCH1 (hatching on major arm 1) decreased accidents by a factor of 0.42.

VA2 - Rear end shunt and lane changing accidents on the major arm

This accident group included rear end shunts and lane changing accidents occurring on the major arm approach, junction centre or exit side of the major arm. There were 278 of these accidents, 9.5 per cent of the total.

As in VA1, the flow function V15, the sum of the entering flows plus the right turn on the previous minor plus the left turn on the next minor, was relevant and was one of the best flow functions tested. The pedestrian flow function PA, the two-way pedestrian flow across arm 1, was significant and the best of the pedestrian flow functions tested.

TABLE 32 (CONTINUED)

Symbol	Description	
PEL1	Pelican on major arm 1 (without island)	1 = absent 2 = present
PEL3	Pelican on major arm 3 (without island)	1 = absent 2 = present
PEL5	Pelican on major arms 1 or 3 (without island)	1 = absent 2 = present
PIL1	Pelican on major arm 1 (with island)	1 = absent 2 = present
PIL3	Pelican on major arm 3 (with island)	1 = absent 2 = present
PIL5	Pelican on major arms 1 or 3 (with island)	1 = absent 2 = present
PAL1	Pelican on major arm 1 (with or without island)	1 = absent 2 = present
PAL3	Pelican on major arm 3 (with or without island)	1 = absent 2 = present
PAL5	Pelican on major arms 1 or 3 (with or without island)	1 = absent 2 = present
PZC1	Pelican or zebra on arm 1 (with or without island)	1 = absent 2 = present
PZC3	Pelican or zebra on arm 3 (with or without island)	1 = absent 2 = present
PZC5	Pel. or zeb. on arms 1 or 3 (with or without island)	1 = absent 2 = present
ISL1	Island on major arm 1	1 = absent 2 = present
ISL2	Island on minor arm 2	1 = absent 2 = present
ISL3	Island on major arm 3	1 = absent 2 = present
ISL4	Island on minor arm 4	1 = absent 2 = present
ISL5	Island on arms 1 or 3	1 = absent 2 = present

The best model without factors was:

$$A = 0.00331\ V15^{1.501} \exp(0.338\ PA^{0.8}) \qquad (10.3)$$

The flow function for the best model with factors was:

$$A = 0.00294\ V15^{1.574} \qquad (10.4)$$

Three factors were included in this model: LON, ZAB5 and ISL5. The effect of the factors was as follows: LON (in London) increased accidents by a factor of 1.3; ZAB5 (zebra on arm 1 or 3) increased accidents by a factor of 1.7; ISL5 (island on arms 1 or 3) decreased accidents by a factor of 0.56.

VA3 - Right angle accidents: major arm with previous minor

These accidents involved vehicles travelling ahead on the major arm (arm 1 to arm 3) and vehicles travelling ahead on the previous, right hand, minor arm (arm 4 to arm 2). This was the largest accident group with 492 accidents, 16.9 per cent of the total.

The flows Q2 and Q11 were the ones directly involved in the accident group.

TABLE 32 (CONTINUED)

Symbol	Description	
ISL6	Island on arms 2 or 4	1 = absent 2 = present
ISL7	Island on arms 1 and 3	1 = absent 2 = present
ISL8	Island on arms 2 and 4	1 = absent 2 = present
HCH1	Hatching on major arm 1	1 = absent 2 = present
HCH2	Hatching on minor arm 2	1 = absent 2 = present
HCH3	Hatching on major arm 3	1 = absent 2 = present
HCH4	Hatching on minor arm 4	1 = absent 2 = present
HCH5	Hatching on arms 1 or 3	1 = absent 2 = present
HCH6	Hatching on arms 2 or 4	1 = absent 2 = present
HCH7	Hatching on arms 1 and 3	1 = absent 2 = present
HCH8	Hatching on arms 2 and 4	1 = absent 2 = present

Note:

1. STJ - a junction was considered to be staggered if the absolute value of the displacement of the centre lines of he minor arms was greater than 5m (see Fig 1).

The best model without factors was:

$$A = 0.168\ Q2^{0.497}\ Q11^{0.854} \qquad (10.5)$$

The flow function for the best model with factors was:

$$A = 0.182\ Q2^{0.557}\ Q11^{0.869} \qquad (10.6)$$

Two factors were included in this model: STJ and ISL1. The effect of the factors was as follows: STJ (staggered junction) decreased accidents by a factor of 0.49; ISL1 (island on arm 1) increased accidents by a factor of 1.4.

VA4 - Right angle accidents: major arm with next minor

These accidents involved vehicles travelling ahead on the major arm (arm 1 to arm 3) and vehicles travelling ahead on the next, left hand, minor arm (arm 2 to arm 4). This is the second largest accident type group with 410 accidents, 14.1 per cent of the total.

The flows Q2 and Q5 were the ones directly involved in the accident group.

The best model without factors was:

$$A = 0.165\ Q2^{0.382}\ Q5^{0.710}\ \exp(-0.261\ PI^{1.0}) \qquad (10.7)$$

The exponent of PI is negative implying that accidents are reduced as PI (pedestrian flow across the minor arms) increases. This is probably due to the correlation (-0.6) between SMN1 (mean speed on arm 1) and PI. Higher speeds are associated with lower pedestrian flows.

An alternative model without PI is also given in Table 33.

The flow function for the best model with factors was:

$$A = 0.167\ Q2^{0.320}\ Q5^{0.732} \qquad (10.8)$$

Three factors were included in this model: STJ, LON and HCH5. The effect of the factors was as follows: STJ (staggered junction) decreased accidents by a factor of 0.54; LON (in London) increased accidents by a factor of 1.5; HCH5 (hatching on arms 1 or 3) increased accidents by a factor of 1.5.

TABLE 33

Accident-flow models by accident group

Model	Model terms[1]	Parameter value	s.e.[2]	Exp.[3]	Deviance	Degrees of freedom	Scale factor
VA1 - Single vehicle accidents on a major arm (133)							
Null	Lk	-3.285	0.094	0.037	475.3	625	1.20
Without factors	Lk	-4.966	0.470	0.0070	457.6	624	1.15
	LV15	0.858	0.227				
	Lk	-6.860	0.940	0.001	451.2	622[4]	1.16
	LV15	0.789	0.235				
	$PTB^{0.1}$	2.194	0.932				
With factors	Lk	-4.783	0.462	0.0084	426.3	621	1.08
	LV15	0.782	0.227				
	SP	-1.007	0.332	0.365			
	LON	0.475	0.189	1.608			
	HCH1	-0.859	0.433	0.424			
VA2 - Rear end shunt and lane changing on a major arm (278)							
Null	Lk	-2.547	0.073	0.076	725.3	625	1.48
Without factors	Lk	-5.634	0.387	0.0036	623.6	624	1.19
	LV15	1.530	0.179				
	Lk	-5.710	0.389	0.0033	615.4	622[4]	1.18
	LV15	1.501	0.180				
	$PA^{0.8}$	0.338	0.121				
With factors	Lk	-5.831	0.393	0.0029	584.5	621	1.10
	LV15	1.574	0.185				
	LON	0.287	0.142	1.332			
	ZAB5	0.526	0.148	1.692			
	ISL5	-0.572	0.179	0.564			
VA3 - Right angle: major arm with previous minor (492)							
Null	Lk	-1.977	0.069	0.138	1135	625	2.36
Without factors	Lk	-1.781	0.133	0.168	799.7	623	1.46
	LQ2	0.497	0.094				
	LQ11	0.854	0.064				
With factors	Lk	-1.704	0.130	0.182	737.6	621	1.31
	LQ2	0.557	0.092				
	LQ11	0.869	0.063				
	STJ	-0.708	0.121	0.493			
	ISL1	0.345	0.121	1.412			

TABLE 33 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Exp.[3]	Deviance	Degrees of freedom	Scale factor
VA4 - Right angle: major arm with next minor (410)							
Null	Lk	-2.159	0.067	0.115	954.7	625	1.88
Without	Lk	-1.801	0.135	0.165	722.6	621[4]	1.36
factors	LQ2	0.382	0.097				
(a)	LQ5	0.710	0.064				
	$PI^{1.0}$	-0.261	0.118				
(b)	Lk	-1.845	0.136	0.158	730.5	623	1.40
alt.	LQ2	0.353	0.098				
	LQ5	0.733	0.065				
With	Lk	-1.790	0.134	0.167	666.9	620	1.32
factors	LQ2	0.320	0.095				
	LQ5	0.732	0.065				
	STJ	-0.608	0.134	0.544			
	LON	0.396	0.122	1.486			
	HCH5	0.392	0.159	1.480			
VA5 - Right turn from major with own ahead (47)							
Null	Lk	-4.325	0.145	0.013	246.4	625	1.00
Without	Lk	-4.447	0.166	0.012	241.7	624	1.00
factors	LX23	0.269	0.127				
With	Lk	-4.505	0.203	0.011	224.7	622	1.00
factors	LX23	0.271	0.127				
	LON	0.855	0.298	2.351			
	ISL5	-1.684	0.554	0.186			
VA6 - Right turn from minor with next ahead (105)							
Null	Lk	-3.521	0.106	0.030	421.9	625	1.22
Without	Lk	-8.718	1.970	0.00016	397.5	621[4]	1.13
factors	LQ6	0.311	0.105				
	LQ8	0.453	0.184				
	$V64^{0.1}$	4.625	1.700				
With factors	no factors were significant						

TABLE 33 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Exp.[3]	Deviance	Degrees of freedom	Scale factor
VA7 - Right turn from major with opposite ahead (270)							
Null	Lk	-2.577	0.077	0.076	725.0	625	1.60
Without factors	Lk	-4.750	0.775	0.0087	611.2	621[4]	1.27
	LQ3	0.635	0.077				
	LQ8	0.477	0.122				
	$Q9^{0.1}$	2.263	0.838				
With factors	Lk	-4.853	0.763	0.0078	597.8	619[4]	1.21
	LQ3	0.648	0.076				
	LQ8	0.498	0.120				
	$Q9^{0.1}$	2.434	0.832				
	STJ	-0.363	0.141	0.696			
	ISL3	0.341	0.158	1.406			
VA8 - Right turn from minor with previous ahead (209)							
Null	Lk	-2.833	0.082	0.059	618.8	625	1.40
Without factors	Lk	-3.276	0.309	0.038	467.8	621[4]	1.07
	LQ2	0.706	0.137				
	LQ6	0.659	0.102				
	$Q1^{1.0}$	0.241	0.114				
With factors	No factors were significant						
VA9 - Other right turn from minor (45)							
Null	Lk	-4.368	0.168	0.013	248.8	625	1.29
Without factors	Lk	-4.996	0.474	0.0068	207.1	623	1.00
	LQ6	0.434	0.154				
	LV39	1.396	0.351				
With factors	No factors were significant						
VA10 - Left turn from minor with previous ahead (61)							
Null	Lk	-4.064	0.143	0.017	306.9	625	1.25
Without factors	Lk	-4.949	0.590	0.0071	291.6	621[4]	1.16
	LQ2	0.502	0.262				
	LQ4	0.306	0.153				
	$V56^{1.0}$	0.463	0.222				
With factors	Lk	-4.900	0.600	0.0074	283.5	620[4]	1.15
	LQ2	0.553	0.266				
	LQ4	0.329	0.157				
	$V56^{1.0}$	0.514	0.227				
	RLJ	-1.139	0.491	0.320			

TABLE 33 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Exp.[3]	Deviance	Degrees of freedom	Scale factor
VA11 - Head-on/U-turn/Parked/Parking accidents on a major arm (87)							
Null	Lk	-3.708	0.116	0.025	382.4	625	1.23
Without factors	Lk	-6.247	0.711	0.0019	363.6	624	1.14
	LV7	1.000	0.266				
	Lk	-9.766	1.190	0.000057	347.7	622[4]	1.10
	LV7	0.809	0.274				
	$PT^{0.1}$	3.882	1.029				
With factors	Lk	-8.378	1.172	0.00023	294.3	620[4]	1.01
	LV7	0.553	0.249				
	$PT^{0.1}$	2.654	1.058				
	LON	1.461	0.231	4.310			
	HCH5	-1.833	0.719	0.160			
	Lk	-5.990	0.640	0.0025	293.3	621	1.00
	LV7	0.623	0.245				
	LON	1.500	0.230	4.482			
	HCH5	-1.893	0.173	0.151			
	PZC3	0.646	0.228	1.908			
VA12 - Other vehicle accidents on a major arm (72)							
Null	Lk	-3.898	0.122	0.020	326.6	625	1.07
Without factors	Lk	-3.384	0.169	0.034	311.7	623	1.03
	LQ1	0.327	0.128				
	LQ25	0.215	0.105				
	Lk	-3.626	0.205	0.027	305.3	621[4]	1.07
	LQ1	0.291	0.136				
	LV25	0.284	0.114				
	$PT^{1.0}$	0.125	0.046				
With factors	Lk	-4.484	0.450	0.011	300.8	620[4]	1.03
	LQ1	0.290	0.134				
	LV25	0.333	0.116				
	$PT^{1.0}$	0.146	0.045				
	HCH5	0.729	0.328	2.073			

TABLE 33 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Exp.[3]	Deviance	Degrees of freedom	Scale factor
VA13 - Other vehicle accidents on a minor arm (76)							
Null	Lk	-3.843	0.124	0.021	350.0	625	1.22
Without factors	Lk	-4.257	0.164	0.014	286.1	624	1.00
	LV2	1.352	0.191				
	Lk	-4.723	0.279	0.0089	281.5	622[4]	1.00
	LV2	1.342	0.191				
	$PTB^{0.5}$	0.622	0.284				
With factors	Lk	-4.435	0.186	0.012	280.6	623	1.00
	LV2	1.348	0.189				
	LON	0.569	0.236	1.766			

Pedestrian accidents

Model	Model terms[1]	Parameter value	s.e.[2]	Exp.[3]	Deviance	Degrees of freedom	Scale factor
PA1 - Pedestrian with vehicle entering on a major arm (197)							
Null	Lk	-2.892	0.082	0.055	598.4	625	1.32
Without factors	Lk	-3.321	0.352	0.036	482.5	623	1.10
	LV1	0.659	0.173				
	LPA	0.492	0.058				
With factors	Lk	-3.722	0.362	0.024	442.5	619	1.06
	LV1	0.552	0.178				
	LPA	0.280	0.077				
	STJ	-0.386	0.160	0.680			
	LON	0.435	0.160	1.545			
	ZAB1	0.996	0.222	2.707			
	PAL1	0.686	0.263	1.986			
PA2 - Pedestrian with vehicle exiting on a major arm (242)							
Null	Lk	-2.686	0.080	0.068	706.4	625	1.55
Without factors	Lk	-2.323	0.300	0.098	531.3	623	1.16
	LV5	0.307	0.153				
	LPA	0.619	0.056				
With factors	Lk	-2.806	0.304	0.060	482.3	622	1.07
	LV5	0.352	0.149				
	LPA	0.488	0.060				
	ZAB1	1.072	0.153	2.921			

TABLE 33 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Exp.[3]	Deviance	Degrees of freedom	Scale factor
PA3 - other pedestrian accidents on a major arm (97)							
Null	Lk	-3.600	0.105	0.027	393.6	625	1.11
Without factors	Lk	-3.684	0.577	0.025	377.8	623	1.05
	LQMA (ns)	0.146	0.221				
	LPTB	0.357	0.101				
With factors	Lk	-3.551	0.567	0.029	369.6	622	1.03
	LQMA (ns)	0.136	0.217				
	LPTB	0.396	0.100				
	ZAB3	-1.354	0.593	0.258			
PA4 - pedestrian accidents on a minor arm (96)							
Null	Lk	-3.610	0.100	0.027	372.7	625	1.00
Without factors	Lk	-3.880	0.198	0.021	314.0	623	1.00
	LV8	0.863	0.156				
	LPI	0.427	0.080				
With factors	Lk	-4.030	0.215	0.018	310.3	622	1.00
	LV8	0.860	0.155				
	LPI	0.412	0.082				
	LON	0.415	0.211	1.514			

Notes:

1. L prefix indicates log form of variable e.g. LQT = log (QT)
2. Standard error of estimate. The values of the standard errors quoted *have been scaled by the square root of the scale factor.*
3. Exp column gives exponential values of constants and factors
4. The number of degrees of freedom has been reduced by 1 because the exponent of one of the flow terms has been empirically determined using the value that gave the lowest scaled deviance

( ) Figures in brackets are the number of accidents

VA5 - Right turn from major with own ahead

These accidents involved vehicles turning right from the major arm across the path of vehicles travelling ahead on the same arm. This was one of the smallest accident groups with 47 accidents, 1.6 per cent of the total.

As separate variables Q2 and Q3 did not reach statistical significance. Their coefficients were not very different so X23, the product of Q2 and Q3 was tried and was just significant. Other flow functions did not fit better.

The best model without factors was:

$$A = 0.0117\ X23^{0.269} \qquad (10.9)$$

The flow function for the best model with factors was:

$$A = 0.0111\ X23^{0.271} \qquad (10.10)$$

The effect of the factors was as follows: LON (in London) increased accidents by a factor of 2.4; ISL5 (island on arms 1 or 3) decreased accidents by a factor of 0.19.

VA6 - Right turn from minor with next ahead

These accidents involved vehicles turning right out of the minor arm (arm 2) and vehicles travelling ahead on the next major arm (arm 3 to arm 1). There were 105 of these accidents, 3.6 per cent of the total.

The flows directly involved were Q6 and Q8. Q8 was just below the 5 per cent significance level. The spoiling flow function V64, the sum of the other flows from both minor arms, was the best of the spoiling flow functions and its inclusion allowed Q8 to achieve significance.

The best model without factors was:

$$A = 0.000164\ Q6^{0.311}\ Q8^{0.453}\ \exp(4.625\ V64^{0.1}) \quad (10.11)$$

No factors were statistically significant.

VA7 - Right turn from major with opposite ahead

These accidents involved vehicles turning right from the major arm (arm 1) and vehicles travelling ahead on the opposite major arm (arm 3 to arm 1). This is the third largest accident group with 270 accidents, 9.3 per cent of the total.

The flows Q3 and Q8 were the ones directly involved in the accident group. The spoiling flow function Q9, the right turn flow from arm 3, was the best of the spoiling flow functions.

The best model without factors was:

$$A = 0.00865\ Q3^{0.635}\ Q8^{0.477}\ \exp(2.263\ Q9^{0.1}) \quad (10.12)$$

The flow function for the best model with factors was:

$$A = 0.00780\ Q3^{0.648}\ Q8^{0.498}\ \exp(2.434\ Q9^{0.1}) \quad (10.13)$$

The effect of the factors was as follows: STJ (staggered junction) decreased accidents by a factor of 0.70; ISL3 (island on arm 3) increased accidents by a factor of 1.4.

VA8 - Right turn from minor with previous ahead

These accidents involved vehicles turning right from the minor arm (arm 2) and vehicles travelling ahead on the previous major arm (arm 1 to arm 3). This was quite a large accident group with 209 accidents, 7.2 per cent of the total.

The flows Q2 and Q6 were the ones directly involved in the accident group. The spoiling flow function Q1, the left turn from the major arm, was the best of the spoiling flow functions.

The best model without factors was:

$$A = 0.0378\ Q2^{0.706}\ Q6^{0.659}\ \exp(0.241\ Q1^{1.0}) \quad (10.14)$$

No factors were statistically significant.

VA9 - Other right turn accidents from the minor arm

This was a small group of five different accident types each involving a vehicle turning right from the minor arm (arm 2). The conflicting vehicles were: left turners from arm 1 (6); right turners from arm 3 (12), left turners from arm 4 (5); ahead vehicles on arm 4 (18) and right turners from arm 4 (4). There were 45 accidents in this group, 1.5 per cent of the total.

Numerous combinations of Q6, the right turn flow from the minor arm, with conflicting and non-conflicting flows were tried. The best fitting model included Q6 and V39, the sum of all the conflicting movements listed above.

The best model without factors was:

$$A = 0.00676\ Q6^{0.434}\ V39^{1.396} \quad (10.15)$$

No factors were statistically significant.

VA10 - Left turn from minor with previous ahead

These accidents involved vehicles turning left from the minor arm (arm 2) and vehicles travelling ahead on the previous major arm (arm 1 to arm 3). There were 61 of these accidents, 2.1 per cent of the total.

The flows Q2 and Q4 were the ones directly involved in the accident group. Q2 was just below the 5 per cent significance level. The spoiling flow function V56, the sum of the other flows on the minor arm, was among the best of the spoiling flow functions and its inclusion allowed Q2 to achieve significance.

The best model without factors was:

$$A = 0.00709\ Q2^{0.502}\ Q4^{0.306}\ \exp(0.463\ V56^{1.0}) \quad (10.16)$$

The flow function for the best model with factors was:

$$A = 0.00745\ Q2^{0.553}\ Q4^{0.329}\ \exp(0.514\ V56^{1.0}) \quad (10.17)$$

One factor was included in this model: RLJ (right/left staggered junction) decreased accidents by a factor of 0.32.

VA11 - Head-on/U-turn/Parked/Parking accidents on a major arm

These major arm accidents occurred on the entry or exit side of arm 1 and included head-on (31) and U-turn accidents (10) as well as accidents involving vehicles hitting a parked vehicle (33) or another moving vehicle whilst entering or leaving a parking place (13). There were 87 accidents in this group, 3.0 per cent of the total.

The flow function V7, the two-way flow on arm 1, was relevant to this accident group and among the best fitting flow functions. The pedestrian flow function PT, total pedestrian flow, was also statistically significant.

The best model without factors was:

$$A = 0.0000574\ V7^{0.809}\ \exp(3.882\ PT^{0.1}) \quad (10.18)$$

The flow function for the best model with factors was:

$$A = 0.000230\ V7^{0.553} \exp(2.654\ PT^{0.1}) \qquad (10.19)$$

The effect of the factors was as follows: LON (in London) increased accidents by a factor of 4.3; HCH5 (hatching on arms 1 or 3) decreased accidents by a factor of 0.16.

VA12 - Other vehicle-only accidents on a major arm

This accident group comprised the remaining vehicle-only accidents on the major arm. It included: accidents involving vehicles turning left from the major arm (39), accidents involving vehicles entering or leaving private drives on the major arm (10), reversing accidents on the major arm (3) and right turn accidents on the major arm except those already included in VA5 and VA7 (20). There were 72 accidents in this group, 2.4 per cent of the total.

Left turn from major accidents formed a large part of this amalgamated group and Q1, the left turn flow from arm 1, was found to be the most statistically significant vehicle flow function tested. V25, the sum of the ahead flows from the minor arms, was relevant and significant. The pedestrian flow function PT, total pedestrian flow, was also significant.

The best model without factors was:

$$A = 0.0266\ Q1^{0.291}\ V25^{0.284} \exp(0.125\ PT^{1.0}) \qquad (10.20)$$

The flow function for the best model with factors was:

$$A = 0.0113\ Q1^{0.290}\ V25^{0.333} \exp(0.146\ PT^{1.0}) \qquad (10.21)$$

One factor was included in this model: HCH5 (hatching on arms 1 or 3) increased accidents by a factor of 2.1.

VA13 - Other vehicle-only accidents on a minor arm

These minor arm accidents included single vehicle accidents (21), rear shunt and lane changing accidents (27), left turn accidents except those included in VA10 (11), head-on and U-turn accidents (5), parking accidents (9), reversing (1) and private drive accidents (2). There were 76 accidents in this group, 2.6 per cent of the total.

The best model without factors was:

$$A = 0.00889\ V2^{1.342} \exp(0.622\ PTB^{0.5}) \qquad (10.22)$$

The flow function for the best model with factors was:

$$A = 0.0119\ V2^{1.348} \qquad (10.23)$$

One factor was included in this model: LON (in London) increased accidents by a factor of 1.8.

10.5 MODELS FOR PEDESTRIAN ACCIDENT GROUPS

The models given in this Section are *arm based models* and predict accident frequency for a particular accident group on *a major arm* or *a minor arm*. Thus the models will need to be applied twice when predicting accidents for the whole junction with arms 'ABCD'; firstly with major arms A,C as arm 1 and arm 3 and minor arms B,D as arm 2 and arm 4, and secondly with major arms C,A as arm 1 and arm 3 and minor arms D,B as arm 2 and arm 4 respectively.

PA1 - Pedestrian accidents with vehicle entering on a major arm

These accidents involved vehicles entering on the major arm (arm 1) and pedestrians crossing the arm from the nearside or the offside. Most of the vehicles were travelling straight ahead (arm 1 to arm 3); only 2 accidents involved a left turning vehicle and none a right turning vehicle. There were 197 accidents in this group, 6.8 per cent of the total. In 63 per cent of the accidents (124) the pedestrian was crossing from the nearside and so was in the first half of the carriageway when the accident occurred.

Several vehicle flow functions were tested and marginally the best was V1, the entering flow on arm 1. All of the pedestrian functions tried gave a much greater reduction in scaled deviance than any of the vehicle functions; the best fitting pedestrian flow function was also the most appropriate PA, the two-way pedestrian flow across arm 1.

The best model without factors was:

$$A = 0.0361\ V1^{0.659}\ PA^{0.492} \qquad (10.24)$$

The flow function for the best model with factors was:

$$A = 0.0242\ V1^{0.552}\ PA^{0.280} \qquad (10.25)$$

The effect of the factors was as follows: STJ (staggered junction) increased accidents by a factor of 0.68); LON (in London) increased accidents by a factor of 1.5; ZAB1 (zebra on arm 1 with or without an island) increased accidents by a factor of 2.7; PAL1 (pelican on arm 1 with or without an island) increased accidents by a factor of 2.0.

PA2 - Pedestrian accidents with vehicle exiting on a major arm

These accidents involved vehicles exiting on the major arm (arm 1) and pedestrians crossing the arm from the nearside or the offside. Most of the vehicles were travelling straight ahead (arm 3 to arm 1); only 8 accidents involved a left turning vehicle and 16 a right turning vehicle. This was the largest pedestrian accident group with 242 accidents, 8.3 per cent of the total.

The proportion of pedestrians crossing from the nearside, was similar to accident group PA1. In 59 per cent of the accidents (142) the pedestrian was crossing from the nearside and so was in the first half of the carriageway when the accident occurred.

Several vehicle flow functions were tested and marginally the best was V5, the exiting flow on arm 1. The pedestrian flow function PA, the two-way flow across arm 1, was the most appropriate and gave the best fit.

The best model without factors was:

$$A = 0.0980\ V5^{0.307}\ PA^{0.619} \qquad (10.26)$$

The flow function for the best model with factors was:

$$A = 0.0604\ V5^{0.352}\ PA^{0.488} \qquad (10.27)$$

One factor was included in this model: ZAB1 (zebra on arm 1 with or without an island). ZAB1 increased accidents by a factor of 2.9.

PA3 - Other pedestrian accidents on a major arm

These accidents included: accidents involving pedestrians crossing the major arm from the nearside or the offside where the vehicle direction is unknown (46), accidents involving pedestrians crossing in the centre of the junction (8), accidents involving pedestrians hit by a reversing vehicle (11), accidents involving pedestrians walking/standing in the carriageway (12) or on the footway (8) and accidents involving pedal cyclists crossing the major arm (12). There were 97 accidents in this group, 3.3 per cent of the total.

Several vehicle flow functions were tried but none reached the 5 per cent level of significance. The flow function V1, the entering flow on arm 1, gave the marginally lowest scaled deviance but as the location on the major arms of many of these accidents was uncertain, the two-way flow, QMA, was considered more appropriate. The pedestrian flow function PTB, the pedestrian flow across both major arms and the junction centre, was the most appropriate and gave the best fit.

The best model without factors was:

$$A = 0.0251\ QMA^{0.146}\ PTB^{0.357} \qquad (10.28)$$

The flow function for the best model with factors was:

$$A = 0.0287\ QMA^{0.136}\ PTB^{0.396} \qquad (10.29)$$

One factor was included in this model: ZAB3 (zebra on arm 3 with or without an island). ZAB3 decreased accidents by a factor of 0.26.

PA4 - Pedestrian accidents on a minor arm

These accidents comprised all accidents involving pedestrians on the minor arm. They included accidents involving: a pedestrian crossing and a vehicle entering (23), a pedestrian crossing and a vehicle exiting (52), a reversing vehicle hits a pedestrian (5), pedestrian hit while standing in the carriageway (5), pedestrian hit on the footway (4), pedestrian trips over tow rope (3), pedal cyclist crosses minor arm (2) and pedestrian location unknown (2). There were 96 accidents in this group 3.3 per cent of the total.

The flow function V8, the two-way flow on arm 2, was relevant to this accident group and among the best fitting flow functions. Several pedestrian flow functions were tested and showed only marginal differences in fit. The pedestrian flow function PI, the two-way pedestrian flow on arm 2, was relevant and also significant.

The best model without factors was:

$$A = 0.0207\ V8^{0.863}\ PI^{0.427} \qquad (10.30)$$

The flow function for the best model with factors was:

$$A = 0.0178\ V8^{0.860}\ PI^{0.412} \qquad (10.31)$$

One factor was included in this model: LON (in London) increased accidents by a factor of 1.5.

11. ACCIDENT-FLOW-GEOMETRY MODELS BY ACCIDENT GROUP AND ARM OF JUNCTION

11.1 INTRODUCTION

In the third stage of the modelling of accidents at priority crossroads and staggered junctions, 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 in the accident-flow models (Section 10.4), the basic unit of analysis was *the junction arm.* Each junction gave two major arms and two minor arms. The total number of analysis units was 626 for the major arms and 626 for the minor arms.

The vehicle and pedestrian flows on the junction arms are illustrated in Figure 2. For the analysis of the accident groups on the major arms, arm 1 is the major arm, arm 3 is the opposite major arm, arm 4 is the previous minor arm and arm 2 is the next minor arm. For the analysis of accident groups on the minor arms, arm 2 is the minor arm, arm 4 is the opposite minor arm, arm 1 is the previous major arm and arm 3 is the next major arm. The terms 'next' and 'previous' are used in a clockwise sense.

11.2 THE FORM OF THE MODEL

In order to be able to examine the effects of the various variables of flow proportions, geometric and other junction characteristics, both of a discrete and continuous form, it is necessary to extend the basic forms of accident-flow models by accident group presented in Section 10.

The forms of the extended models are:

$$A = k\, Q_a^{\alpha} \exp\left(\Sigma\, \gamma_{ij} D_{ij} + \Sigma\, \varepsilon_i G_i\right) \qquad (11.1)$$

$$A = k\, Q_a^{\alpha} Q_b^{\beta} \exp\left(\Sigma\, \gamma_{ij} D_{ij} + \Sigma\, \varepsilon_i G_i\right) \qquad (11.2)$$

$$A = k\, Q_a^{\alpha} \exp\left(bQ_b^{\beta}\right) \exp\left(\Sigma\, \gamma_{ij} D_{ij} + \Sigma\, \varepsilon_i G_i\right) \qquad (11.3)$$

where A is the accident frequency (per year per junction);

Q_a, Q_b are functions of the vehicle and pedestrian flows;

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;

G_i are the continuous variables of the flow proportions, geometric and junction variables;

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

The transformed linear forms of the models used in the fitting procedures are:

$$\log(A.YR) = \log(YR) + \log(k) + \alpha \log(Q_a) + \Sigma\, \gamma_{ij} D_{ij} + \Sigma\, \varepsilon_i G_i \qquad (11.4)$$

$$\log(A.YR) = \log(YR) + \log(k) + \alpha \log(Q_a) + \beta \log(Q_b) + \Sigma\, \gamma_{ij} D_{ij} + \Sigma\, \varepsilon_i G_i \qquad (11.5)$$

$$\log(A.YR) = \log(YR) + \log(k) + \alpha \log(Q_a) + b\, Q_b^{\beta} + \Sigma\, \gamma_{ij} D_{ij} + \Sigma\, \varepsilon_i G_i \qquad (11.6)$$

where log (YR) is the offset variable.

11.3 FLOW FUNCTIONS AND OTHER VARIABLES AND FACTORS

The traffic and pedestrian flow functions from the accident-flow models developed in Section 10 were used as the basis of the full analysis in this Section.

A wide range of geometric and other features were measured at each junction and from these and the traffic and pedestrian flow, a large number (about 800) 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) Vehicle flow proportions by vehicle type.

(ii) Site features, such as speed limit, presence of pedestrian crossing, traffic islands, land use, bus stops

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

(iv) Road markings

(v) Parking regulations, occupancy and activity

(vi) Traffic signing

(vii) Pedestrian flow proportions by sex and age group

(viii) Vehicle speed, queue length, sex and age of drivers

A full list of all the explanatory variables and factors used in the analysis is given in Appendix A. Details of how the variables were measured are given in Appendix C.

11.4 DEVELOPMENT OF PRELIMINARY ACCIDENT-FLOW-GEOMETRY MODELS

For each accident group, the first step in the modelling procedure was to take the most suitable accident-flow model and to test the effect of individually trying each of the flow proportion, feature, geometric and land use variables at the 5 per cent level of statistical significance. Not all variables were tested; only those which were considered in any way relevant to the particular accident group.

This formed a pool of statistically significant 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.

Some of the accident groups had large numbers of significant variables and factors in the pool. Many of these were very similar and they were sorted into groups of similar variables to aid comprehension.

Preliminary accident-flow geometry 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 were 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 preliminary models are briefly described, for each accident type, in Sections 11.6 and 11.7.

11.5 DEVELOPMENT OF PREFERRED FULL ACCIDENT-FLOW-GEOMETRY MODELS

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. In the final stage of the study, the preliminary accident-flow-geometry models were refined using the following criteria:

(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) consistency between similar variables and factors. The effects of replacing variables and factors in the models with similar or alternative variables and factors was examined to check for consistency;

(iii) 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 selection of one variable in preference to another.

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

(v) 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.

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

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

Tables 34 and 35 provide an overall summary of the variables and factors that appear in the preferred accident-flow-geometry models. Table 36 presents for each accident group the linear forms of the preferred and preliminary accident-flow geometry models.

11.6 MODELS FOR VEHICLE-ONLY ACCIDENT GROUPS

The models given in this Section are *arm based models* and predict accident frequency for a particular accident group on *a major arm* or *a minor arm.*

The models will need to be applied twice when predicting accidents for a whole junction with arms 'ABCD'; firstly with major arms A,C as arm 1 and arm 3 and minor arms B,D as arm 2 and arm 4, and secondly with major arms C,A as arm 1 and arm 3 and minor arms D,B as arm 2 and arm 4 respectively.

VA1 - Single vehicle accidents on a major arm (133)

This accident group included all single vehicle (non-pedestrian) accidents occurring on the arm 1 approach, the junction centre and the exit of arm 3; accidents on the exit of arm 3 involving vehicles turning from arms 2 or 4 were also included.

Most of the accidents involved cars (37 per cent), public service vehicles (35 per cent) or motor cycles (20 per cent). The main types of accident within the VA1 group were: approaching (19 per cent), left at centre of junction (8 per cent), hit object off carriageway (20 per cent), hit object in carriageway (12 per cent), passenger falls in PSV (21 per cent) and passenger falls off PSV (11 per cent).

The flow function of the preferred full model was:

$$A = 0.00236\ V15^{0.682} \qquad (11.7)$$

where V15 is the entering flow on the major arm, plus the right turn on the previous minor, plus the left turn on the next minor.

The preferred full model included 6 additional explanatory variables or factors. Accidents increased with: PBQMA (the proportion of public service vehicles in the major road inflow QMA); PMQMA (proportion of motor cycles in the major road inflow QMA); LON (junction within London);

TABLE 34

Variables and factors used in the preferred vehicle-only accident-flow-geometry models

	Vehicle-only accident groups												
	VA1	VA2	VA3	VA4	VA5	VA6	VA7	VA8	VA9	VA10	VA11	VA12	VA13
Flow variables													
Veh. flow 1	V15 ++	V15 ++	Q2 ++	Q2 ++	X23 +	Q6 ++	Q3 ++	Q2 ++	Q6 ++	Q2 +	V7 ++	Q1 +	V2 ++
Veh. flow 2			Q11 ++	Q5 ++		Q8 ++	Q8 ++	Q6 ++	V39 ++	Q4 +		V25 ++	
Spoiling flow Q9							++						
Spoiling flow V56										+			
Spoiling flow V64						++							
PBQMA proptn. of PSV in QMA	++												
PMQMA proptn. of MC in QMA	++						++						
PBQMI proptn. of PSV in QMI													+
PMQMI proptn. of MC in QMI													+
PT total pedestrian flow												+	
Junction variables and factors													
ASTAG absolute stagger length of minor arms			2-	2-									
RLJ Right/left staggered junction										2-			
LON junction in London	++	++		++	+						++		++
ZAB1 zebra on arm 1		++											
PAL1 pelican on arm 1		+											
ISL1 island on arm 1			++										
ISL3 island on arm 3							+						
ISL5 island on arms 1 or 3	+	2-			2-								
HCH1 ghost island on arm 1	1-												
HCH5 ghost island on arms 1 or 3											2-		
ANGLE4 angle between arms 4 and 1 greater than 90 degrees									+				

TABLE 34 (CONTINUED)

	Vehicle-only accident groups												
	VA1	VA2	VA3	VA4	VA5	VA6	VA7	VA8	VA9	VA10	VA11	VA12	VA13
DEVMJR abs (ANA1+ANA2-180) see Appendix A	++				2-								
DEVMNR abs (ANA2+ANA3-180) see Appendix A				1-									
GDN1 gradient 0-50m on arm 1			2-										
GDN3 gradient 0-50m on arm 3							2-						
ISD1 inv. of stopping sight distance on arm 1			2-										
ISD3 inv. of stopping sight distance on arm 3				2-			1-			1-			
I9L152 1/(visib. left+15) at 9m on arm 2						+							
I9L154 1/(visib. left+15) at 9m arm 4			1-										
I9R152 1/(visib. right+15) at 9m on arm 2				1-									
I9R154 1/(visib. right+15) at 9m on arm 4									1-				
C2D1 presence of curvature within 50m on arm 1						1-				+			

TABLE 34 (CONTINUED)

	Vehicle-only accident groups												
	VA1	VA2	VA3	VA4	VA5	VA6	VA7	VA8	VA9	VA10	VA11	VA12	VA13
C2D2 presence of curvature within 50m on arm 2			2-										
C2D3 presence of curvature within 50m on arm 3			1-										
RCC1 radius of entry corner on arm 1								+					
RCC3 radius of entry corner on arm 3							2-						
GSL4 presence of a stop line on arm 4			2-										
NAE1 number of ahead lanes at entry on arm 1		+											

+ / 1- positive/negative and statistically significant at the 5% level
++ /2- positive/negative and statistically significant at the 1% level

TABLE 35

Variables and factors used in the preferred pedestrian accident-flow-geometry models

	Pedestrian accident groups			
	PA1	PA2	PA3	PA4
Flow variables				
Vehicle flow	V1 +	V5 +	QMA not sig.	V8 ++
PMQMA proportion of MC in QMA	+			
Pedestrian flow	PA ++	PA ++	PTB ++	PI ++
Junction variables and factors				
STJ staggered junction	1-			
LON within London	+			+
Major arm variables and factors				
ZAB1 zebra on arm 1	++	++		
PAL1 pelican on arm 1	++			
ISD1 reciprocal of stopping sight distance on arm 1		2-		
NAE1 number of ahead lanes at entry on arm 1	+			
Y2E1 bus bay entry side within 50m on arm 1	++			
Minor arm variables and factors				
B1E2 bus stop within 25m on entry of arm 2				+
UE1N2 residential as dominant land use within 0-20m on entry of arm 2				2-

+ / 1- positive/negative and statistically significant at the 5% level
++ / 2-positive/negative and statistically significant at the 1% level

ISL5 (the presence of an island on arms 1 or 3) and DEVMJR (absolute angular deviation of the major arms across the junction). Accidents were reduced by HCH1 (hatching on arm 1).

The preliminary model is given as an alternative in Table 36. It contained the additional or alternative terms: PBV15 (the proportion of public service vehicles in flow V15); PMV15 (proportion of motor cycles in V15); HCH7 (hatching on arms 1 and 3) and Y2E1 (the presence of a bus bay within 50m on entry side of arm 1).

VA2 - Rear end shunt and lane changing accidents on a major arm (278)

This accident group included all rear end shunt and lane changing accidents occurring on the arm 1 approach, the junction centre and the exit of arm 3; accidents on the exit of arm 3 involving vehicles turning from arms 2 or 4 were also included.

Most of the accidents in the VA2 group were rear end shunts (90 per cent). The main types of rear end shunt were: both vehicles travelling straight ahead on the approach to the junction (43 per cent); front vehicle turning right, rear vehicle travelling straight ahead (26 per cent) and both vehicles travelling straight ahead on the exit from the junction (16 per cent). In the rear end shunt accidents, a large proportion of the vehicles running into the back of the first vehicle were pedal cycles or motor cycles (17 per cent).

The flow function of the preferred full model was:

$$A = 0.00246\ V15^{1.387} \qquad (11.8)$$

where V15 is the entering flow on the major arm, plus the right turn on the previous minor, plus the left turn on the next minor.

There were 5 additional explanatory variables or factors. Accidents increased with: LON (junction within London); ZAB1 (zebra with or without an island on arm 1); PAL1

TABLE 36

Accident-flow-geometry models by accident group and arm of junction

Model	Model terms[1]	Parameter value	s.e.[2]	Deviance difference[3]	Multiplicative effect Min.	Multiplicative effect Mean	Multiplicative effect Max.	Deviance	Degrees of freedom	Scale factor
VA1 - Single vehicle accidents on a major arm (133)										
Null	Lk	-3.285	0.094					475.3	625	1.20
Full	Lk	-6.047	0.481					399.2	618	1.01
	LV15	0.682	0.211	12.3	0.14	1	1.8			
(a)	PBQMA	28.39	5.57	23.1	0.6	1	6.2			
pref.	PMQMA	16.35	5.56	7.6	0.8	1	5.6			
	LON	0.508	0.194	6.7	1		1.7			
	ISL5	0.520	0.200	6.5	1		1.7			
	HCH1	-0.834	0.420	5.1	1		0.4			
	DEVMJR	0.051	0.011	17.2	0.8	1	5.4			
(b)	Lk	-5.492	0.482					414.3	619	1.09
alt.	LV15	0.680	0.222	11.7	0.17	1	1.7			
	PBV15	20.80	5.72	12.7	0.7	1	3.7			
	PMV15	14.24	5.93	5.6	0.8	1	4.7			
	LON	0.531	0.196	7.8	1		1.7			
	HCH7	-1.539	0.731	8.0	1		0.2			
	Y2E1	0.927	0.334	6.6	1		2.5			
VA2 - Rear shunt and lane changing accidents on a major arm (278)										
Null	Lk	-2.547	0.073					725.3	625	1.48
Full	Lk	-6.008	0.404					572.9	619	1.10
	LV15	1.387	0.191	67.4	0.03	1	3.0			
(a)	LON	0.374	0.139	7.7	1		1.5			
pref.	ZAB1	0.763	0.176	18.1	1		2.1			
	PAL1	0.447	0.189	5.8	1		1.6			
	ISL5	-0.546	0.181	10.9	1		0.6			
	NAE1	0.467	0.221	4.4	1	1	1.6			
(b)	Lk	-5.661	0.390					539.1	618	1.04
alt.	LV15	1.520	0.179	85.7	0.02	1	3.4			
	ZAB5	0.587	0.137	17.5	1		1.8			
	ISL5	-0.523	0.170	10.8	1		0.6			
	GUSB5	0.613	0.150	15.4	1		1.8			
	UX6N3	-1.239	0.413	13.4	1		0.3			
	DXL3	-1.189	0.063	10.4	2.8	1	0.002			
	C1D3	0.394	0.138	8.0	1		1.5			

TABLE 36 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Deviance difference[3]	Multiplicative effect Min.	Mean	Max.	Deviance	Degrees of freedom	Scale factor
VA3 - Right angle: major arm with previous minor (492)										
Null	Lk	-1.977	0.069					1135	625	2.36
Full	Lk	-0.607	0.207					601.0	615	1.13
	LQ2	0.538	0.085	50.2	0.1	1	1.7			
(a)	LQ11	0.855	0.060	291.1	0.01	1	5.0			
pref.	ASTAG	-0.117	0.014	113.7	1.9	1	0.1			
	ISL1	0.337	0.115	9.1	1		1.4			
	GDN1	-0.066	0.018	14.9	2.0	1	0.5			
	ISD1	-86.3	24.4	16.2	1.1	1	0.3			
	I9L154	-11.43	5.88	4.3	1.1	1	0.7			
	C2D2	-0.365	0.129	9.7	1		0.7			
	C2D3	-0.226	0.116	4.4	1		0.8			
	GSL4	-0.697	0.201	16.3	1		0.5			
(b)	Lk	-2.097	0.270					581.4	614	1.09
alt.	LQ2	0.604	0.087	59.8	0.1	1	1.8			
	LQ11	0.891	0.060	306.4	0.005	1	5.3			
	ASTAG	-0.127	0.014	133.9	2	1	0.1			
	I9L4	-7.44	2.97	7.2	1.2	1	0.3			
	SSD1	0.0042	0.0011	17.1	0.5	1	1.1			
	GSL4	-0.638	0.198	13.3	1		0.5			
	GDN1	-0.065	0.018	13.9	2.0	1	0.5			
	C2D2	-0.418	0.125	13.0	1		0.7			
	PDS6	10.83	3.29	10.9	0.9	1	2.2			
	ISL1	0.280	0.113	6.4	1		1.3			
	GUC2	-0.837	0.295	11.2	1		0.4			
VA4 - Right angle: Major arm with next minor (410)										
Null	Lk	-2.159	0.067					954.7	625	1.88
Full	Lk	-0.762	0.237					622.3	618	1.23
	LQ2	0.257	0.092	10.1	0.4	1	1.3			
(a)	LQ5	0.686	0.063	173.2	0.02	1	3.6			
pref.	ASTAG	-0.077	0.014	43.5	1.5	1	0.3			
	LON	0.475	0.116	19.5	1		1.6			
	DEVMNR	-0.015	0.007	7.7	1.2	1	0.4			
	ISD3	-78.0	26.7	12.0	1.1	1	0.3			
	I9R152	-12.22	5.21	6.7	1.2	1	0.7			
(b)	Lk	-5.49	1.19					612.0	618	1.18
alt.	LQ2	0.271	0.090	11.3	0.3	1	1.3			
	LQ5	0.699	0.062	185.3	0.01	1	3.7			
	LSMN1	1.295	0.343	17.0	0.4	1	1.6			
	ASTAG	-0.079	0.014	45.2	1.6	1	0.2			
	LON	0.572	0.118	26.5	1		1.8			
	DEVMNR	-0.014	0.007	7.2	1.2	1	0.4			
	ISD3	-67.3	26.5	8.5	1.1	1	0.3			

TABLE 36 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Deviance difference[3]	Multiplicative effect Min.	Multiplicative effect Mean	Multiplicative effect Max.	Deviance	Degrees of freedom	Scale factor
VA4 - Right angle: Major arm with next minor (410) (continued)										
(c)	Lk	-2.663	0.423					608.2	618	1.22
alt.	LQ2	0.307	0.092	14.7	0.3	1	1.4			
	LQ5	0.686	0.063	176.2	0.02	1	3.6			
	ASTAG	-0.085	0.014	56.6	1.6	1	0.2			
	LON	0.502	0.118	21.3	1		1.7			
	S851	0.036	0.012	11.6	0.6	1	1.7			
	C3D4	-0.375	0.120	12.2	1		0.7			
	US8C1	-0.354	0.140	8.1	1		0.7			
VA5 - Right turn from major with own ahead (47)										
Null	Lk	-4.325	0.145					246.4	625	1.00
Full	LK	-4.143	0.228					214.5	621	1.00
pref.	LX23	0.279	0.133	4.7	0.2	1	2.0			
	LON	0.784	0.300	6.3	1		2.2			
	ISL5	-1.744	0.597	13.6	1		0.2			
	DEVMJR	-0.123	0.049	10.2	1.7	1	0.02			
VA6 - Right turn from minor with next ahead (105)										
Null	Lk	-3.521	0.106					421.9	625	1.22
Full	Lk	-9.96	2.15					385.9	619[4]	1.17
	LQ6	0.393	0.114	14.8	0.00	1	2.4			
(a)	LQ8	0.535	0.194	10.1	0.1	1	1.7			
pref.	$V64^{0.1}$	5.46	1.82	11.3	0.3	1	2.1			
	I9L152	28.9	12.3	6.3	0.7	1	2.7			
	C2D1	-0.534	0.249	5.8	1		0.6			
(b)	Lk	-9.43	2.14					379.4	618[4]	1.17
alt.	LQ6	0.412	0.114	16.2	0.00	1	2.5			
	LQ8	0.489	0.194	8.4	0.1	1	1.6			
	$V64^{0.1}$	5.19	1.81	10.4	0.3	1	2.0			
	I9L152	31.3	12.3	7.4	0.7	1	2.9			
	C2D1	-0.562	0.250	6.4	1		0.6			
	KBB3	-0.273	0.128	6.4	1.5	1	0.03			
(c)	Lk	-8.780	1.99					377.0	618[4]	1.11
alt.	LQ6	0.382	0.106	14.8	0.00	1	2.3			
	LQ8	0.613	0.188	13.4	0.1	1	1.8			
	$V64^{0.1}$	5.38	1.728	11.4	0.3	1	2.1			
	V4L2	-0.0041	0.0015	8.2	1.7	1	0.7			
	KE3C2	-0.642	0.251	8.1	1		0.5			
	C2D2	-0.581	0.242	6.9	1		0.6			

TABLE 36 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Deviance difference[3]	Multiplicative effect Min.	Mean	Max.	Deviance	Degrees of freedom	Scale factor
VA7 - Right turn from major with opposite ahead (270)										
Null	Lk	-2.577	0.077					725.0	625	1.60
Full	LK	-4.345	0.769					565.6	616[4]	1.13
	LQ3	0.665	0.074	97.1	0.03	1	3.6			
(a)	LQ8	0.393	0.116	13.9	0.2	1	1.5			
pref.	$Q9^{0.1}$	2.325	0.796	9.5	0.4	1	1.6			
	PMQMA	11.76	3.73	9.6	0.8	1	3.4			
	ISL3	0.419	0.155	7.5	1		1.5			
	GDN3	-0.074	0.024	10.1	2.2	1	0.4			
	ISD3	-62.7	30.9	5.4	1.1	1	0.4			
	RCC3	-0.043	0.015	12.2	1.3	1	0.06			
(b)	Lk	-4.545	0.774					569.2	616[4]	1.12
alt.	LQ3	0.688	0.075	102.5	0.02	1	3.8			
	LQ8	0.436	0.120	15.9	0.18	1	1.5			
	$Q9^{0.1}$	2.458	0.805	10.4	0.4	1	1.6			
	PM8	7.50	3.57	4.4	0.9	1	2.5			
	GDF3	-0.071	0.023	10.0	2.2	1	0.4			
	W2X4	-0.062	0.023	8.5	1.3	1	0.3			
	WIS3	0.131	0.047	7.8	0.9	1	2.7			
	STJ	-0.286	0.138	4.9	1		0.8			
VA8 - Right turn from minor with previous ahead (209)										
Null	Lk	-2.833	0.082					618.8	625	1.40
Full	Lk	-3.151	0.265					466.4	622	1.07
	LQ2	0.715	0.133	34.3	0.1	1	2.0			
(a)	LQ6	0.772	0.077	115.9	0.0	1	5.5			
pref.	RCC1	0.018	0.007	5.8	0.9	1	3.1			
(b)	Lk	-2.660	0.249					463.9	622	1.11
alt.	LQ2	0.613	0.133	26.3	0.1	1	1.8			
	LQ6	0.799	0.077	126.6	0.0	1	5.6			
	KBB1	-0.223	0.087	8.2	1.4	1	0.1			
(c)	Lk	-3.987	0.373					438.2	618	1.00
alt.	LQ2	0.689	0.131	30.7	0.1	1	2.0			
	LQ6	0.539	0.091	38.4	0.0	1	3.3			
	PM2	8.36	3.99	3.9	0.9	1	2.8			
	QUA2	0.137	0.039	11.4	0.7	1	3.2			
	RCC1	0.021	0.007	6.6	0.9	1	3.7			
	KEB1	-0.109	0.040	8.5	1.2	1	0.3			
	Y1E1	1.131	0.366	7.0	1		3.1			

TABLE 36 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Deviance difference[3]	Multiplicative effect Min.	Mean	Max.	Deviance	Degrees of freedom	Scale factor
VA9 - Other right turn from minor (45)										
Null	Lk	-4.368	0.168					248.8	625	1.29
Full	Lk	-4.752	0.633					196.7	621	1.0
	LQ6	0.529	0.165	11.1	0.0	1	3.2			
(a)	LV39	1.392	0.364	17.2	0.03	1	5.2			
pref.	ANGLE4	0.759	0.313	6.1	1		2.1			
	I9R154	-27.8	14.4	3.8	1.7	1	0.4			
(b)	Lk	-7.91	1.29					191.9	620	1.0
alt.	LQ6	0.499	0.164	9.9	0.0	1	3.0			
	LV39	1.464	0.363	19.0	0.02	1	5.6			
	ANA4	0.023	0.009	5.6	0.2	1	3.5			
	I9R154	-31.2	14.5	4.7	1.8	1	0.4			
	WPE1	0.297	0.132	4.7	0.6	1	2.9			
VA10 - Left turn from minor with previous ahead (61)										
Null	Lk	-4.064	0.143					306.9	625	1.25
Full	Lk	-3.925	0.727					272.2	618[4]	1.0
	LQ2	0.465	0.244	4.0	0.2	1	1.6			
(a)	LQ4	0.344	0.146	5.6	0.3	1	2.0			
pref.	$V56^{1.0}$	0.470	0.210	4.4	0.8	1	1.1			
	RLJ	-1.162	0.458	8.4	1		0.3			
	ISD3	-187.2	84.0	6.6	1.4	1	0.1			
	C2D1	0.557	0.257	4.5	1		1.7			
(b)	Lk	-5.622	0.777					248.5	616	1.0
alt.	LQ2	0.003	0.215	0.0	1.0	1	1.0			
	LQ4	0.504	0.148	11.8	0.2	1	2.7			
	PM2	14.39	6.51	4.0	0.8	1	6.0			
	V9R2	0.006	0.002	11.5	0.7	1	2.7			
	V2L2	0.008	0.003	8.1	0.3	1	1.4			
	RCC2	-0.117	0.036	13.2	2.1	1	0.01			
	GDF1	-0.154	0.049	9.3	5.7	1	0.1			
	C2D1	0.668	0.258	6.4	1		2.0			
	STAG	-0.033	0.016	4.0	2.2	1	0.5			

TABLE 36 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Deviance difference[3]	Multiplicative effect Min.	Multiplicative effect Mean	Multiplicative effect Max.	Deviance	Degrees of freedom	Scale factor
VA11 - Head-on/U-turn/Parked/Parking accidents on major (87)										
Null	Lk	-3.708	0.116					382.4	625	1.23
Full	Lk	-5.930	0.619					300.8	622	1.02
	LV7	0.662	0.236	9.2	0.1	1	1.8			
(a)	LON	1.532	0.230	46.7	1		4.6			
pref.	HCH5	-2.045	0.655	17.3	1		0.1			
(b)	Lk	-6.529	0.686					293.6	621	1.01
alt.	LV7	0.824	0.252	12.8	0.1	1	2.0			
	LON	1.402	0.233	38.0	1		4.1			
	HCH5	-1.899	0.656	13.7	1		0.1			
	KBB1	0.230	0.080	7.2	0.7	1	17.2			
(c)	Lk	-6.369	0.741					273.1	618	1.03
alt.	LV7	0.644	0.281	5.8	0.1	1	1.7			
	LON	1.162	0.250	22.4	1		3.2			
	CHAJ	-1.331	0.506	9.6	1		0.3			
	KBB5	0.118	0.045	6.3	0.8	1	4.2			
	KB2N5	0.748	0.300	5.8	1		2.1			
	PZC3	0.863	0.251	11.4	1		2.4			
	ZBB1	0.598	0.283	4.2	1		1.8			
VA12 - Other vehicle-only accidents on a major arm (72)										
Null	Lk	-3.898	0.122					326.6	625	1.07
Full	LK	-3.626	0.205					305.3	621[4]	1.07
	LQ1	0.291	0.136	4.9	0.3	1	2.0			
(a)	LV25	0.284	0.114	7.2	0.2	1	1.6			
pref.	$PT^{1.0}$	0.125	0.046	6.4	0.8	1	5.2			
(b)	Lk	-3.512	0.214					296.7	620[4]	1.17
alt.	LQ1	0.304	0.141	5.4	0.3	1	2.0			
	LV25	0.303	0.118	8.2	0.2	1	1.7			
	$PT^{1.0}$	0.150	0.048	8.8	0.8	1	7.3			
	KE3N1	-1.094	0.461	8.6	1		0.3			
VA13 - Other vehicle-only accidents on a minor arm (76)										
Null	Lk	-3.843	0.124					350.0	625	1.22
Full	Lk	-5.031	0.271					270.3	621	1.00
	LV2	1.294	0.191	54.5	0.01	1	7.0			
(a)	PBQMI	15.59	6.37	5.1	0.8	1	3.3			
pref.	PMQMI	18.00	6.65	6.4	0.7	1	3.0			
	LON	0.679	0.240	7.4	1		2.0			
(b)	Lk	-5.104	0.270							
alt.	LV2	1.405	0.191	66.3	0.01	1	7.0	266.3	621	1.00
	PBV2	15.28	4.83	7.8	0.9	1	11.2			
	PWV2	5.80	1.76	8.3	0.7	1	12.3			
	LON	0.810	0.248	9.9	1		2.2			

TABLE 36 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Deviance difference[3]	Multiplicative effect Min.	Mean	Max.	Deviance	Degrees of freedom	Scale factor
PA1 - Pedestrian with vehicle entering on major arm (197)										
Null	Lk	-2.892	0.082					598.4	625	1.32
Full	Lk	-4.416	0.434					423.6	616	1.05
	LV1	0.395	0.179	5.3	0.3	1	1.4			
(a)	PMQMA	11.12	4.38	6.0	0.8	1	3.2			
pref.	LPA	0.245	0.078	10.7	0.3	1	1.9			
	STJ	-0.334	0.161	4.6	1		0.7			
	LON	0.337	0.163	5.4	1		1.4			
	ZAB1	1.045	0.223	22.0	1		2.8			
	PAL1	0.805	0.267	9.2	1		2.2			
	NAE1	0.586	0.292	3.8	1.0	1	1.8			
	Y2E1	0.926	0.295	8.3	1		2.5			
(b)	Lk	-4.435	0.437					423.5	616	1.05
alt.	LV1	0.403	0.179	5.5	0.3	1	1.4			
	PMV1	11.15	4.32	6.1	0.8	1	3.7			
	LPA	0.244	0.078	10.6	0.3	1	1.9			
	STJ	-0.338	0.161	4.7	1		0.7			
	LON	0.376	0.163	5.3	1		1.5			
	ZAB1	1.058	0.223	22.5	1		2.9			
	PAL1	0.803	0.267	9.1	1		2.2			
	NAE1	0.588	0.292	3.8	1.0	1	1.8			
	Y2E1	0.926	0.295	8.3	1		2.5			
(c)	Lk	-8.46	1.91					434.5	617	1.06
alt.	LV1	0.455	0.178	7.1	0.2	1	1.5			
	LPA	0.277	0.085	11.7	0.2	1	2.0			
	LPI	0.174	0.080	5.1	0.4	1	1.6			
	LSMN1	1.514	0.591	7.0	0.4	1	1.8			
	STJ	-0.392	0.159	6.7	1		0.7			
	LON	0.562	0.168	11.4	1		1.8			
	ZAB1	1.069	0.227	22.1	1		2.9			
	PAL1	0.688	0.265	7.0	1		2.0			
PA2 - Pedestrian with vehicle exiting on the major arm (242)										
Null	Lk	-2.686	0.080					706.4	625	1.55
Full	Lk	-2.196	0.396					474.3	619	1.05
	LV5	0.306	0.147	4.7	0.4	1	1.3			
(a)	LPA	0.478	0.058	74.3	0.07	1	3.4			
pref.	ZAB1	1.038	0.151	46.1	1		2.8			
	ISD1	-98.8	39.2	8.0	1.2	1	0.2			
(b)	Lk	-2.251	0.377					465.5	620	1.04
alt.	LV5	0.359	0.148	6.3	0.3	1	1.4			
	LPA	0.477	0.057	75.9	0.07	1	3.4			
	ZAB1	1.009	0.150	43.9	1		2.7			
	P2B1	-0.884	0.340	8.9	1		0.4			
	ISD1	-94.8	39.3	7.1	1.1	1	0.2			

TABLE 36 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Deviance difference[3]	Multiplicative effect Min.	Multiplicative effect Mean	Multiplicative effect Max.	Deviance	Degrees of freedom	Scale factor
PA3 - other pedestrian accidents on major (97)										
Null	Lk	-3.600	0.105					393.6	625	1.11
Full	Lk	-3.684	0.577					377.8	623	1.05
(a)	LQMA	0.146	0.220	0.5	0.6	1	1.1			
pref.	LPTB	0.357	0.101	13.7	0.2	1	2.0			
(b)	Lk	-3.313	0.564					353.4	620	1.00
alt.	LQMA	0.046	0.217	0.0	0.9	1	1.0			
	LPTB	0.407	0.099	18.0	0.2	1	2.2			
	AEF1	0.473	0.149	7.6	0.6	1	4.0			
	KXA1	-0.878	0.397	7.9	1.2	1	0.03			
	ZAB3	-1.234	0.584	6.5	1		0.3			
PA4 - pedestrian accidents on minor (96)										
Null	Lk	-3.610	0.100					372.7	625	1.00
Full	Lk	-3.908	0.221					297.9	620	1.00
	LV8	0.841	0.156	32.3	0.08	1	3.3			
(a)	LPI	0.318	0.088	14.0	0.2	1	2.4			
pref.	LON	0.518	0.213	5.6	1		1.7			
	B1E2	1.224	0.514	4.0	1		3.4			
	UE1N2	-0.656	0.238	7.8	1		0.5			
(b)	Lk	-4.013	0.229							
alt.	LV8	0.818	0.157	29.6	0.08	1	3.2	294.9	620	1.00
	LPI	0.340	0.091	15.2	0.2	1	2.5			
	LON	0.566	0.215	6.6	1		1.8			
	PBV8	14.47	4.86	7.0	0.9	1	6.4			
	UE1N2	-0.698	0.238	8.9	1		0.5			

1 L prefix indicates log form of variable e.g. LQT = log (QT)

2 Standard error of estimate. The values of the standard errors quoted *have been scaled by the square root of the scale factor.*

3 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.

4 The number of degrees of freedom has been reduced by 1 because the exponent of the spoiling flow or pedestrian flow has been empirically determined using the value that gave the lowest scaled deviance

( ) Figures in brackets are the number of accidents (pelican with or without an island on arm 1) and NAE1 (number of ahead entry lanes at entry on arm 1). Accidents decreased with ISL5 (the presence of islands on arms 1 or 3).

The preliminary model is given as an alternative in Table 36. It contained the additional or alternative terms: ZAB5 (the presence of a zebra crossing on either arm 1 or arm 3); GUSB5 (the presence of a guard rail on the entry of arm 1, or the corner of arm 1, or the corner of arm 2); UX6N3 (the presence of public buildings on the exit side of arm 3 within 20m of the junction); DXL3 (the number of private drives on the exit side of arm 3 within 50m of the junction); and C1D3 (the presence of curvature on arm 3 within 25m of the junction).

VA3 - Right angle accidents: major arm with previous minor (492)

These accidents involved vehicles travelling ahead on the major arm (arm 1 to arm 3) and vehicles travelling ahead on the previous, right hand, minor arm (arm 4 to arm 2).

A large proportion of vehicles travelling ahead on the major arm that were involved in the VA3 group of accidents were two-wheelers (pedal cyclists 13 per cent and motor cyclists 20 per cent). However, the proportions of these types of vehicles in flow Q2 were not found to be statistically significant.

The flow function of the preferred full model was:

$$A = 0.545\ Q2^{0.538}\ Q11^{0.855} \qquad (11.9)$$

where Q2 is the ahead flow on the major arm and Q11 is the ahead flow on the previous minor.

There were 8 additional explanatory variables or factors. Accidents increased with: ISL1 (island on arm 1). Accidents decreased with ASTAG (absolute value of stagger length); GDN1 (uphill gradient over 0-50m on approach arm 1); ISD1 (inverse of stopping sight distance on arm 1); I9L154 (inverse of visibility to left plus 15 metres at 9m back from give way line on minor arm 4); C2D2 (curvature within 50m on arm 2); C2D3 (curvature within 50m on arm 3) and GSL4 (stop line on arm 4).

S851, the 85th percentile speed on arm 1, increased accidents and was statistically significant when tested against a model containing Q2, Q11 and ASTAG. It was forced out by the inclusion of variables related to ISD1 (the stopping sight distance on the major arm 1) and I9L154 (the visibility from the minor arm). S851 was not strongly correlated with ISD1 or I9L154 (correlation coefficients of -0.23 and -0.19 respectively).

The preliminary model is given as an alternative in Table 36. It contained the additional terms: PDS6 (senior females as a proportion of drivers on the minor arms) and GUC2 (the presence of a guard rail on the entry corner of arm 2).

VA4 - Right angle accidents: major arm with next minor (410)

These accidents involved vehicles travelling ahead on the major arm (arm 1 to arm 3) and vehicles travelling ahead on the next, left hand, minor arm (arm 2 to arm 4).

As in VA3, a large proportion of vehicles travelling ahead on the major arm that were involved in this type of accident were two-wheelers (pedal cyclists 11 per cent and motor cyclists 19 per cent) but the proportions of these types of vehicles in flow Q2 were not found to be statistically significant.

The flow function of the preferred full model was:

$$A = 0.467\ Q2^{0.257}\ Q5^{0.686} \qquad (11.10)$$

where Q2 is the ahead flow on the major arm and Q5 is the ahead flow on the next minor.

There were 5 additional explanatory variables or factors. Accidents increased with: LON (within London). Accidents were reduced by ASTAG (absolute value of stagger length); DEVMNR (absolute angular deviation of the minor arms across the junction); ISD3 (the inverse stopping sight distance on arm 3) and I9R152 (the inverse visibility to the right plus 15 metres at 9m back from giveway line on minor arm 2).

An alternative model containing SMN1 (the mean speed on arm 1) is given in Table 36. SMN1 increased accidents and was statistically significant when tested against a model containing Q2 and Q5 and also statistically significant when tested against the preferred model. It was omitted from the preferred model on the grounds of lack of ease of measurement and consistency across accident groups. Its inclusion into the preferred model forced out I9R152 (the inverse visibility to the right plus 15 metres at 9m back from giveway line on minor arm 2).

The preliminary model is also given as an alternative in Table 36. It contained the additional or alternative terms: C3D4 (the presence of curvature on arm 4 within 100m of the junction); and US8C1 (the presence of shops within 20m on the corner between arms 1 and 2).

VA5 - Right turn from major with own ahead (47)

These accidents involved vehicles turning right from the major arm across the path of vehicles travelling ahead on the same arm.

About 60 per cent of vehicles travelling ahead on the major arm that were involved in this type of accident were motor cycles. Neither the ahead flow, Q2, nor the proportion of motor cycles in Q2 was statistically significant, probably because of the relatively small number of accidents of this type.

The flow function of the preferred full model was:

$$A = 0.0159\ X23^{0.279} \qquad (11.11)$$

where X23 is the product of ahead on major arm with right turn on major arm.

Accidents increased with: LON (within London). Accidents were reduced by ISL5 (island on arm 1 or 3) and DEVMJR (absolute angular deviation of major arms across the junction).

The preliminary model was similar to the preferred model apart from the term DEVMJR which was not tested in the development of the preliminary model.

VA6 - Right turn from minor with next ahead (105)

These accidents involved vehicles turning right out of the minor arm (arm 2) and vehicles travelling ahead on the next major arm (arm 3 to arm 1).

About 24 per cent of vehicles travelling ahead on the major that were involved in this type of accident were motor cycles. However, the proportion of motor cycles in vehicle flow Q8 was not found to be statistically significant.

The flow function of the preferred full model was:

$$A = 0.0000473\ Q6^{0.393}\ Q8^{0.535}\ \exp(5.46\ V64^{0.1}) \qquad (11.12)$$

where Q6 is the right turn from the minor arm, Q8 is the ahead flow on the next major arm and V64 is the sum of other flows from both minor arms.

Accidents increased with: I9L152 (the inverse visibility to the left plus 15 metres at 9m back from giveway line on minor arm 2). Accidents were reduced by C2D1 (curvature on approach within 50m on arm 1).

An alternative model is given in Table 36. Accidents were reduced with KBB3 (the average number of vehicles parked within 100m on the exit and entry of arm 3). KBB3 was omitted from the preferred model on the grounds of lack of ease of measurement.

The preliminary model is also given as an alternative in Table 36. It contained the alternative terms: V4L2 (visibility left at 4m from minor arm 2); KE3C2 (parking regulations, least restrictive, double yellow or zigzag, 20-100m, entry corner on arm 2) and C2D1 (curvature on approach within 100m on arm 1).

VA7 - Right turn from major with opposite ahead (270)

These accidents involved vehicles turning right from the major arm (arm 1) and vehicles travelling ahead on the opposite major arm (arm 3 to arm 1). Of the vehicles travelling ahead on the opposite arm that were involved in this type of accident, 23 per cent were pedal cycles and 32 per cent were motor cycles. The proportion of motor cycles in Q8 was found to be statistically significant.

The flow function of the preferred full model was:

$$A = 0.0130\ Q3^{0.665}\ Q8^{0.393}\ \exp(2.325\ Q9^{0.1}) \qquad (11.13)$$

where Q3 is the right turn from the major arm, Q8 is the ahead flow on the opposite major arm and Q9 is the right turn from the opposite major arm.

There were 5 additional explanatory variables or factors. Accidents were increased with: PMQMA (proportion of motor cycles in major road inflow QMA) and ISL3 (presence of island on arm 3). Accidents were reduced by GDN3 (uphill gradient on approach over 0-50m on arm 3); ISD3 (the inverse stopping sight distance on arm 3); and RCC3 (the radius of curvature of the entry corner on arm 3.

The preliminary model is given as an alternative in Table 36. It contained the additional or alternative terms: PM8 (proportion of motor cycles in flow Q8); GDF3 (uphill gradient on approach over 50-100m on arm 3); W2X4 (width on exit at 2m on arm 4); WIS3 (width of island or central area on arm 3) and STJ (staggered junction).

VA8 - Right turn from minor with previous ahead (209)

These accidents involved vehicles turning right out of the minor arm (arm 2) and vehicles travelling ahead on the previous major arm (arm 1 to arm 3). Of the vehicles travelling ahead on the major arm that were involved in this type of accident, 12 per cent were pedal cycles and 42 per cent were motor cycles.

The flow function of the preferred full model was:

$$A = 0.0428\ Q2^{0.715}\ Q6^{0.772} \qquad (11.14)$$

where Q6 is the right turn from the minor arm and Q2 is the ahead flow on the previous major arm.

Accidents were increased with: RCC1 (radius of entry arm corner on arm 1). A large proportion of the accidents involved motor cycles travelling on the major road. The variable PM2 (proportion of motor cycles in flow Q2) was tried and found to increase accidents but was not statistically significant at the 5% level.

An alternative model is given in Table 36. Accidents were reduced with KBB1 (the average number of vehicles parked within 100m on the exit and entry of arm 1). KBB1 was omitted from the preferred model on the grounds of lack of ease of measurement.

The preliminary model is also given as an alternative in Table 36. It contained the additional or alternative terms: PM2 (proportion of motor cycles in flow Q2); QUA2 (average maximum queue on arm 2); KEB1 (average number of parked vehicles within 100m on entry side of arm 1) and Y1E1 (bus bay on entry side within 25m on arm 1).

VA9 - Other right turn accidents from a minor arm (45)

These accidents comprise all the accidents involving vehicles turning right out of the minor arm except those already included in VA6 and VA8. The main types of accident in the VA9 group were: right turn with right turn from next major (27 per cent) and right turn with opposite ahead (53 per cent).

The flow function of the preferred full model was:

$$A = 0.00863\ Q6^{0.529}\ V39^{1.392} \qquad (11.15)$$

where Q6 is the right turn from the minor arm and V39 is the sum of the conflicting movements.

Accidents were increased with: ANGLE4 (angle on opposite minor arm approach greater than 90 degrees, arm 4 with arm 1). Accidents were reduced by I9R154 (inverse visibility to right plus 15 metres at 9m on minor arm 4).

A further variable was also significant. Accidents were increased with QUM2 (the overall maximum queue on arm 2). QUM2 was omitted from the model on the grounds of lack of ease of measurement.

The preliminary model is also given as an alternative in Table 36. It contained the additional term: WPE1 (width of entry carriageway at 20m from arm origin).

VA10 - Left turn from minor with previous ahead (61)

These accidents involved vehicles turning left out of the minor arm (arm 2) and vehicles travelling ahead on the previous major arm (arm 1 to arm 3). Of the vehicles travelling ahead on the major arm that were involved in this type of accident, 26 per cent were pedal cycles and 20 per cent were motor cycles. The ahead flow on the major arm, Q2, was only just statistically significant and it was not possible to introduce PM2, the proportion of motor cycles in Q2, into the model without eliminating the Q2 term.

The flow function of the preferred full model was:

$$A = 0.0197\ Q2^{0.465}\ Q4^{0.344} \exp(0.470\ V56^{1.0}) \qquad (11.16)$$

where Q4 is the left turn from the minor arm, Q2 is the ahead flow on the previous major arm and V56 is the sum of the other flows on the minor arm.

Accidents were increased with: C2D1 (approach curvature within 50m on arm 1). Accidents were reduced by RLJ (junction has right-left stagger) and ISD3 (inverse stopping sight distance on arm 3).

The preliminary model is also given as an alternative in Table 36. It contained the additional or alternative terms: PM2 (proportion of motor cycles in flow Q2); V9R2 (visibility to the right at 9 metres from giveway line on arm 2); V2L2 (visibility to the left at 2 metres from giveway line on arm 2); RCC2 (radius of curvature of the entry corner on arm 2); GDF1 (uphill gradient over 50 to 100m on arm 1) and STAG (stagger length between minor arms). These variables and factors (or their alternative forms) were omitted from the preferred model because their inclusion caused the flow term LQ2 to be non significant.

VA11 - Head-on/U-turn/Parked/Parking accidents on a major arm (87)

These accidents were head-on/U-turn/parked vehicle/parking accidents that occurred on the entry or exit side of the major arm (arm 1). The main types of accident within the VA11 group were: simple head-on (32 per cent), parked vehicle hit (38 per cent) and unparking vehicle hit by vehicle on same side of carriageway (14 per cent). One-third of 'parked vehicle' accidents involved a pedal cyclist riding into a parked vehicle usually a car or light goods vehicle. In about half the 'unparking' accidents, the unparking vehicle collided with a pedal cycle or motor cycle.

The flow function of the preferred full model was:

$$A = 0.00266\ V7^{0.662} \qquad (11.17)$$

where V7 is the two-way flow on the major arm.

There were 2 additional explanatory variables or factors. Accidents were increased with: LON (inside London). Accidents were reduced by HCH5 (hatching on arms 1 or 3).

An alternative model is given in Table 36. Accidents increased with KBB1 (the average number of vehicles parked within 100m on the exit and entry of arm 1). KBB1 was omitted from the preferred model on the grounds of lack of ease of measurement.

The preliminary model is also given as an alternative in Table 36. It contained the additional or alternative terms: CHAJ (presence of hatching in the central area), KBB5 (the average number of vehicles parked within 100m on both sides of arms 1 and 3, KB2N5 (parking restricted within 20m on both sides of arms 1 and 3, PZC3 (the presence of a pelican or zebra crossing on arm 3), and ZBB1 (the presence of a zebra crossing more than 27.5m from the junction on arm 1).

VA12 - Other vehicle-only accidents on a major arm (72)

This accident group comprised the remaining vehicle-only accidents on the major arm. It included: accidents involving vehicles turning left on the major arm (54 per cent), accidents involving vehicles entering or leaving private drives on the major arm (14 per cent), reversing accidents on the major arm (4 per cent) and right turn accidents on the major arm except those already included in VA5 and VA7 (28 per cent). The largest left turn type accident was 'left turn from major with own ahead' comprising 24 accidents most of which involved a car turning left colliding with a pedal cycle or motor cycle going ahead on the major arm.

The flow function of the preferred full model was:

$$A = 0.0266\ Q1^{0.291}\ V25^{0.284}\ \exp(0.125\ PT^{1.0}) \quad (11.18)$$

where Q1 is the left turn from the major arm, V25 is the sum of the ahead flows from the minor arms and PT is the total pedestrian flow.

None of the variables tested were highly statistically significant or particularly convincing in terms of comprehensibility of the effect. In view of the diverse nature of this accident group, the preferred full model contains no additional explanatory variables or factors.

The preliminary model is also given as an alternative in Table 36. It contained the additional term: KE3N1 (presence of double yellow lines as the least restrictive parking regulation on the entry side of arm 1).

VA13 - Other vehicle-only accidents on a minor arm (76)

These minor arm accidents included single vehicle accidents, rear shunt and lane changing accidents, left turn accidents except those included in VA10, head-on and U-turn accidents, parking accidents and reversing and private drive accidents. VA13 was a very diverse group of accidents the main types were: straight with straight rear shunts (15 per cent) and parked vehicle hit (11 per cent).

The flow function of the preferred full model was:

$$A = 0.00653\ V2^{1.294} \quad (11.19)$$

where V2 is the entering flow on the minor arm.

Accidents were increased with: PBQMI (proportion of public service vehicles in minor road inflow QMI; PMQMI (proportion of motor cycles in minor road inflow QMI) and LON (within London).

The preliminary model is also given as an alternative in Table 36. It contained the alternative terms: PBV2 (proportion of public service vehicles in flow V2) and PWV2 (proportion of two wheelers in flow V2).

11.7 MODELS FOR PEDESTRIAN ACCIDENT GROUPS

The models given in this Section are *arm based models* and predict accident frequency for a particular accident group on *a major arm* or *a minor arm.*

The models will need to be applied twice when predicting accidents for a whole junction with arms 'ABCD'; firstly with major arms A,C as arm 1 and arm 3 and minor arms B,D as arm 2 and arm 4, and secondly with major arms C,A as arm 1 and arm 3 and minor arms D,B as arm 2 and arm 4 respectively.

PA1 - Pedestrian accidents with vehicle entering on major arm (197)

These accidents involved vehicles entering on the major arm and pedestrians crossing the major arm from the nearside or the offside. Almost all of the vehicles involved in the accidents were travelling straight ahead (arm 1 to arm 3) and 63 per cent of the pedestrians were crossing from the nearside. The majority of accidents involved cars; motor cycles were involved in 8 per cent and heavy goods vehicles and buses were involved in 3 per cent.

The flow function of the preferred full model was:

$$A = 0.0121\ V1^{0.395}\ PA^{0.245} \quad (11.20)$$

where V1 is the entering flow on the major arm and PA is the pedestrian flow across the major arm.

There were 7 additional explanatory variables or factors. Accidents were increased with: PMQMA (proportion of motor cycles in major road inflow QMA); LON (within London); ZAB1 (zebra with or without island on arm 1; PAL1 (pelican with or without island on arm 1); NAE1 (the number of ahead lanes at entry on arm 1) and Y2E1 (bus bay entry side within 50m on arm 1). Accidents were reduced by STJ (staggered junction).

The preliminary model, given in Table 36, was similar to the preferred model, and contained the term PMV1 (proportion of motor cycles in flow V1) which was replaced in the preferred model by PMQMA.

An alternative model containing SMN1 (mean speed on arm 1) and PI (pedestrian flow across the minor arms) is also given in Table 36. Accidents increased with SMN1 and PI. The terms PI and SMN1 were not included in the preferred model because they were not statistically significant at the 5% level after the addition of Y2E1. Y2E1 was deliberately omitted from this alternative model; PMQMA and NAE1 were not statistically significant.

PA2 - Pedestrian accidents with vehicle exiting on major arm (242)

These accidents involved vehicles exiting on the major arm and pedestrians crossing the arm from the nearside or the offside. Most (93 per cent) of the vehicles involved in the accidents were travelling straight ahead (arm 3 to arm 1) and 59 per cent of the pedestrians were crossing from the nearside. The majority of accidents involved cars; motor cycles were involved in 10 per cent and heavy goods vehicles and buses were involved in 2 per cent.

The flow function of the preferred full model was:

$$A = 0.111\ V5^{0.306}\ PA^{0.478} \qquad (11.21)$$

where V5 is the exiting flow on the major arm and PA is the pedestrian flow across the major arm.

Accidents were increased with: ZAB1 (zebra with or without island on arm 1). Accidents were reduced by: ISD1 (reciprocal of stopping sight distance on arm 1).

Though significant for accident group PA1, the variable PMQMA (proportion of motor cycles in major road inflow QMA) and the factors LON (within London) and PAL1 (pelican with or without island on arm 1) were not found to be statistically significant at the 5% level.

The preliminary model is also given as an alternative in Table 36. It contained the additional term P2B1 (pedestrian facility beyond 27.5m, within 100m, on arm 1). Accidents decreased with P2B1 possibly as a result of lower speeds at arms with a pedestrian crossing near, but not at, the junction. Speed variables were tested but not found to be statistically significant.

PA3 - Other pedestrian accidents on major arm (97)

This accident group comprised the remaining pedestrian accidents on the major arm.

The main accident types were: position of collision in junction unknown (47 per cent), reversing vehicle hits pedestrian (11 per cent), pedestrian in carriageway (11 per cent) and pedal cyclist (treated as a pedestrian) crossing the major arm (11 per cent).

The flow function of the preferred full model was:

$$A = 0.0251\ QMA^{0.146}\ PTB^{0.357} \qquad (11.22)$$

where QMA is the major road inflow (not statistically significant see Section 10.5) and PTB is the pedestrian flow across both major arms and junction centre.

The flow model without factors or variables was accepted as the preferred model because of the lack of statistical significance of the important major road flow term.

The preliminary model is also given as an alternative in Table 36. It contained the additional terms AEF1 (number of public accesses, entry side, 50-100m, on arm 1), KXA1 (average number of vehicles parked within 20m, exit side on arm 1) and ZAB3 (zebra with or without an island on arm 3).

PA4 - Pedestrian accidents on minor arm (96)

These accidents comprised all accidents involving pedestrians on the minor arm. The main accident types in this group were 'pedestrian crossing minor arm and vehicle exiting' (54 per cent) and 'pedestrian crossing minor arm and vehicle entering' (24 per cent).

The flow function of the preferred full model was:

$$A = 0.0201\ V8^{0.841}\ PI^{0.318} \qquad (11.23)$$

where V8 is the two-way flow on the minor arm and PI is the pedestrian flow across the minor arm.

Accidents were increased with: LON (within London) and B1E2 (presence of a bus stop within 25m on the entry of arm 2). Accidents were reduced by: UE1N2 (land use, dominant, residential, 0-20m, entry side on arm 2).

The preliminary model is also given as an alternative in Table 36. It contained PBV8 (proportion of public service vehicles in flow V8) as an alternative to B1E2.

11.7.1 Correlations between pedestrian flow, pedestrian crossings and speed

The pedestrian flow across the major arm (LPA - PA in log form) was strongly correlated (0.56) with the presence of a pedestrian crossing. Arms without a crossing had a lower mean value of PA (527 arms, mean 170) than arms with a crossing (zebra crossing on 52 arms, mean 790; pelican crossing on 47 arms, mean 1270).

For the PA1 accident type, the pedestrian flow (LPA) and the presence of a zebra (ZAB1) and pelican (PAL1) were statistically significant when included in the regression model. However, the correlation between pedestrian flows and the presence of a crossing made the determination of the exponent of PA and the coefficients of ZAB1 and PAL1 more difficult to determine precisely, with little change in the scaled deviance for values of the exponent of PA between 0.2 and 0.4 and for multiplicative effects of the ZAB1 and PAL1 factors of 1.5 and 3.0.

The pedestrian flow across the major arms (LPA) and across the minor arms (LPI - PI in log form) were also strongly correlated (-0.38 and -0.62 respectively) with the mean speed on the major arm (LSMN1 - SMN1 in log form). Higher speeds were associated with lower values of pedestrian flow and it may be that drivers reduce speeds depending on the numbers of pedestrians present at a junction. The coefficient of variation of speed on arm 1 (COV1) was strongly correlated with LSMN1 (-0.55), fairly strongly correlated with LPI and with LON (0.33, 0.35) but not so strongly with LPA (0.18).

For the individual pedestrian accident types, the terms SMN1, COV1 and PI were generally not statistically significant when included in the models. However, the degree of correlation suggests that the PA term alone in the model may include some speed reduction effects on accident frequency as well as the direct effects of increasing accident numbers.

11.8 EXPLANATORY VARIABLES AND THEIR EFFECTS

In assessing the usefulness of the significant variables in the models 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. Thus, for example, if $\overline{G}_i$ is the mean value of variables G_i, equation 11.2 may be written as:

$$A = K.Q_a^{\alpha}.Q_b^{\beta}.\ \Pi\exp(\gamma_{ij}D_{ij})\ .\Pi\exp(\varepsilon_i(G_i - \overline{G}_i)) \quad (11.24)$$

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

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 $D_{ij}=0$) all the exponent terms become unity, so K is the accident frequency for the particular type of accident when the vehicle flow and pedestrian flow are also unity. At values of the G_i different from the mean, each term $\exp(\varepsilon_i(G_i - \overline{G}_i))$ 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 $\exp(\gamma_{ij})$ is a multiplier of the constant k of equation 11.2 which shows the average effect on the accident frequency for the 2nd and higher levels of the factor F_i compared with the 1st level.

Tables 34 and 35 provide an overall summary of the variables and factors that appeared in the full models for each accident group. The level of statistical significance at which each variable and factor appears in the models is also indicated. Table 36 gives the multiplicative effect of each variable or factor in the full models. The following paragraphs give the effect of the geometric variables and factors over their range from maximum to minimum. Details of how the variables were measured are given in Appendix C.

All of the relevant vehicle and pedestrian flows had an effect on accident risk such that increasing these flows increased accident risk.

PBQMA (the proportion of public service vehicles in the major arm flow QMA) increased accident risk by a factor of 10.3 for VA1 (single vehicle accidents).

PMQMA (the proportion of motor cyclists in the major arm flow QMA) increased accident risk by a factor of 7.0 for VA1 (single vehicle accidents), by a factor of 4.3 for VA7 (right turn from major with opposite ahead accidents), and by a factor of 4.0 for PA1 (pedestrian with vehicle entering on the major arm).

PBQMI (the proportion of public service vehicles in the minor arm flow QMI) increased accident risk by a factor of 4.1 for VA13 (other vehicle-only accidents on the minor arm).

PMQMI (the proportion of motor cyclists in the minor arm flow QMI) increased accident risk by a factor of 4.3 for VA13 (other vehicle-only accidents on the minor arm).

ASTAG (the absolute stagger length of the minor arms) reduced accident risk by a factor of 0.05 for VA3 (right angle accidents, major with previous minor) and by a factor of 0.2 for VA4 (right angle accidents, major with next minor). **STJ** (staggered junction) reduced accident risk by a factor of 0.7 for PA1 (pedestrian with vehicle entering on the major arm). **RLJ** (right/left staggered junction) reduced accident risk by a factor of 0.3 for VA10 (left turn from minor with previous ahead).

LON (London) increased accident risk for several accident groups: by a factor of 1.7 for VA1 (single vehicle accidents); by a factor of 1.5 for VA2 (rear shunt and lane changing accidents); by a factor of 1.6 for VA4 (right angle, major with next minor); by a factor of 2.2 for VA5 (right turn from major with own ahead); by a factor of 4.6 for VA11 (head-on/U-turn/parked/parking accidents); by a factor of 2.0 for VA13 (other vehicle-only accidents on minor); by a factor of 1.4 for PA1 (pedestrian with vehicle entering on the major arm); and by a factor of 1.7 for PA4 (pedestrian accidents on minor arm).

ZAB1 (zebra crossing on major arm 1) increased accident risk by a factor of 2.1 for VA2 (rear shunt and lane changing accidents), by a factor of 2.8 for PA1 (pedestrian with vehicle entering on the major arm), and by a factor of 2.8 for PA2 (pedestrian with vehicle exiting on the major arm). **PAL1** (pelican crossing on major arm 1) increased accident risk by a factor of 1.6 for VA2 (rear shunt and lane changing accidents) and by a factor of 2.2 for PA1 (pedestrian with vehicle entering on the major arm).

ISL1 (island on major arm 1) increased accident risk by a factor of 1.4 for VA3 (right angle, major with previous minor). **ISL3** (island on major arm 3) increased accident risk by a factor of 1.5 for VA7 (right turn from major with opposite ahead). **ISL5** (island on major arm 1 or 3) increased accident risk by a factor of 1.7 for VA1 (single vehicle accidents on major,) but reduced accident risk by a factor of 0.6 for VA2 (rear shunt and lane changing accidents on major) and by a factor of 0.2 for VA5 (right turn from major with own ahead).

HCH1 (ghost island on major arm 1) reduced accident risk by a factor of 0.4 for VA1 (single vehicle accidents). **HCH5** (ghost island on major arms 1 or 3) reduced accident risk by a factor of 0.1 for VA11 (head-on/U-turn/parked/parking accidents).

ANGLE4 (angle between major arm 1 and minor arm 4 greater than 90 degrees) increased accident risk by a factor of 2.1 for VA9 (other right turn from minor). **DEVMJR** (absolute angular deviation of major arms across junction) increased accident risk by a factor of 6.8 for VA1 (single vehicle accidents on major) but reduced accident risk by a factor of 0.01 for VA5 (right turn from major with own ahead). **DEVMNR** (absolute angular deviation of minor arms across junction) reduced accident risk by a factor of 0.3 for VA4 (right angle, major with next minor).

GDN1 (gradient 0 to 50m on major arm 1) uphill (positive) gradient reduced accident risk by a factor of 0.3 for VA3 (right angle, major with previous minor). **GDN3** (gradient 0 to 50m on major arm 3) reduced accident risk by a factor of 0.2 for VA7 (right turn from major with opposite ahead).

ISD1 (inverse of stopping sight distance on major arm 1) reduced accident risk (i.e. better visibility increased accident risk) by a factor of 0.3 for VA3 (right angle, major with previous minor) and by a factor of 0.2 for PA2 (pedestrian with vehicle exiting on major). **ISD3** (inverse of stopping sight distance on major arm 3) reduced accident risk for several accident groups: by a factor 0.3 for VA4 (right angle, major with next minor); by a factor of 0.4 for VA7 (right turn from major with opposite ahead); and by a factor of 0.1 for accident type VA10 (left turn from minor with previous ahead).

I9L152 (inverse of visibility to left plus 15m at 9m on minor arm 2) increased accident risk (i.e. better visibility reduced accident risk) by a factor of 3.8 for VA6 (right turn from minor with next ahead). **I9L154** (inverse of visibility to left plus 15m at 9m on minor arm 4) reduced accident risk (i.e. better visibility increased accident risk) by a factor of 0.6 for VA3 (right angle, major with previous minor). **I9R152** (inverse of visibility to right plus 15m at 9m on minor arm 2) reduced accident risk by a factor of 0.6 for VA4 (right angle, major with next minor). **I9R154** (inverse of visibility to right plus 15m at 9m on minor arm 4) reduced accident risk by a factor of 0.2 for VA9 (other right turn from minor).

C2D1 (curvature within 50m on major arm 1) reduced accident risk by a factor of 0.6 for VA6 (right turn from minor with next ahead) and increased accident risk by a factor of 1.7 for VA10 (left turn from minor with previous ahead). **C2D3** (curvature within 50m on major arm 3) reduced accident risk by a factor of 0.8 for VA3 (right angle, major with previous minor). **C2D2** (curvature within 50m on minor arm 2) reduced accident risk by a factor of 0.7 for VA3 (right angle, major with previous minor).

RCC1 (radius of entry corner on major arm 1) increased accident risk by a factor of 3.4 for VA8 (right turn from minor with previous ahead). RCC3 (radius of entry corner on major arm 3) reduced accident risk by a factor of 0.05 for VA7 (right turn from major with opposite ahead).

GSL4 (stop line on minor arm 4) reduced accident risk by a factor of 0.5 for VA3 (right angle, major with previous minor).

NAE1 (number of ahead lanes at entry on major arm 1) increased accident risk by a factor of 1.6 for VA2 (rear shunt and lane changing accidents on major) and by a factor of 1.8 for PA1 (pedestrian with vehicle entering on major).

Y2E1 (bus bay on entry side within 50m on major arm 1) increased accident risk by a factor of 2.5 for PA1 (pedestrian with vehicle entering on major). **B1E2** (bus stop within 25m on entry of minor arm 2) increased accident risk by a factor of 3.4 for PA4 (pedestrian accidents on minor).

UE1N2 (residential as dominant land use within 0 to 20m on entry of arm 2) reduced accident risk by a factor of 0.5 for PA4 (pedestrian accidents on minor).

In the alternative models for VA4, VA6, and VA11 in Table 36, the effect of the speed and parking terms was as follows: **SMN1** (mean speed approaching junction on major arm 1) increased accident risk by a factor of 4.0 for VA4 (right angle, major with next minor); **KBB1** (average number of vehicles parked within 100m on entry and exit of major arm 1) reduced accident risk by a factor of 0.1 for VA8 (right turn from minor with previous ahead), but increased accident risk by a factor of 24.5 for VA11 (head-on/U-turn/parked/parking accidents on major); **KBB3** (average number of vehicles parked within 100m on entry and exit of major arm 3) reduced accident risk by a factor of 0.02 for VA6 (right turn from minor with next ahead).

11.8.1 Two-wheeled vehicles

About 45 percent of vehicle accidents involved pedal cyclists or motorcyclists, and in these accidents the pedal cyclist or motor cyclist was generally travelling ahead on the major arm. One would expect therefore that higher flows of two-wheelers on the major arm would result in more vehicle accidents and that variables representing the proportion of two-wheelers in the relevant ahead flows would appear in the accident-flow-geometry models. While PMQMA (the proportion of motor cyclists in major arm flow) was present in the aggregate junction-based model for vehicle accidents (Section 11.9), similar variables were statistically significant in only 3 of the 13 arm-based models for the vehicle accident groups (Sections 11.6 and 11.7).

The problem was not one of small accident numbers since some the accident groups contained large numbers of accidents that involved two-wheeled vehicles. For example, the right-angle accident groups VA3 and VA4 contained 492 and 410 accidents respectively, of which about 35 per cent involved two-wheeled vehicles.

A possible reason for the lack of proportion variables in the models may be the relatively large uncertainty in the estimates of the numbers of two wheelers travelling on the major arm. The estimates of the flow of two-wheelers are likely to be subject to greater uncertainty than the flow of cars and taxis because of the small numbers of two-wheelers and because two-wheelers are subject to greater seasonal and daily variation.

11.9 AGGREGATE EFFECTS ACROSS ALL ACCIDENT GROUPS

Junction based accident-flow-geometry models 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 non-directional equivalents of those that appeared in any of the accident group models. The testing was performed at the 5 per cent level of statistical significance. The null models, models without factors and the full models are presented in Table 37.

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

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

$$A = 0.248\ QMA^{0.548}\ QMI^{0.504}\ \exp(1.089\ PQMIS + 0.449\ PQMIR)\ \exp(0.297\ PTA^{0.6}) \quad (11.25)$$

where QMA is the two-way flow on the major arms,

QMI is the two-way flow on the minor arms,

PQMIS is the proportion of minor road traffic going straight ahead across the junction,

PQMIR is the proportion of minor road traffic turning right at the junction and PTA is the pedestrian flow across the major arms.

The preferred full model contained 6 additional explanatory variables or factors. Accidents were increased with: LON (junction within London). Accidents were reduced with: ASTAG (absolute stagger length of minor arms); ISDMJR (inverse of average stopping sight distance on major arms), ie better visibility increased accident risk; C2DMNR (curvature within 50m on either minor arm); and DEVMJR (absolute angular deviation of major arms across the junction).

An alternative model is given in Table 37 which includes the speed terms: SMNMJR (average of mean speeds on major arms) and COVMJR (the average of the coefficients of variation of speed measurements on the major arms); and the additional terms PMQMA (proportion motor cycles in major arm flow); PBQMA (proportion public service vehicles in major arm flow); and RCCMJR (the average radius of the entry corner on the major arms).

For the *vehicle-only accidents,* the flow function of the best full model was:

$$A = 0.215\ QMA^{0.587}\ QMI^{0.623}\ \exp(0.981\ PQMIS) \quad (11.26)$$

The preferred full model contained 6 additional explanatory variables or factors. Accidents were increased with: PMQMA (proportion of motor cycles in major arm flow QMA); and LON (junction within London). Accidents were reduced with: ASTAG (absolute stagger length of minor arms); ISDMJR (inverse of average stopping sight distance on major arms); C2DMNR (curvature within 50m on either minor arm); and DEVMJR (absolute angular deviation of major arms across the junction).

An alternative model is given in Table 37 which includes the speed terms: SMNMJR (average of mean speeds on major arms) and COVMJR (average of the coefficients of variation of the speed measurements on the major arms); and the additional terms PQMIR (proportion of minor arm traffic turning right at junction); PBQMA (proportion of public service vehicles in major arm flow); and DEVMNR (absolute angular deviation of minor arms across the junction).

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

$$A = 0.195\ QMA^{0.233}\ PTA^{0.355} \quad (11.27)$$

where QMA is the two-way flow on the major arms and PTA is the two-way pedestrian across the major arms.

The preferred full model contained 4 additional explanatory variables or factors. Accidents were increased with: LON (junction within London); ZEBA (zebra on major) and PELA (pelican on major). Accidents were reduced with: C2DMNR (curvature within 50m on minor).

An alternative model is given in Table 37 which includes the speed term: SMNMJR (average of mean speeds on major arms); and the additional terms LQMI (two-way flow on the minor arms); and PBQMA (proportion of public service vehicles in major arm flow). SMNMJR was not statistically significant at the 5% level.

TABLE 37

Aggregate junction-based accident-flow-geometry models

Model	Model terms[1]	Parameter value	s.e.[2]	Deviance difference[3]	Multiplicative effect Min.	Mean	Max.	Deviance	Degrees of freedom	Scale factor
Total accidents (2917)										
Null	Lk	0.496	0.040					1379	312	4.52
Full	Lk	-1.394	0.26					599.4	301[4]	1.93
	LQMA	0.548	0.068	134.8	0.2	1	1.6			
(a)	LQMI	0.504	0.053	185.6	0.3	1	1.7			
pref.	PQMIS	1.089	0.193	61.5	0.7	1	1.7			
	PQMIR	0.449	0.204	9.2	0.9	1	1.3			
	$PTA^{0.6}$	0.297	0.058	47.4	0.8	1	1.6			
	ASTAG	-0.0272	0.0051	56.5	1.2	1	0.6			
	LON	0.341	0.058	64.8	1		1.4			
	ISDMJR	-73.1	20.3	26.9	1.1	1	0.6			
	C2DMNR	-0.158	0.054	16.8	1		0.9			
	DEVMJR	-0.0092	0.0046	7.9	1.0	1	0.7			
(b)	Lk	-4.178	0.915					569.3	297[4]	1.86
alt.	LQMA	0.488	0.068	101.6	0.2	1	1.5			
	LQMI	0.537	0.055	195.0	0.3	1	1.8			
	PQMIS	0.949	0.195	44.0	0.8	1	1.6			
	PQMIR	0.411	0.205	7.5	0.9	1	1.2			
	$PTA^{0.6}$	0.306	0.074	31.4	0.8	1	1.6			
	PBQMA	3.80	1.90	7.3	0.9	1	1.3			
	PMQMA	4.23	1.73	10.5	0.9	1	1.6			
	SMNMJR	0.723	0.241	16.8	0.7	1	1.3			
	COVMJR	0.020	0.0075	12.9	0.8	1	1.5			
	ASTAG	-0.0255	0.0052	46.6	1.2	1	0.6			
	LON	0.287	0.065	35.4	1		1.3			
	ISDMJR	-59.9	20.5	16.7	1.1	1	0.7			
	C2DMNR	-0.145	0.053	13.8	1		0.9			
	RCCMJR	-0.0114	0.0059	7.4	1.1	1	0.7			

TABLE 37 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Deviance difference[3]	Multiplicative effect Min.	Mean	Max.	Deviance	Degrees of freedom	Scale factor
Vehicle accidents (2285)										
Null	Lk	0.252	0.043					1279	312	4.14
Full	Lk	-1.535	0.265					580.0	303	1.82
	LQMA	0.587	0.072	125.1	0.2	1	1.6			
(a)	LQMI	0.623	0.059	212.4	0.2	1	2.0			
pref.	PQMIS	0.981	0.188	49.4	0.8	1	1.6			
	PMQMA	4.35	1.89	9.2	1.0	1	1.7			
	ASTAG	-0.031	0.0058	56.3	1.2	1	0.6			
	LON	0.315	0.063	43.4	1		1.4			
	ISDMJR	-72.2	22.0	21.1	1.1	1	0.6			
	C2DMNR	-0.160	0.059	13.6	1		0.9			
	DEVMJR	-0.0127	0.0050	12.3	1.1	1	0.7			
(b)	Lk	-4.217	0.888					556.9	299	1.79
alt.	LQMA	0.562	0.074	111.3	0.2	1	1.6			
	LQMI	0.662	0.061	226.0	0.2	1	2.1			
	PQMIS	1.031	0.214	42.3	0.8	1	1.6			
	PQMIR	0.468	0.227	7.5	0.9	1	1.3			
	PBQMA	4.46	2.09	8.0	0.9	1	1.3			
	PMQMA	4.91	1.94	10.9	0.9	1	1.7			
	SMNMJR	0.622	0.229	13.3	0.7	1	1.3			
	COVMJR	0.0207	0.0080	11.5	0.8	1	1.6			
	ASTAG	-0.0299	0.0059	49.0	1.2	1	0.6			
	LON	0.270	0.070	26.2	1		1.3			
	ISDMJR	-64.0	21.9	16.0	1.1	1	0.7			
	C2DMNR	-0.139	0.059	9.9	1		0.9			
	DEVMNR	-0.0059	0.0027	9.4	1.1	1	0.7			

12. APPLICATION OF THE MODELS

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

12.1 TOTAL, VEHICLE AND PEDESTRIAN ACCIDENT-FLOW MODELS

These accident-flow models treat the whole junction as a unit, and separate total junction accidents in a simple way into vehicle-only accidents and pedestrian accidents. The models are built from vehicle flows on major and minor arms, turning proportions on minor arms, pedestrian flow across major arms and from a limited number of factors representing the main characteristics of the junctions. 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 interactions 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 9.3, 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 char-

TABLE 37 (CONTINUED)

Model	Model terms[1]	Parameter value	s.e.[2]	Deviance difference[3]	Multiplicative effect Min.	Mean	Max.	Deviance	Degrees of freedom	Scale factor
Pedestrian accidents (632)										
Null	Lk	-1.033	0.061					712.9	312	2.35
Full	Lk	-1.637	0.288					429.5	306	1.37
	LQMA	0.233	0.112	6.1	0.5	1	1.2			
(a)	LPTA	0.355	0.061	47.7	0.2	1	2.0			
pref.	LON	0.361	0.102	16.6	1	1	1.4			
	ZEBA	0.665	0.130	36.0	1		1.9			
	PELA	0.408	0.155	9.6	1		1.5			
	C2DMNR	-0.199	0.095	6.1	1		0.8			
(b)	Lk	-4.25	1.21					423.5	304	1.36
alt.	LQMA	0.228	0.114	5.5	0.5	1	1.2			
	LQMI	0.159	0.080	5.4	0.7	1	1.2			
	PBQMA	6.73	3.32	5.4	0.9	1	1.5			
	LPTA	0.396	0.071	44.6	0.2	1	2.1			
not sig-->	SMNMJR	0.689	0.357	5.1	0.7	1	1.3			
	LON	0.410	0.109	19.0	1		1.5			
	ZEBA	0.680	0.131	37.1	1		2.0			
	PELA	0.356	0.157	6.9	1		1.4			

1 L prefix indicates log form of variable e.g. LQT = log (QT)

2 Standard error of estimate. The values of the standard errors quoted *have been scaled by the square root of the scale factor.*

3 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.

4 The number of degrees of freedom has been reduced by 1 because the exponent of the spoiling flow or pedestrian flow has been empirically determined using the value that gave the lowest scaled deviance

( ) Figures in brackets are the number of accidents

acteristics of the junction. For urban traffic management assessment, they are likely to be of most use outside 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 junctions has been worked out.

12.2 ACCIDENT-FLOW MODELS BY ACCIDENT GROUP

The accident-flow models by accident group and arm of junction predict separately for each accident group. They are built from individual vehicle and pedestrian flows relevant to the accident group in question and the factors in 12.1. They 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 the different accident groups can be explicitly taken into account. They require no geometric measurements at the junction.

The applications of these 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 arm of junction 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 the mechanisms are fully understood). The models indicate the 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 at priority crossroads and staggered junctions which are subject to remedial treatment or other direct traffic engineering measures.

Junction based accident-flow-geometry models were also developed for total, vehicle-only and pedestrian accidents using variables and factors that were contained within the arm based accident group models. These models provide a useful indication of the aggregate effect of the more important variables and factors. The predictions obtained from them are likely to be more accurate than the junction based accident-flow models referred to in Section 12.1 but the data input requirements are greater.

13. SUMMARY AND CONCLUSIONS

A substantive study of accidents on priority cross roads and staggered junctions has been completed. The study was based on a national stratified sample of 300 junctions with 30 mph and 40 mph speed limits. There were 2197 personal injury accidents at the junctions during the six year period from 1984 to 1989 in which the accident data were 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 have given useful insights into the characteristics of the accidents. However, since they relate to a stratified sample of junctions, they do not necessarily reflect the distribution of characteristics of the overall accident population for urban crossroads.

Accident predictive models have been developed ranging from junction-based total accident models to arm-based 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 junction. 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) For the whole-junction models, the vehicle flow function used for predicting total and vehicle-only accidents included the major and minor road inflows, and the proportion of minor road inflow travelling straight ahead or making a right turn. For pedestrian accidents, the vehicle flow function was the major road inflow. The pedestrian flow function was the total pedestrian flow crossing the major arms of the junction.

(ii) Longer stagger lengths between the minor arms resulted in fewer total, vehicle and right angle accidents (major with previous minor and major with next minor). Staggered junctions had fewer pedestrian with entering vehicle accidents. Right/left staggered junctions reduced left turn from minor with previous ahead accidents.

(iii) The models indicated that the presence of a pedestrian crossing facility on the major road was associated with more pedestrian accidents in total by a factor varying between 1.5 and 1.9, depending on the type of crossing. Thus the models predict on average more accidents at crossroads with a facility than at those without, for given vehicle and pedestrian flow. However, those junctions in the sample without crossings had substantially lower pedestrian flows 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 flows is non-linear (with index less than one) it is the case that the mean number of accidents per pedestrian crossing the road at those crossroads with pedestrian crossings was similar to the mean number at those crossroads 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) There were more rear shunt and lane-changing accidents at crossroads with a zebra or a pelican crossing.

(v) This study was not intended or designed to investigate speed mechanisms and relationships in depth, and only coarse measures of speed were included. Speed variables were omitted from the preferred models on the grounds of lack of ease of measurement and consistency across accident groups. Alternative models with speed variables showed that higher mean speed on the major road approaching the junction was associated with increased total, vehicle-only and right angle accidents (major with next minor) and with increased pedestrian with vehicle entering accidents. A higher coefficient of variation of speed also increased total and vehicle-only accidents. For the right angle accidents, the mean speed on the major road was an alternative to the inverse visibility to the right from the minor arm. For the other accident types, there was no evidence that the speed of vehicles on either the major or the minor road influenced accident occurrence when other variables were taken into account.

(vi) There were other physical variables that were found to have an effect on accidents which may be correlated with speed, but these variables produced much stronger relationships than did speed. For example, a curved approach on either minor arm reduced total, vehicle and pedestrian accidents, whilst increased stopping sight distance on the major arms increased total, vehicle and pedestrian accidents and several other accident groups. Pedestrian flow was also found to be strongly correlated with mean speed; crossroads with higher mean speeds on the major road also had lower pedestrian crossing flow. The results do not mean to say that speed does not influence accidents. It is likely that some of the variables found to affect accidents do so by modifying speeds.

(vii) 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 approach speeds.

(viii) The presence of an island on the major road had a mixed effect. For vehicles approaching the junction on the major road, an island on the entry increased right angle (major with previous minor) accidents, whilst an island on the exit increased right turn from major with opposite ahead accidents. An island on either the entry or the exit increased single vehicle accidents, but reduced rear shunt and lane-changing accidents and right turn from major with own ahead accidents. A ghost island on the entry reduced single vehicle accidents, whilst a ghost island on either entry or exit reduced head-on/U-turn/parked/parking accidents.

(ix) More traffic lanes increased rear shunt and lane-changing accidents on a major arm and also increased pedestrian with vehicle entering accidents.

(x) A stop-line on the minor arm reduced right angle (major with previous minor) accidents.

(xi) Parking variables were omitted from the preferred models on the grounds of lack of ease of measurement.

(xii) Other key results were: more single vehicle accidents on the major road with a higher proportion of PSVs; more single vehicle and vehicle-only accidents with a higher proportion of motor cyclists in the major road flow; increased total, vehicle-only and several accident groups at crossroads in Greater London. Higher values for the absolute angular deviation of the major arms across the junction increased single vehicle accidents on the major but reduced total, vehicle and right turn from major with own ahead accidents. The same variable for the minor arms reduced right angle (major with next minor) accidents.

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.

14. ACKNOWLEDGEMENTS

The authors would like to thank Mr D Baynes at TRL for his assistance with the development of the accident-flow-geometry models.

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APPENDIX A: VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

This appendix lists those explanatory variables which were used in the course of the analysis. For each accident group, however, the variables tried were only those which were considered in any way relevant to the particular accident group. The minimum, mean and maximum values of each continuous variable over the full sample of 626 units are given. For the discrete variables or factors, the number of sites with each level of the factor is given.

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Variable(s)	Description		Min	Mean	Max
1. VEHICLE AND PEDESTRIAN FLOWS					
Total vehicle flow (thousands)					
Q1	left from arm 1		0.008	0.437	4.405
Q2	ahead from arm 1		0.102	5.413	14.674
Q3	right from arm 1		0.002	0.473	3.348
Q4	left from arm 2		0.016	0.540	3.933
Q5	ahead from arm 2		0.001	0.417	2.712
Q6	right from arm 2		0.000	0.315	2.891
Q7	left from arm 3		0.008	0.437	4.405
Q8	ahead from arm 3		0.102	5.413	14.674
Q9	right from arm 3		0.002	0.473	3.348
Q10	left from arm 4		0.016	0.540	3.933
Q11	ahead from arm 4		0.001	0.417	2.712
Q12	right from arm 4		0.000	0.315	2.891
V1	Q1+Q2+Q3		0.203	6.323	15.193
V2	Q4+Q5+Q6		0.040	1.271	5.075
V5	Q6+Q8+Q10		0.290	6.267	15.090
V7	V1+V5		0.493	12.590	29.882
V8	Q1+Q4+Q5+Q6+Q9+Q11		0.126	2.598	10.769
V15	Q1+Q2+Q3+Q4+Q12		0.532	7.177	15.992
V25	Q5+Q11		0.002	0.834	4.321
V39	Q1+Q9+Q10+Q11+Q12		0.159	2.181	7.119
V56	Q5+Q6		0.004	0.732	4.199
V64	Q4+Q5+Q10+Q11+Q12		0.183	2.228	7.213
QMA	Q1+Q2+Q3+Q7+Q8+Q9		0.615	12.645	29.220
X23	Q2*Q3		0.003	2.471	29.748
Proportion of Vehicle type in flow					
	Pedal cycles in flow				
PP1,PP7		Q1,Q7	0.0	0.031	0.480
PP2,PP8		Q2,Q8	0.0	0.021	0.381
PP3,PP9		Q3,Q9	0.0	0.023	0.546
PP4,PP10		Q4,Q10	0.0	0.031	0.460
PP5,PP11		Q5,Q11	0.0	0.081	0.913
PP6,PP12		Q6,Q12	0.0	0.034	0.551
PP15		V15	0.0	0.021	0.213
	Motor cycles in flow				
PM1,PM7		Q1,Q7	0.0	0.017	0.122
PM2,PM8		Q2,Q8	0.0	0.018	0.142
PM3,PM9		Q3,Q9	0.0	0.015	0.276
PM4,PM10		Q4,Q10	0.0	0.016	0.102
PM5,PM11		Q5,Q11	0.0	0.022	0.235
PM6,PM12		Q6,Q12	0.0	0.015	0.134
PMV15		V15	0.001	0.018	0.127
PMV1		V1	0.000	0.018	0.136
PMQMA		QMA	0.002	0.018	0.123
PMQMI		QMI	0.000	0.017	0.078

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Variable(s)	Description		Min	Mean	Max
	Two-wheelers in flow				
PW1,PW7		Q1,Q7	0.0	0.048	0.497
PW2,PW8		Q2,Q8	0.002	0.039	0.472
PW3,PW9		Q3,Q9	0.0	0.039	0.546
PW4,PW10		Q4,Q10	0.0	0.047	0.546
PW5,PW11		Q5,Q11	0.0	0.102	0.913
PW6,PW12		Q6,Q12	0.0	0.050	0.559
PW15		V15	0.004	0.039	0.251
PWV2		V2	0.000	0.057	0.490
	Light Goods Vehicles in flow				
PL1,PL7		Q1,Q7	0.0	0.079	0.250
PL2,PL8		Q2,Q8	0.002	0.079	0.163
PL3,PL9		Q3,Q9	0.0	0.075	0.273
PL4,PL10		Q4,Q10	0.0	0.074	0.313
PL5,PL11		Q5,Q11	0.0	0.080	0.333
PL6,PL12		Q6,Q12	0.0	0.082	0.265
PL15		V15	0.002	0.078	0.158
	Heavy Goods Vehicles in flow				
PG1,PG7		Q1,Q7	0.0	0.024	0.193
PG2,PG8		Q2,Q8	0.003	0.039	0.210
PG3,PG9		Q3,Q9	0.0	0.025	0.276
PG4,PG10		Q4,Q10	0.0	0.024	0.204
PG5,PG11		Q5,Q11	0.0	0.023	0.267
PG6,PG12		Q6,Q12	0.0	0.030	0.200
PG15		V15	0.004	0.036	0.204
	PSVs (closed) in flow				
PV1,PV7		Q1,Q7	0.0	0.011	0.402
PV2,PV8		Q2,Q8	0.0	0.018	0.093
PV3,PV9		Q3,Q9	0.0	0.009	0.500
PV4,PV10		Q4,Q10	0.0	0.010	0.357
PV5,PV11		Q5,Q11	0.0	0.009	0.151
PV6,PV12		Q6,Q12	0.0	0.013	0.435
PV15		V15	0.0	0.017	0.081
	PSVs (open) in flow				
PO1,PO7		Q1,Q7	0.0	0.0002	0.023
PO2,PO8		Q2,Q8	0.0	0.0006	0.032
PO3,PO9		Q3,Q9	0.0	0.0004	0.132
PO4,PO10		Q4,Q10	0.0	0.0002	0.020
PO5,PO11		Q5,Q11	0.0	0.0002	0.032
PO6,PO12		Q6,Q12	0.0	0.0004	0.048
PO15		V15	0.0	0.0006	0.023
	All PSVs (open/closed) in flow				
PB1,PB7		Q1,Q7	0.0	0.011	0.402
PB2,PB8		Q2,Q8	0.0	0.019	0.093
PB3,PB9		Q3,Q9	0.0	0.010	0.500
PB4,PB10		Q4,Q10	0.0	0.010	0.357
PB5,PB11		Q5,Q11	0.0	0.009	0.151
PB6,PB12		Q6,Q12	0.0	0.013	0.468
PBV8		V8	0.0	0.010	0.138
PBV15		V15	0.0	0.018	0.081
PBQMA		QMA	0.0	0.018	0.082
PBQMI		QMI	0.0	0.011	0.088
PBV2		V2	0.0	0.011	0.169

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Variable(s)	Description		Min	Mean	Max
Pedestrian flow (thousands)					
P1	across arm 1 clockwise		0.0004	0.153	1.934
P2	anticlockwise		0.0004	0.149	1.908
P3	across arm 2 clockwise		0.0010	0.264	3.782
P4	anticlockwise		0.0004	0.245	3.937
P5	across arm 3 clockwise		0.0004	0.153	1.934
P6	anticlockwise		0.0004	0.149	1.908
P7	across arm 4 clockwise		0.0010	0.264	3.782
P8	anticlockwise		0.0004	0.245	3.937
	across centre to entry corner of				
P9	arm 1		0.000	0.003	0.188
P10	arm 2		0.000	0.005	0.258
P11	arm 3		0.000	0.003	0.188
P12	arm 4		0.000	0.005	0.258
PA	across arm 1		0.001	0.302	3.842
PI	across arm 2		0.003	0.509	7.719
PTA	across arms 1 and 3		0.011	0.604	4.124
PTB	across arms 1 and 3 and centre		0.011	0.621	4.165
PT	sum of 12 basic flows		0.045	1.638	14.864
Proportion of sex-age group in pedestrian flow					
	Male children in				
PMC1,PMC5		P1,P5	0.0	0.114	0.667
PMC2,PMC6		P2,P6	0.0	0.111	0.600
PMC3,PMC7		P3,P7	0.0	0.107	0.615
PMC4,PMC8		P4,P8	0.0	0.108	0.667
PMCA		PTA	0.0	0.122	0.420
	Female children in				
PFC1,PFC5		P1,P5	0.0	0.108	0.833
PFC2,PFC6		P2,P6	0.0	0.107	0.610
PFC3,PFC7		P3,P7	0.0	0.102	0.786
PFC4,PFC8		P4,P8	0.0	0.101	0.697
PFCA		PTA	0.0	0.124	0.561
	Male adults in				
PMA1,PMA5		P1,P5	0.0	0.327	1.000
PMA2,PMA6		P2,P6	0.0	0.332	1.000
PMA3,PMA7		P3,P7	0.0	0.335	1.000
PMA4,PMA8		P4,P8	0.0	0.337	1.000
PMAA		PTA	0.042	0.295	0.702
	Female adults in				
PFA1,PFA5		P1,P5	0.0	0.339	1.000
PFA2,PFA6		P2,P6	0.0	0.330	1.000
PFA3,PFA7		P3,P7	0.0	0.334	1.000
PFA4,PFA8		P4,P8	0.0	0.329	1.000
PFAA		PTA	0.055	0.339	0.635

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Variable(s)	Description		Min	Mean	Max
	Male seniors in				
PMS1,PMS5		P1,P5	0.0	0.053	0.500
PMS2,PMS6		P2,P6	0.0	0.058	1.000
PMS3,PMS7		P3,P7	0.0	0.060	0.667
PMS4,PMS8		P4,P8	0.0	0.060	0.500
PMSA		PTA	0.0	0.057	0.318
	Female seniors in				
PFS1,PFS5		P1,P5	0.0	0.056	0.667
PFS2,PFS6		P2,P6	0.0	0.058	0.523
PFS3,PFS7		P3,P7	0.0	0.063	0.750
PFS4,PFS8		P4,P8	0.0	0.063	0.461
PFSA		PTA	0.0	0.063	0.506
PACA	all children in	PTA	0.005	0.246	0.855
PAAA	all adults in	PTA	0.097	0.634	0.956
PASA	all seniors in	PTA	0.0	0.120	0.727
Proportion of pedestrian flow (two-way) on crossing (198 units)					
PON1	male children		0.0	0.898	1.000
PON2	female children		0.0	0.922	1.000
PON3	male adults		0.0	0.883	1.000
PON4	female adults		0.564	0.950	1.000
PON5	male seniors		0.0	0.878	1.000
PON6	female seniors		0.0	0.922	1.000
PON7	all children		0.0	0.938	1.000
PON8	all adults		0.497	0.924	1.000
PON9	all seniors		0.0	0.950	1.000
PON0	all pedestrians		0.525	0.938	1.000
Proportion of drivers who are					
PDS1	young males		0.0	0.092	0.406
PDS2	young females		0.0	0.057	0.299
PDS3	adult males		0.172	0.539	0.867
PDS4	adult females		0.036	0.245	0.487
PDS5	senior males		0.0	0.054	0.253
PDS6	senior females		0.0	0.013	0.087

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Variable(s)	Description	Min	Mean	Max
2. JUNCTION GEOMETRY				
Junction centre geometry				
Note: The junction extends 20 m on each major arm beyond the junction centre origin points (where a major arm meets the nearest minor arm)				
Length along give way from minor arm centre line to:				
ME2	entry kerbline (MC to EC)	1.2	4.7	15.3
ME4	entry kerbline (MD to ED)	1.2	4.7	15.3
MX2	exit kerbline (MC to XC)	1.9	5.3	19.9
MX4	exit kerbline (MD to XD)	1.9	5.3	19.9
STAG	Stagger length (perpendicular)	-23.4	0.1	23.2
STAE	Stagger length (extended alignments)	-23.4	0.3	21.8
ASTAG	Absolute stagger length (perp.)	0.0	5.6	23.4
ASTAE	Absolute stagger length (exten. al.)	0.0	5.1	23.4
WRTJ	Width of right turn/hatching area (at junction centre)	0.0	0.6	9.6
Major arm geometry (* suffix 1 for arm 1, 3 for arm 3)				
At arm origin point (where major arm meets nearest minor arm):				
NIX1*	Number of initial exit lanes	1	1.04	2
NAE1	Number of ahead lanes at entry	1	1.04	2
WIX1	Width of initial exit lanes	2.7	4.7	8.5
WCM1	Width of central road markings	0.0	0.6	9.6
WAE1	Width of ahead lanes at entry	2.8	4.8	9.2
At 20m from arm origin:				
WPX1	Width of exit carriageway	2.6	4.6	8.2
WPE1	Width of entry carriageway	2.7	4.6	8.2
WIS1	Width of island or central area	0.0	0.6	8.3
BCI1	Breadth of crossing between studs or within island (189)	0.7	2.9	5.2
LIS1	Length of island (116)	0.8	6.4	49.6
RTZ1	Distance end of right turn lane (129) (sites with no lane have zero)	-32.4	-12.3	-1.5
LRT1	Length of right turn lane (129)	6.0	23.1	75.8
HAZ1	Distance to end of hatching (135)	-26.2	8.6	62.4
LHA1	Length of hatching (135)	6.9	70.7	201.8
ISZ1	Distance to island end (within 27.5m) (116)	-3.2	7.0	23.7
DPF1	Distance to crossing studs (within 27.5m) (198)	-2.0	5.8	27.3
SLS1	Distance to speed limit change sign (10)	76	124.3	193

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Variable(s)	Description	Min	Mean	Max
At 100m from arm origin:				
NAL1	Number of approach lanes (at 100m)	1	1.04	2
NXL1	Number of exit lanes (at 100m)	1	1.06	2
WAL1	Width of approach lanes (at 100m)	2.4	4.7	8.3
WXL1	Width of exit lanes (at 100m)	2.6	4.7	9.9
WCA1	Width of central areas (at 100m)	0.0	0.2	4.3
NWS1	Number of other warning signs	0	0.21	3
NMS1	Number of mandatory or prohibitory signs	0	0.06	3
NDS1	Number of advance direction sign displays	0	0.12	3
NOS1	Number of other sign displays	0	0.23	3
Number of private drives				
DEN1	entry side 0-20m	0	0.16	2
DEM1	entry side 20-50m	0	0.64	5
DEF1	entry side 50-100m	0	1.03	7
DXN1	exit side 0-20m	0	0.20	2
DXM1	exit side 20-50m	0	0.65	4
DXF1	exit side 50-100m	0	1.16	6
DXL3	exit side 0-50m = (DXN3+DXM3)	0	0.85	6
Number of public accesses				
AEN1	entry side 0-20m	0	0.02	1
AEM1	entry side 20-50m	0	0.08	2
AEF1	entry side 50-100m	0	1.12	4
AXN1	exit side 0-20m	0	0.02	2
AXM1	exit side 20-50m	0	0.06	2
AXF1	exit side 50-100m	0	1.11	3
Number of side roads				
REN1	entry side 0-20m	0	0	0
REM1	entry side 20-50m	0	0.05	1
REF1	entry side 50-100m	0	1.22	2
RXN1	exit side 0-20m	0	0	0
RXM1	exit side 20-50m	0	0.05	1
RXF1	exit side 50-100m	0	0.24	1
SSD1	Stopping sight distance	46.0	193.7	225.0
ISD1	1/SSD1	0.0044	0.0058	0.0217

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Variable(s)	Description	Min	Mean	Max
Gradient of approach to junction (uphill positive)				
GDN1	0-50m (%)	-10.5	-0.0	12.0
GDF1	50-100m (%)	-11.5	-0.2	14.0
ICA1	Curvature of approach within 100m (1/radius)	-0.033	0.000	0.050
RCC1	Radius of entry corner	1.0	7.5	70.0
ICC1	Curvature of entry corner (1/RCC1)	0.014	0.235	1.000
ANJ1	Angle at junction with next arm clockwise (deg)	42	88.6	131
ANA1	Angle on approach with next arm clockwise (deg)	33	89.4	172
DEVMJR	Angular deviation along major rd. (absolute value of (ANA1+ANA2-180))	0	4.358	38
DEVMNR	Angular deviation along minor rd. (absolute value of (ANA2+ANA3-180))	0	10.725	78
Minor arm geometry (* suffix 2 for arm 2, 4 for arm 4)				
NGM2*	No. of 'Give-way' or 'STOP' marks	0	0.74	2
NGS2	No. of 'Give-way' or 'STOP' signs	0	0.69	2
SGS2	Size of 'Give-way' or 'STOP' signs (cm) (399)	60	71.3	135
NEG2	No. of entry lanes at give way	1	1.04	2
NNO2	No. of lanes with no designated marking	0	1.01	2
NLO2	No. of lanes with left only marking	0	0.012	1
NLA2	No. of lanes with left and ahead marking	0	0.002	1
NAR2	No. of lanes with ahead and right marking	0	0.009	1
NRO2	No. of lanes with right only marking	0	0.005	1
NIX2	Number of initial exit lanes	1	1	1
WIX2	Initial exit width	3.0	6.7	17.3
WHG2	Width of hatching at centre of give way line	0.0	0.09	5.6
WHE2	Width of hatching between entry lanes at give way	0.0	0.05	6.2
GWX2	Length of give way line from centre to exit kerb	3.5	10.7	39.7
GWE2	Length of give way line from centre to entry kerb	3.6	9.7	45.6
WEE2	Entry width	2.7	6.3	18.4
W2X2	Width of exit at 2m	2.4	7.1	29.7
W2H2	Width of hatching at 2m	0.0	0.2	8.0
W2E2	Width of entry at 2m	2.3	6.6	34.2
SBI2	Set-back of island from give-way (103)	0.0	2.6	6.5

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Variable(s)	Description	Min	Mean	Max
WXI2	Minimum exit width at island (103)	3.3	5.9	12.1
WIS2	Width of island (103)	0.7	1.8	7.0
BCI2	Breadth of crossing area (87)	0.8	2.1	5.0
LIS2	Length of island (103)	0.8	5.4	15.7
WEI2	Minimum entry width at island (103)	3.3	5.4	10.6
HAZ2	Distance to end of hatching (50)	0.0	1.0	4.1
LHA2	Length of hatching (50)	3.0	20.8	38.7
SLS2	Distance to speed limit change sign (113)	1.0	15.4	170
NAL2	Number of approach lanes (at 30m)	1	1.003	2
NXL2	Number of exit lanes (at 30m)	1	1	1
WAL2	Width of approach lanes (at 30m)	1.9	3.9	7.6
WCA2	Width of central markings on approach (at 30m)	0.0	0.008	1.5
WXL2	Width of exit lanes at 30m	1.9	3.9	7.7
NWS2	No. of other warning sign displays	0	0.04	2
NMS2	No. of mandatory or prohibitory signs	0	0.44	6
NDS2	No. of advance direction sign displays	0	0.05	1
NOS2	No. of other sign displays	0	0.11	3
Number of private drives				
DEN2	entry side 0-20m	0	0.10	2
DEM2	entry side 20-50m	0	0.82	5
DEF2	entry side 50-100m	0	1.36	7
DXN2	exit side 0-20m	0	0.10	2
DXM2	exit side 20-50m	0	0.73	4
DXF2	exit side 50-100m	0	1.28	8
Number of public accesses				
AEN2	entry side 0-20m	0	0.003	1
AEM2	entry side 20-50m	0	0.10	2
AEF2	entry side 50-100m	0	0.07	2
AXN2	exit side 0-20m	0	0.029	1
AXM2	exit side 20-50m	0	0.15	2
AXF2	exit side 50-100m	0	0.09	2
Number of side roads				
REN2	entry side 0-20m	0	0	0
REM2	entry side 20-50m	0	0.03	1
REF2	entry side 50-100m	0	0.20	2
RXN2	exit side 0-20m	0	0	0
RXM2	exit side 20-50m	0	0.03	1
RXF2	exit side 50-100m	0	0.18	2
SSD2	Stopping sight distance	23.0	171.5	225.0
ISD2	1/SSD2	0.0044	0.0072	0.0435

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Variable(s)	Description	Min	Mean	Max
Gradient of approach to junction				
GDN2	0-50m (%)	-14.5	-0.1	15.0
GDF2	50-100m (%)	-14.5	-0.4	10.0
ICA2	Curvature of approach within 100m (1/radius)	-0.167	0.001	0.125
RCC2	Radius of entry corner	1.0	7.3	75.0
ICC2	Curvature of entry corner (1/RCC2)	0.013	0.224	1.0
ANJ2	Angle at junction with next arm clockwise (deg)	49	91.4	145
ANA2	Angle on approach with next arm clockwise (deg)	8	90.6	145
Visibilities from minor arm along major arms				
V2L2	to left from 2m	39.0	186.0	225
V4L2	4m	17.0	143.9	225
V9L2	9m	5.0	76.8	225
V2R2	to right from 2m	9.0	175.2	225
V4R2	4m	6.0	114.2	225
V9R2	9m	4.0	56.9	225
Inverse visibilities from minor arm along major arms				
I2L2	1/V2L2 to left from 2m	0.0044	0.0062	0.0256
I4L2	1/V4L2 4m	0.0044	0.0103	0.0588
I9L2	1/V9L2 9m	0.0044	0.0247	0.2000
I2R2	1/V2R2 to left from 2m	0.0044	0.0076	0.1111
I4R2	1/V4R2 4m	0.0044	0.0185	0.1667
I9R2	1/V9R2 9m	0.0044	0.0405	0.2500
I9L152	1/(V9L2+15) 9m	0.004	0.016	0.050
I9R152	1/(V9R2+15) 9m	0.004	0.022	0.053
Vehicle speeds (mph)				
Mean speed				
SMN1,SMN3	arm 1, arm 3	15.2	29.7	43.2
SMN2,SMN4	arm 2, arm 4	11.6	25.7	39.5
85 percentile speed				
S851,S853	arm 1, arm 3	17.8	34.4	49.1
S852,S854	arm 2, arm 4	14.6	30.2	43.7
Coefficient of variation of speeds on major arms				
COV1	=(S851-SMN1)*100/SMN1	7.305	16.482	38.264
COV3	=(S853-SMN3)*100/SMN3	7.305	16.482	38.264

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Variable(s) Description	Min	Mean	Max
Vehicle queueing			
Overall Max queue			
QUM1,QUM3 arm 1, arm 3	0	8.61	46
QUM2,QUM4 arm 2, arm 4	0	7.94	40
Average of half-hour max queues			
QUA1,QUA3 arm 1, arm 3	0	2.33	17.1
QUA2,QUA4 arm 2, arm 4	0	3.05	11.5
Vehicle parking			
Average no. of vehicles parked within 100m:			
KEB1,KEB3 entry side arm 1, arm 3	0.0	1.35	13.0
KEB2,KEB4 entry side arm 2, arm 4	0.0	3.14	15.0
KXB1,KXB3 exit side arm 1, arm 3	0.0	1.28	15.0
KXB2,KXB4 exit side arm 2, arm 4	0.0	3.32	18.0
Maximum no. of vehicles parked within 20m:			
KEM1,KEM3 entry side arm 1, arm 3	0	0.66	7
KEM2,KEM4 entry side arm 2, arm 4	0	1.23	6
KXM1,KXM3 exit side arm 1, arm 3	0	0.63	6
KXM2,KXM4 exit side arm 2, arm 4	0	1.23	6
Average no. of vehicles parked within 20m:			
KEA1,KEA3 entry side arm 1, arm 3	0.0	0.20	3.8
KEA2,KEA4 entry side arm 2, arm 4	0.0	0.52	4.1
KXA1,KXA3 exit side arm 1, arm 3	0.0	0.18	4.1
KXA2,KXA4 exit side arm 2, arm 4	0.0	0.57	4.3
Total no. of stops and starts over 12 hours within 20m:			
KET1,KET3 entry side arm 1, arm 3	0	18.3	507
KET2,KET4 entry side arm 2, arm 4	0	20.7	224
KXT1,KXT3 exit side arm 1, arm 3	0	15.4	348
KXT2,KXT4 exit side arm 2, arm 4	0	19.8	221

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Variable(s)	Description	Min	Mean	Max
KBB1	Average no. of vehicles parked within 100m on entry and exit, arm 1 = (KEB1+KXB1)/2	0	1.54	13.90
KBB2	Average no. of vehicles parked within 100m on entry and exit, arm 2 = (KEB2+KXB2)/2	0	3.55	16.50
KBB3	Average no. of vehicles parked within 100m on entry and exit, arm 3 = (KEB3+KXB3)/2	0	1.54	13.90
KBB4	Average no. of vehicles parked within 100m on entry and exit, arm 4 = (KEB4+KXB4)/2	0	3.55	16.50
KBB5	Average no. of vehicles parked within 100m on entry and exit, arms 1 and 3 = (KBB1+KBB3)/2	0	1.54	13.65
KBB6	Average no. of vehicles parked within 100m on entry and exit, arms 2 and 4 = (KBB2+KBB4)/2	0	3.55	14.80
Non directional variables used in junction-based models (Section 11.9)				
QMA	Major road inflow (Q1+Q2+Q3+Q7+Q8+Q9)	0.615	12.645	29.220
QMI	Minor road inflow (Q4+Q5+Q6+Q10+Q11+Q12)	0.212	2.543	7.512
PQMIS	Minor road traffic going ahead (Q5+Q11)/QMI	0.003	0.2817	0.746
PQMIR	Minor road traffic turning right (Q6+Q12)/QTI	0.03	0.2748	0.801
PTA	Pedestrn. flow across major arms (P1+P2+P5+P6)	0.011	0.6041	4.124
PBQMA	Public service vehicles in QMA	0.0	0.018	0.082
PMQMA	Motor cycles in QMA	0.002	0.01809	0.123
SMNMJR	Mean speed on major arms (SMN1+SMN3)/2	16.95	29.66	42.95
COVMJR	Coefficient of variation of speed on major arms (COV1+COV3)/2	7.85	16.45	37.52
ASTAG	Absolute stagger length of minor arms	0.0	5.587	23.4
DEVMJR	Angular deviation along major road at junction	0.0	4.358	38.0
DEVMNR	Angular deviation along minor road at junction	0.0	10.73	78.0
ISDMJR	Inverse of stopping sight distance on major arms 2/(SSD1+SSD3)	0.0044	0.00541	0.012
RCCMJR	Radius of curvature of entry corner on major arms (RCC1+RCC3)/2	1.0	7.484	49

Label	Description	Levels and (number of units)	
3. JUNCTION FACTORS			
Levels are 1 = feature absent, 2 = feature present, unless stated otherwise			
Label	Description	Levels and (number of units)	
JTA	Junction Type A (operational defn.)	1 = Cross-road	(424)
		2 = Left-Right staggered junction	(98)
		3 = Right-Left staggered junction	(104)
JTB	Junction Type B (5m perpendicular defn.)	1 = Cross-road	(374)
		2 = Left-Right staggered junction	(132)
		3 = Right-Left staggered junction	(120)
JTC	Junction Type C (5m centre line defn.)	1 = Cross-road	(402)
		2 = Left-Right staggered junction	(110)
		3 = Right-Left staggered junction	(114)

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Label	Description		Levels and (number of units)	
JFT	Junction Features			
	maj/min/maj/min		maj/min/maj/min	
	1 = - / - / - / -	(176)		
	2 = P+I/ - / - / -	(1)	32 = - / - /P+I/ -	(1)
	3 = PEL/ - / - / -	(37)	33 = - / - /PEL/ -	(37)
	4 = PEL/ISL/ISL/ -	(1)	34 = ISL/ - /PEL/ISL	(1)
	5 = PEL/ISL/ - / -	(3)	35 = - / - /PEL/ISL	(3)
	6 = PEL/ - / - /ISL	(3)	36 = - /ISL/PEL/ -	(3)
	7 = PEL/ - /HCH/ -	(2)	37 = HCH/ - /PEL/ -	(2)
	8 = Z+I/ - / - / -	(9)	38 = - / - /Z+I/ -	(9)
	9 = Z+I/ - /ISL/ -	(3)	39 = ISL/ - /Z+I/ -	(3)
	10 = Z+I/ISL/ - / -	(1)	40 = - / - /Z+I/ISL	(1)
	11 = Z+I/ - /HCH/ -	(1)	41 = HCH/ - /Z+I/ -	(1)
	12 = ZEB/ - / - / -	(36)	42 = - / - /ZEB/ -	(36)
	13 = ZEB/ISL/ - / -	(2)	43 = - / - /ZEB/ISL	(2)
	14 = ISL/ - / - / -	(13)	44 = - / - /ISL/ -	(13)
	15 = ISL/ - /ISL/ -	(28)		
	16 = ISL/ISL/ISL/ -	(4)	46 = ISL/ - /ISL/ISL	(4)
	17 = ISL/ISL/ - /ISL	(1)	47 = - /ISL/ISL/ISL	(1)
	18 = ISL/ISL/ISL/ISL	(26)		
	19 = - /ISL/ - / -	(16)	49 = - / - / - /ISL	(16)
	20 = - /ISL/ - /ISL	(34)		
	21 = ISL/ - /HCH/ -	(19)	51 = HCH/ - /ISL/ -	(19)
	22 = ISL/ - /HCH/ISL	(2)	52 = HCH/ISL/ISL/ -	(2)
	23 = HCH/ISL/HCH/ -	(2)	53 = HCH/ - /HCH/ISL	(2)
	24 = HCH/ISL/HCH/ISL	(6)		
	25 = - /ISL/ - /HCH	(1)	55 = - /HCH/ - /ISL	(1)
	26 = HCH/ - /HCH/ -	(32)		
	27 = - /HCH/ - /HCH	(6)		
	28 = - /HCH/ - / -	(2)	58 = - / - / - /HCH	(2)

where

P+I	=	Pelican with island
PEL	=	Pelican without island
Z+I	=	Zebra with island,
ZEB	=	Zebra without island
ISL	=	Island (with/without hatching)
HCH	=	Hatching

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Label	Description	Levels and (number of units)	
STA	Staggered junction type A (from JTA) - not used in final models	1 = crossroads 2 = staggered junction	(414) (202)
STB	Staggered junction type B (from JTB) - see STJ	1 = crossroads 2 = staggered junction	(374) (252)
STC	Staggered junction type C (from JTC) - not used in final models	1 = crossroads 2 = staggered junction	(402) (224)
STJ	Staggered junction definition adopted (equivalent to STB)	1 = crossroads 2 = staggered junction	(374) (252)
SP	Speed limit of major arms (junction factor)	1 = 30 mile/hr 2 = 40 mile/hr	(486) (140)
LON	London	1 = non-London junction 2 = London junction	(468) (158)
CRMJ	Centre road markings at junction		
	1 = none	(68)	
	2 = short broken	(16)	
	3 = long broken	(316)	
	4 = zig-zag	(112)	
	5 = continuous hatching	(4)	
	6 = hatching with central gap	(104)	
	7 = hatching with gaps each end	(6)	
CHAJ	Hatching in central area	(114)	
CZGJ	Zig-zag centre road markings at junction	(112)	
CBLJ	Broken line centre road markings at junction	(332)	
RTAJ	Right turn arrow pattern		
	1 = no arrows	(562)	
	2 = arm 1 only	(9)	
	3 = arm 3 only	(9)	
	4 = non-hooking	(36)	
	5 = hooking	(10)	
RTA	Right turn arrows	(62)	

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Label	Description	Levels and (number of units)
4. ARM BASED FACTORS		
The factor name has suffix 1 or 3 for major arms, 2 or 4 for minor arms		
Pedestrian crossing facilities		
PIL1	Pelican with island arm 1	(1)
PIL3	Pelican with island arm 3	(1)
PEL1	Pelican without island arm 1	(46)
PEL3	Pelican without island arm 3	(46)
PAL1	Pelican with or without island arm 1	(47)
PAL3	Pelican with or without island arm 3	(47)
PAL5	Pelican with or without island arm 1 or 3	(94)
ZIB1	Zebra with island arm 1	(14)
ZIB3	Zebra with island arm 3	(14)
ZEB1	Zebra without island arm 1	(38)
ZEB3	Zebra without island arm 3	(38)
ZAB1	Zebra with or without island arm 1	(52)
ZAB3	Zebra with or without island arm 3	(52)
ZAB5	Zebra with or without island arm 1 or 3	(104)
PZC1	Pelican or Zebra with or without island arm 1	(99)
PZC3	Pelican or Zebra with or without island arm 3	(99)
PZC5	Pelican or Zebra with or without island arm 1 or 3	(198)
Islands and hatching		
ISL1	Island arm 1 (no sites with zeb or pel but includes those with hatching & islands)	(101)
ISL2	Island arm 2	(103)
ISL3	Island arm 3	(101)
ISL4	Island arm 4	(103)
ISL5	Island arm 1 or 3	(140)
ISL6	Island arm 2 or 4	(138)
ISL7	Island arm 1 and arm 3	(62)
ISL8	Island arm 2 and arm 4	(68)
HCH1	Hatching arm 1 (hatching only)	(66)
HCH2	Hatching arm 2	(9)
HCH3	Hatching arm 3	(66)
HCH4	Hatching arm 4	(9)
HCH5	Hatching arm 1 or 3	(90)
HCH6	Hatching arm 2 or 4	(12)
HCH7	Hatching arm 1 and arm 3	(42)
HCH8	Hatching arm 1 and arm 4	(6)

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Label	Description	Levels and (number of units)	
The factor name in the models has suffix 1 or 3 for major arms, 2 or 4 for minor arms			
TRT	Type of separate right turn lane	(major)	(minor)
	1 = none	497	-
	2 = tapered on approach	13	-
	3 = constant width on approach	41	-
	4 = in central gap only	75	-
RTL	Right turn lane	129	-
GRE	Guard rail pattern entry side		
	1 = none	587	617
	2 = continuous	23	6
	3 = continuous with gap	16	3
GUE	Guard rail entry side	39	9
GUC	Guard rail entry corner	25	28
GRX	Guard rail pattern exit side		
	1 = none	583	617
	2 = continuous	23	7
	3 = continuous with gap	20	2
GUX	Guard rail exit side	43	9
GUSB5	Guard rail present on arm 1 entry or arm 1 corner or arm 2 corner	(57)	
SKD	Anti-skid surfacing location		
	1 = none	596	-
	2 = present pedestrian facility	27	-
	3 = present for arm approach	3	-
SKS	Anti-skid surfacing	30	
LTH	Lighting height		
	1 = low	23	342
	2 = high	603	279
	3 = none	0	5

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Label	Description	Levels and (number of units)	
CMN	Centre road marking near (0-20m)	(major)	(minor)
	1 = none	21	10
	2 = short broken	17	0
	3 = long broken	356	574
	4 = zig-zag	101	0
	5 = hatching (no arrows)	71	42
	6 = hatching (with arrows)	60	0
CM1N	Centre road marks - none	21	10
CM2N	Centre road marks - short broken (major only)	17	-
CM3N	Centre road marks - long broken	356	574
CM4N	Centre road marks - zig-zag (major only)	101	-
CM5N	Centre road marks - hatching (no arrows)	71	42
CM6N	Centre road marks - hatching (with arrows - major only)	60	-
CM7N	Centre road marks - hatching (major only)	131	-
CMF	Centre road markings far (20-100m)		
	1 = none	36	425
	2 = short broken	105	45
	3 = long broken	387	154
	4 = zig-zag	11	-
	5 = hatching (no arrows)	66	2
	6 = hatching (with arrows)	21	-
CM1F	Centre road marks - none	36	425
CM2F	Centre road marks - short broken	105	45
CM3F	Centre road marks - long broken	387	154
CM4F	Centre road marks - zig-zag (major only)	11	-
CM5F	Centre road marks - hatching (no arrows)	66	2
CM6F	Centre road marks - hatching (with arrows - major only)	21	-
CM7F	Centre road marks - hatching (major only)	87	-
Loading regulations			
LEN	0-20m entry side	57	18
LEF	20-100m entry side	58	2
LXN	0-20m exit side	59	20
LXF	20-100m exit side	63	3
SPA	Speed limit on approach		
	1 = 30 mph	486	617
	2 = 40 mph or higher	140	9

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Label	Description	Levels and (number of units)	
Bus Stops		(major)	(minor)
B1E	Bus stop entry side within 25m	39	8
B2E	Bus stop entry side within 50m	111	31
B3E	Bus stop entry side within 25m	185	47
B1X	Bus stop exit side within 25m	59	8
B2X	Bus stop exit side within 50m	155	30
B3X	Bus stop exit side within 100m	237	68
Y1E	Bus bay entry side within 25m	8	1
Y2E	Bus bay entry side within 50m	17	1
Y3E	Bus bay entry side within 100m	21	1
Y1X	Bus bay exit side within 25m	19	-
Y2X	Bus bay exit side within 50m	25	-
Y3X	Bus bay exit side within 100m	32	4

Parking regulations 20 to 100m:

KEF Parking regulations most dominant 20-100m entry side

KXF Parking regulations most dominant 20-100m exit side

	KEF (maj)	KEF (min)	KXF (maj)	KXF (min)
1 = none	375	517	375	517
2 = broken yellow	55	11	49	16
3 = single yellow	83	35	87	33
4 = double yellow	87	48	86	40
5 = meters	5	1	5	3
6 = residents	2	7	2	6
7 = zig-zag (white)	10	0	12	0
8 = zig-zag (yellow)	1	4	2	7
9 = single white	8	3	8	4

Parking regulations most dominant 20-100m entry side

		(major)	(minor)
KE1F	Unrestricted	383	520
KE2F	restricted	143	54
KE3F	double yellow or zig-zag	98	52

Parking regulations most dominant 20-100m exit side

		(major)	(minor)
KX1F	Unrestricted	383	521
KX2F	restricted	143	58
KX3F	double yellow or zig-zag	100	47

Parking regulations 0 to 20m:

KEN Parking regulations least restrictive 0-20m entry side

KXN Parking regulations least restrictive 0-20m exit side

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Label	Description	Levels and (number of units)					
KEC	Parking regulations least restrictive entry corner						
		KEN		KXN		KEC	
		(maj)	(min)	(maj)	(min)	(maj)	(min)
	1 = none	304	387	306	393	307	345
	2 = broken yellow	18	3	17	1	8	2
	3 = single yellow	74	92	76	87	84	93
	4 = double yellow	111	138	107	134	170	184
	5 = meters	1	0	3	3	0	0
	6 = residents	2	4	1	3	0	0
	7 = zig-zag (white)	107	0	107	0	50	0
	8 = zig-zag (yellow)	0	0	0	2	0	0
	9 = single white	9	2	9	3	7	2

Label	Description	(major)	(minor)
Parking regulations least restrictive 0-20m entry side			
KE1N	unrestricted	313	389
KE2N	restricted	95	99
KE3N	double yellow	111	138
KE4N	zig-zag	107	-
Parking regulations least restrictive 0-20m exit side			
KX1N	unrestricted	315	396
KX2N	restricted	97	94
KX3N	double yellow	107	136
KX4N	zig-zag	107	-
Parking regulations least restrictive entry corner			
KE1C	Unrestricted	314	347
KE2C	restricted	92	95
KE3C	double yellow	170	184
KE4C	zig-zag	50	-
Parking regulations least restrictive 0-20m			
KB2N1	Restricted on both entry and exit sides, arm 1	(84)	
KB2N3	Restricted on both entry and exit sides, arm 3	(84)	
KB2N5	Restricted on both entry and exit sides, arms 1 & 3	(42)	
Parking bays:			
K1E	Parking bay entry side within 25m	4	2
K2E	Parking bay entry side within 50m	6	7
K3E	Parking bay entry side within 100m	9	10
K1X	Parking bay exit side within 25m	1	1
K2X	Parking bay exit side within 50m	2	3
K3X	Parking bay exit side within 100m	6	4

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Label	Description	Levels and (number of units)	
Pedestrian facility beyond 27.5m:		(major)	(minor)
P1B	within 50m	17	1
P2B	within 100m	55	5
P3B	within 200m	155	9
TPB	Type of pedestrian facility beyond 27.5m, within 200m		
	1 = none	471	617
	2 = island only	59	7
	3 = zebra without island	32	2
	4 = zebra with island	14	0
	5 = pelican without island	36	0
	6 = pelican with island	1	0
	7 = at signalled junction	10	0
	8 = at roundabout	3	0
ISB	Island beyond 27.5m	59	7
ZBB	Zebra beyond 27.5m	46	2
PLB	Pelican beyond 27.5m (major only)	37	-
GWS	Give way sign	-	343
GW7S	Give way sign 75cm or larger	-	204
GW9S	Give way sign 90cm or larger	-	45
STS	STOP sign	-	49
ST9S	STOP sign 90cm or larger	-	20
GSL	Give way or stop line		
	1 = give way	-	576
	2 = stop line	-	50
C1D	Curvature on arm within 25m of junction	126	101
C2D	Curvature on arm within 50m of junction	202	180
C3D	Curvature on arm within 100m of junction	244	249
	1 = no curvature		
	2 = curvature		
M1J	Next major junction within 50m	3	1
M2J	Next major junction within 100m	14	29
M3J	Next major junction within 200m	64	100

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Label	Description	Levels and (number of units)	
TMJ	Type of next major junction	(major)	(minor)
	1 = priority T junction	18	122
	2 = priority crossroads	6	50
	3 = priority L/R stagger	1	4
	4 = priority R/L stagger	1	6
	5 = mini roundabout	14	7
	6 = normal roundabout	66	12
	7 = gyratory system	10	2
	8 = traffic signals	136	19
	9 = not known	374	401
	10 = level crossing	0	3
CRS	Crossroads or staggered junction sign	116	1
AWS	Advance warning sign of give way or stop	-	58
SLO	SLOW marking or carriageway	43	27
ANGLE4	Angle at junction between arms 4 and 1 greater than 90 degrees	(299)	
Land use (dominant) 0-20m entry side			
UE1N	residential (group 7)	309	345
UE2N	shopping (1+8)	155	133
UE4N	sport and open (11+12)	67	63
UE6N	offices/industrial/educational/ public buildings/religious/ petrol station/car park/ other (2+4+5+6+9+10+13+14+16)	51	47
UE7N	recreational/public house (3+15)	44	38
UE8N	shopping/recreational/ public house (1+3+8+15)	199	171
Land use (dominant) 0-20m exit side			
UX1N	residential (group 7)	339	308
UX2N	shopping (1+8)	142	149
UX4N	sport and open (11+12)	67	68
UX6N	offices/industrial/educational/ public buildings/religious/ petrol station/car park/ other (2+4+5+6+10+13+14)	42	58
UX7N	recreational/public house (3+15)	36	43
UX8N	shopping/recreational/ public house (1+3+8+15)	178	192

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Label	Description	Levels and (number of units)	
Land use (dominant) 20-100m entry side		(major)	(minor)
UE1F	residential (group 7)	344	476
UE2F	shopping (1+8)	129	42
UE4F	sport and open (11+12)	67	43
UE6F	offices/industrial/educational/ public buildings/religious/ petrol station/car park/ other (2+4+5+6+10+13+14)	72	54
UE7F	recreational/public house (3+15)	14	11
UE8F	shopping/recreational/ public house (1+3+8+15)	143	53
Land use (dominant) 20-100m exit side			
UX1F	residential (group 7)	382	453
UX2F	shopping (1+8)	113	32
UX4F	sport and open (11+12)	61	54
UX6F	offices/industrial/educational/ public buildings/religious/ petrol station/car park/ other (2+4+5+6+10+13+14)	55	72
UX7F	recreational/public house (3+15)	15	15
UX8F	shopping/recreational/public house (1+3+8+15)	128	47
UEN	Land use (dominant) 0-20m entry side		
UXN	Land use (dominant) 0-20m exit side		

	UEN (maj)	UEN (min)	UXN (maj)	UXN (min)
1 = shops	139	113	130	120
2 = offices	3	13	8	7
3 = recreational	11	10	8	13
4 = industrial	13	3	3	11
5 = educational	11	4	2	10
6 = public buildings	7	6	6	10
7 = residential	309	345	339	308
8 = shops + residential	16	20	12	29
9 = offices + residential	0	0	0	0
10 = religious	12	10	10	10
11 = sport	3	3	4	3
12 = open	64	60	63	65
13 = petrol station	0	0	0	0
14 = car park	3	5	7	3
15 = public house	33	28	28	30
16 = other	2	6	6	7

VARIABLES TESTED IN THE FULL ACCIDENT-FLOW-GEOMETRY MODELS

Label	Description	Levels and (number of units)			
UEF	Land use (dominant) 20-100m entry side				
UXF	Land use (dominant) 20-100m exit side				
		UEF		UXF	
		(maj)	(min)	(maj)	(min)
	1 = shops	102	21	89	19
	2 = offices	7	9	6	11
	3 = recreational	10	8	5	5
	4 = industrial	15	12	4	17
	5 = educational	16	12	8	17
	6 = public buildings	6	5	6	7
	7 = residential	344	476	382	453
	8 = shops + residential	27	21	24	13
	9 = offices + residential	1	1	3	3
	10 = religious	13	4	11	8
	11 = sport	5	3	3	5
	12 = open	62	40	58	49
	13 = petrol station	7	1	7	0
	14 = car park	5	4	5	7
	15 = public house	4	3	10	10
	16 = other	2	6	5	2
SHOP[2] = Dominant land use UE8N[2] or UX8N[2] 0-20m					
Non directional factors used in aggregate junction-based models (Section 11.9)					
LON	Within London		(79)		
ZEBA	Zebra on either of major arms		(52)		
PELA	Pelican on either of major arms		(47)		
C2DMNR	Curvature within 50m on either of minor arms		(142)		

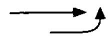
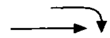
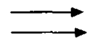
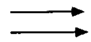
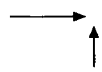
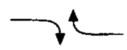
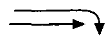
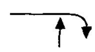
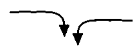
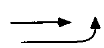
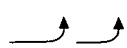
APPENDIX B: NUMBER OF ACCIDENTS BY TYPE, JUNCTION ARM AND VEHICLE MANOEUVRE

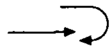
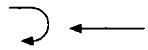
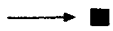
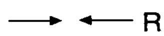
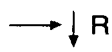
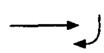
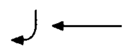
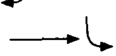
VEHICLE ACCIDENTS

Accident code	Single vehicle	Major arm	Minor arm
1	Approaching	25	5
2, 321	Left at centre	10	2
3, 322	Across at centre	2	2
4, 320	Right at centre	2	6
6	Unknown movement	3	0
8	Leaves carriageway	1	0
9	Exit	4	0
318	Hit object off carriageway	26	2
319	Hit object in carriageway	16	0
311	Passenger falls in PSV (vehicle entering)	22	1
312	Passenger falls in PSV (vehicle exiting)	5	1
315	Passenger falls in taxi	1	0
301	Pasenger falls off PSV (vehicle entering)	9	1
302	Passenger falls off PSV (vehicle exiting)	5	0
325	Passenger falls in PSV (right turn)	1	1
327	Passenger falls off PSV (right turn)	1	0
	Subtotal	133	21

Rear shunts, lane changing and side impacts

Accident code	Rear shunts on approach or at centre	Major arm	Minor arm
11	Left, Left	1	3
12	Straight, left	6	2
14	Left, straight	0	2
15	Straight, straight	120	11
17	Left, right	1	0
18	Straight, right	73	1
19	Right, right	2	1

Accident code			Major arm	Minor arm
	Rear shunts on exit			
69	rear straight		44	1
323	rear right		0	1
324	rear left		2	1
	Changing lanes			
21	changing lanes leftwards		1	1
22	changing lanes rightwards		7	0
	Side collisions			
304	side collision on entry		14	2
70, 316	side collision on exit		7	1
	Subtotal		278	27
Right angle				
31	right angle		492	410
Right turns				
42	right turn with next right		1	12
43	right turn with opposite right		1	4
44	right turn with own ahead		47	0
45	right turn with next ahead		3	105
46	right turn with opposite ahead		270	18
47	right turn with previous ahead		11	209
50	right turn with opposite left		1	5
51	right turn with previous left		3	6
	Subtotal		337	359
Left turns				
52	left turn with own ahead		24	2
53	left turn with left to right		7	5
54	left turn with opposite ahead		3	0
55	left turn with right to left		5	61
56	left turn with left turn, exiting		0	3
57	left turn with next left		0	1
	Subtotal		39	72

Accident code			Major arm	Minor arm
Head-on and U-turns				
61	Head-on		28	4
62	Head-on, overtaking		3	0
	U-turn			
64	with same direction		8	1
66	with opposite direction		2	0
			41	5
Parked and parking				
72	Parked vehicle hit		33	8
76	Parking vehicle hit (on same side of road)		12	1
77	Parking vehicle hit (on far side of road)		1	0
	Subtotal		46	9
Reversing and private drives				
78	Reversing		1	0
35	Right angles, major vehicle reversing		1	1
36	Right angles, minor vehicle reversing		1	0
	Private drives			
81	entering right into		2	0
82	entering right into		5	0
83	exiting right out of		2	1
84	exiting right out of		1	0
87	exiting left out of		0	1
	Subtotal		13	3
	Total		1379	906

PEDESTRIAN ACCIDENTS

Accident code			Major arm	Minor arm
Vehicle entering junction				
102	vehicle left, pedestrian from offside		2	0
104	vehicle ahead, pedestrian from offside		66	6
105	vehicle ahead, pedestrian from nearside		124	17
106	pedestrian direction unknown	?	5	0
	Subtotal		197	23
Vehicle exiting from junction				
111	vehicle left, pedestrian from nearside		3	10
112	vehicle left, pedestrian from offside		5	7
114	vehicle ahead, pedestrian from nearside		124	6
115	vehicle ahead, pedestrian from offside		92	9
116	pedestrian direction unknown	?	2	1
117	vehicle right, pedestrian from nearside		15	10
118	vehicle right, pedestrian from offside		1	9
	Subtotal		242	52
Position of collision in junction unknown				
121	pedestrian from offside		21	1
122	pedestrian from nearside		22	1
123	pedestrian direction unknown	?	3	0
	Subtotal		46	2
Other pedestrian accidents				
131-145	pedestrian crossing centre		8	0
151	reversing vehicle hits ped (+ 155, 159)		11	5
152	pedestrian in carriageway (+ 171, 176, 177)		11	5
153	pedestrian hit on footway (+ 157, 158, 173, 179)		7	4
166	pedestrian at private drive		1	0
307-310	pedal cyclist crossing arm		11	2
124	pedestrian and vehicle from entry		1	0
175	other pedestrian		1	3
	Subtotal		51	19
	Total		536	96
	Grand total		1915	1002

APPENDIX C: MEASUREMENT OF EXPLANATORY VARIABLES AND FACTORS FOR FULL 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. Figure 2 shows how the flows are labelled. The definitions of the more complex vehicle and pedestrian flow functions are given in Table 31.

Unless otherwise specified, distances from the junction (e.g. 'within 20m of the junction') are defined as illustrated in Figures C1 to C3. Measurements on the major road for arm 1 were taken from the reference line OA, defined using XC or ED as appropriate, whichever is furthest from the junction centre. In figure C1, there is no stagger and the lines using XC and ED coincide, so OA is defined from either point. However, OB is defined using EC as it is slightly further from the junction centre than XD. Usually for a left-right stagger, OA is defined using XC, whilst for a right-left stagger, ED is used. Similarly for arm 3, measurements were taken from the reference line OB defined using either EC or XD, whichever was furthest from the junction centre. Usually for a left-right stagger, OB is defined from XD, whilst for a right-left stagger, EC is used. Measurements on the minor arms were taken from the give-way lines.

Arm-based variables and factors have the suffix 1 or 3 for major arms; 2 or 4 for minor arms.

Vehicle flows:

Annual average daily flows entering the junction (thousands of vehicles). Full turning counts were recorded.

Vehicle flow proportions:

Measured from 12 hour manual counts, classified as pedal cycles, motorcycles, cars or taxis, light goods vehicles,

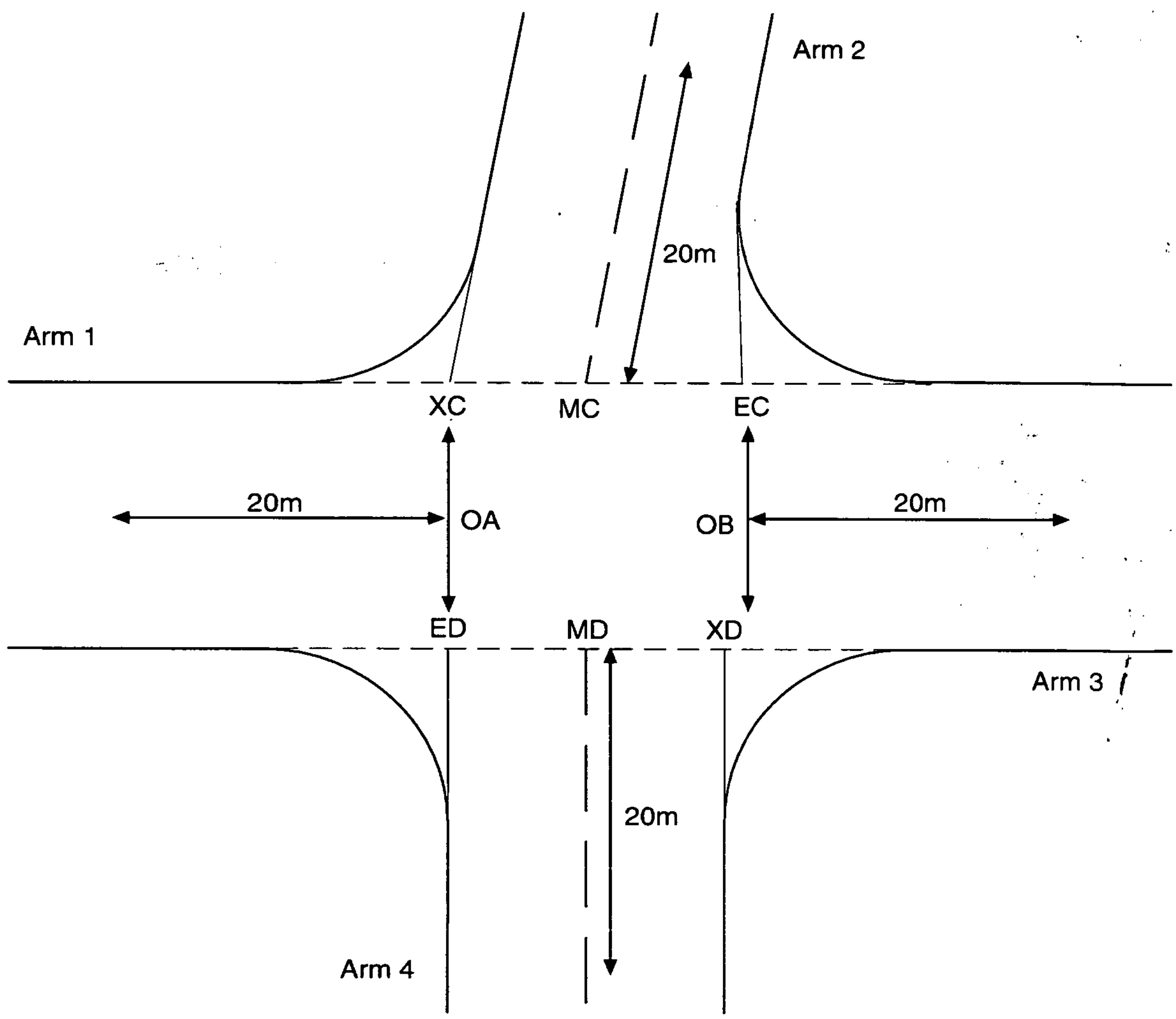


Figure C1 Crossroads (no stagger)

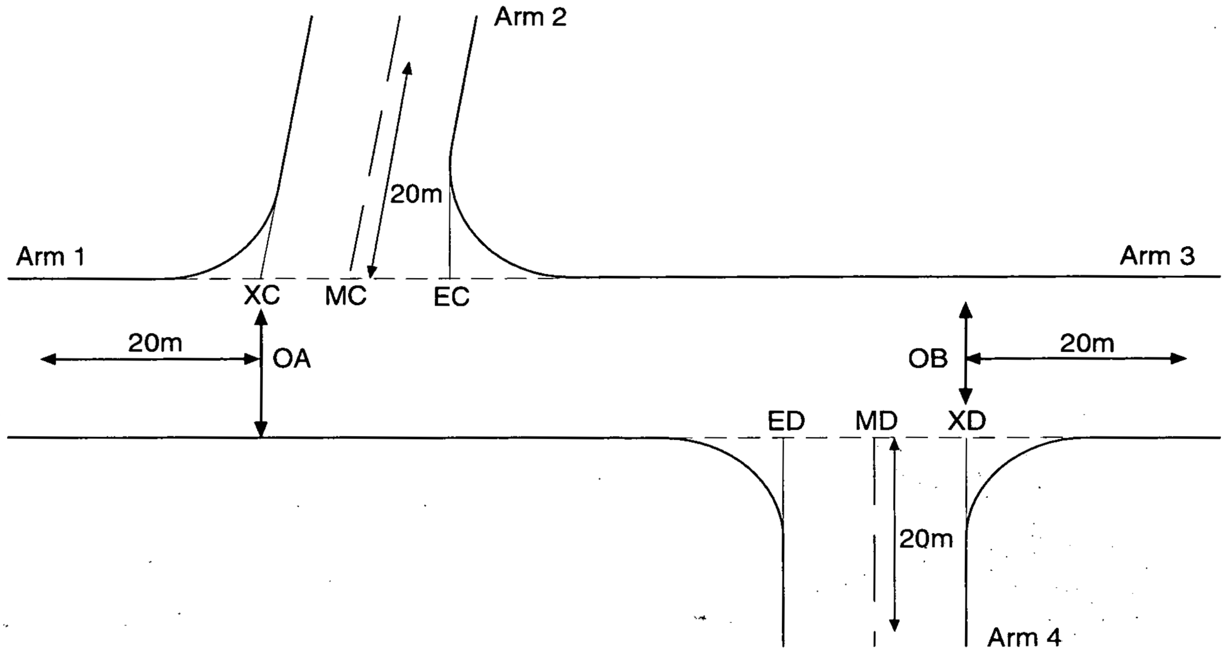


Figure C2 Crossroads (left-right stagger)

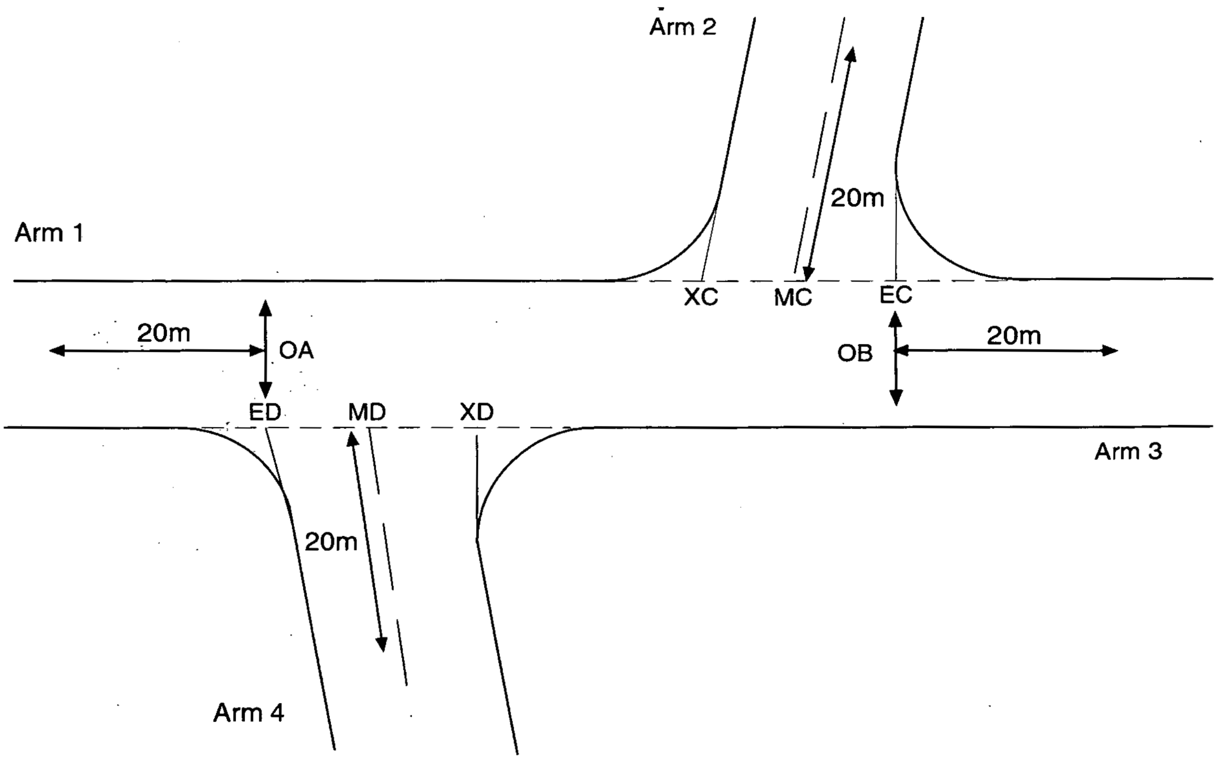


Figure C3 Crossroads (right-left stagger)

heavy goods vehicles, and public service vehicles with and without open rear platforms.

Pedestrian flows:

12 hour pedestrian flows crossing the centre of junction and each arm of the junction within 20m from 0700 to 1900 were recorded. Units: thousands of pedestrians. Pedestrians using a pelican or zebra crossing were included provided that the crossing was within 27.5m of the junction.

GEOMETRY AND FEATURES

Stagger length:

The factor STJ indicates whether or not a junction is staggered. A junction is defined to be staggered when the absolute stagger length ASTAG is greater than 5m. The stagger length STAG is measured as shown in Figure 1. It is the displacement between the perpendiculars from the centre lines of the opposite minor arms, and is positive for a right-left junction and negative for a left-right junction. RLJ indicates a right-left stagger. Junctions with staggers greater than 20m are probably better treated as two separate T-junctions. Measured from a 1:500 plan. Units: metres.

Angles:

ANA1, ANA2, ANA3 and ANA4 are the angles on the approach between each arm and the next arm clockwise, that is, between arms 1 and 2, arms 2 and 3, arms 3 and 4, and arms 4 and 1 respectively. They were measured from 1:500 plans between the projected tangent to the centre line at 20m from the junction on the former arm and the projected tangent to the centre line at 0m from the junction on the latter arm. For example, **ANA1** was measured between the projected tangent to the centre line at 20m from OA on arm 1 and the projected tangent to the centre line at the give-way line on arm 2.

ANGLE4 indicates whether the angle ANA4 between minor arm 4 and major arm 1 is greater than 90^0.

DEVMJR = ABS(ANA1+ANA2-180)

DEVMNR = ABS(ANA2+ANA3-180)

Units: degrees.

Islands:

ISL1 and **ISL3** indicates the presence of a solid island on major arm 1 or 3 within 27.5m of the junction. **ISL5** indicates the presence of a solid island on either arm 1 or arm 3.

Pedestrian crossing:

ZAB1, PAL1, ZAB3 and **PAL3** indicate respectively the presence of a zebra or a pelican crossing with or without an island on major arms 1 or 3 within 27.5m of the junction. **ZAB5** and **PAL5** indicate the presence of a zebra crossing or a pelican on either arm 1 or arm 3. **ZEBA** and **PELA** are junction variables corresponding to **ZAB5** and **PAL5.**

Hatching:

HCH1 and **HCH3** indicate the presence of a ghost island on major arm 1 or 3 within 20m of the junction. **HCH5** indicates the presence of a ghost island on either arm 1 or arm 3. **HCH7** indicates the presence of a ghost island on both arm 1 and arm 3.

Stopping sight distance:

SSD1 and **SSD3** are the stopping sight distances on major arms 1 and 3 respectively. The stopping sight distance was the distance away from the junction that an approaching driver could first see a car at the junction (measured up to maximum distance of 225m). The view was measured from a driver's eye height of 1.05m to an object of height 0.26m (car tail-lights). If the distance to the next major junction was less than the stopping sight distance, this value was used. **ISD1** and **ISD3** are the inverses of the stopping sight distances **SSD1** and **SSD3** respectively. **ISDMJR** is the inverse of the mean stopping sight distance on the major road so that: **ISDMJR** = 2/(SSD1+SSD3). Units: metres.

Number of lanes:

NAE1 is the number of ahead lanes on the entry side of arm 1 at the line OA in Figures C1 to C3.

Visibility from the minor arm:

V9L2 and **V9L4** are the visibilities to the left viewed from the centre line of the minor arm at 9m back from the give-way line on arms 2 and 4 respectively. The visibility was the furthest distance for which an approaching two-wheeled vehicle could be seen. Object and eye heights were 1.05m above the road surface and the object was on the opposite side of the carriageway to the minor arm for visibility to the left, but the same side for visibility to the right. The visibility was measured when not obstructed by parked or stationary vehicles. The distance recorded was along the major road from opposite the centre line of the minor arm to the object (up to a maximum of 225m). If the distance to the next major junction was less than the visibility, this value replaced the visibility. **I9L152** and **I9L154** are the inverses of the visibilities **V9L2** and **V9L4** plus 15m:

I9L152 = 1/(V9L2+15)

I9L154 = 1/(V9L4+15)

V9R2, V9R4, I9R152 and **I9R154** are the corresponding values for the visibility to the right. Units: metres.

Geographical location

LON indicates that the site is in the DOT Greater London Region.

Gradient:

GDN1 and **GDN3** are the average percentage gradients from 50m towards the junction on major arms 1 and 3 respectively, from the reference lines OA or OB (see Figures C1 to C3). They were measured using a clinometer. The gradient was defined to be positive if the road was uphill on the approach and negative if downhill.

Bus bays:

Y2E1 indicates the presence of a bus bay within 50m on the entry side of major arm 1.

Bus stops:

B1E2 indicates the presence of a bus stop within 25m on the entry side of minor arm 2.

Approach curvature:

C2D1, C2D2, C2D3 and **C2D4** indicate the presence of curvature within 50m on arms 1, 2, 3 or 4 respectively. **C2DMNR** indicates the presence of curvature within 50m on either arm 2 or arm 4. Observed on site or taken from a 1:500 plan.

Radius of entry corner:

RCC1, RCC2, RCC3 and **RCC4** are the radii of curvature of the entry corners on arms 1 to 4 respectively. **RCCMJR** is the mean radius of curvature on the entry corners of arms 1 and 3 respectively: **RCCMJR** = (RCC1+RCC3)/2. Measured from a 1:500 plan. Units: metres.

Stop-line:

GSL4 indicates the presence of a stop-line rather than a give-way line on minor arm 4.

Land-use:

UE1N2 indicates that the dominant land-use within 20m on the entry of arm 2 is residential.

VARIABLES USED IN THE ALTERNATIVE MODELS ONLY

Vehicle speeds:

Measured at 100m back from the give-way line on the minor arms and at the centre of the junction on the major arms. Only speeds of freely moving light vehicles (cars, taxis and light goods vehicles) were recorded. Speeds were measured during four 15 minute intervals: the morning peak (0730-0930); the morning off-peak period (1000-1200); the afternoon off-peak period (1400-1600); and the evening peak (1630-1830). Up to 40 vehicles were measured in each 15 minute period and mean **SMN1** to **SMN4** and standard deviation values calculated over all four periods for arms 1 to 4 respectively. The 85th percentile speeds **S851** to **S854** and the coefficients of variation of speed **COV1** to **COV4** were also calculated. The mean speed on the major **SMNMJR** and the corresponding coefficient of variation **COVMJR** were calculated:

SMNMJR = (SM1+SM3)/2

COVMJR = (COV1+COV3)/2

Units: miles/hour.

Vehicle parking:

The terms used in the models refer to parking regulations or to the number of vehicles that were parked or stationary. The number of vehicles which were parked within 100m was recorded for each arm once during each of four periods of the day as for speed measurements. The mean values were calculated over all four periods. **KEB1** and **KEB3** are the average number of vehicles parked within 100m on the entry side of major arms 1 and 3 respectively. **KXB1** and **KXB3** are the average number of vehicles parked within 100m on the exit side of major arms 1 and 3 respectively.

KBB1 = (KEB1+KXB1)/2

KBB3 = (KEB3+KXB3)/2

KBB5 = (KBB1+KBB3)/2

KXA1 and **KXA3** are the average numbers of parked vehicles within 20m on the exit side of arms 1 and 3 respectively. **KB2N5** indicates that parking is restricted within 20m on both the entry and exit sides of arms 1 and 3. **KE3N1** and **KE3N1** indicate that the least restrictive parking regulation is double yellow lines on the entry side of major arm 1 and 3 respectively. **KE3C2** and **KE3C4** indicate that the least restrictive parking regulation is double yellow lines on the entry corners of arm 2 and arm 4 respectively.

Driver/rider category:

PDS6 is the proportion of drivers who are senior females (over 60). Observed on minor arms of junction during four 15-minute intervals (as for vehicle speeds).

Vehicle queuing:

The maximum queue length on each arm was recorded at half-hour intervals throughout the day. Where there were two lanes at the entry, the sum of vehicles waiting in both lanes was recorded. **QUA1** to **QUA4** are the average maximum queues on arms 1 to 4 respectively. **QUM1** to **QUM4** are the overall maximum queues on arms 1 to 4 respectively.

Visibility from the minor arm:

V2L2 and **V4L2** are the visibilities to the left from arm 2 at 2m and 4m back from the give-way line, respectively. **I9L4** is the inverse of **V9L4**, the visibility to the left from arm 4 at 9m from the give-way line.

Private drives, side roads and public accesses:

DXL1 and **DXL3** are the number of private drives within 50m on the exit side of major arms 1 and 3 respectively.

AEF1 and **AEF3** are the number of public accesses from 50m to 100m on the entry sides of arm 1 and arm 3 respectively.

Gradient:

GDF1 and **GDF3** are the average percentage gradients from 100m to 50m on arms 1 and 3 respectively.

Approach curvature:

C1D3 indicates the presence of curvature within 25m on major arm 3. **C3D4** indicates the presence of curvature within 100m on minor arm 4.

Land-use:

UX6N3 indicates that the dominant land-use within 20m on the exit side of arm 3 is offices/industrial/educational/ public buildings/religious/petrol station/car park/other land use. **US8C1** indicates that the dominant land-use on the corner of arm 1 is shopping/recreational/public house.

Island width:

WIS1, WIS2, WIS3 and **WIS4** are the widths of island or central area (i.e. hatched area) on arms 1 to 4 respectively, measured on site. Units: metres.

Road width:

W2X2, W2X4 are the exit widths of minor arms 2 and 4 respectively, measured at 2m from the give-way line and parallel to it. **WPE1, WPE3** are the widths of the entry carriageway at 20m on arms 1 and 3 respectively, measured from reference line OA or OB (see Figures C1 to C3). Units: metres.

Guard rails:

GUSB5 indicates the presence of a guard rail on the arm 1 entry or arm 1 corner or arm 2 corner. **GUC2** indicates the presence of a guard rail on the entry corner of arm 2.

Bus bays:

Y1E1 indicates the presence of a bus bay within 25m on the entry side of major arm 1.

Hatching:

CHAJ indicates the presence of hatching within the central area of the junction.

Pedestrian crossing:

PZC1 and **PZC3** indicate the presence of either a zebra or a pelican crossing on major arm 1 or 3 respectively within 27.5m of the junction. **ZBB1** and **ZBB3** indicate the presence of a zebra crossing on major arms 1 and 3 respectively which is more than 27.5m from the junction (within 200m). **P2B1** and **P2B3** indicate the presence of a pelican or zebra crossing on major arms 1 and 3 respectively which is more than 27.5m from the junction (within 100m).

MORE INFORMATION

The Transport Research Laboratory has published the following other reports on this area of research:

SR582 The traffic capacity of major/minor priority junctions. KIMBER R M and R D COOMBE (1980). Price £10.

SR810 Geometric delay at non-signalised intersections.McDONALD M, HOUNSELL N B and R M KIMBER (1984). Price £10.

LR1120. Accidents at 4-arm roundabouts. MAYCOCK G and R D HALL (1984). Price Code C.

TRL184 Accidents at 3-arm priority junctions on urban single-carriageway roads. SUMMERSGILL I, KENNEDY Janet V and D BAYNES (1996). Price Code L.

TRL183 Non-junction accidents on urban single-carriageway roads. SUMMERSGILL I and R E LAYFIELD (1996). Price: please enquire.

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