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PEDESTRIAN AMENITY:

TESTING THE COVENTRY MODEL

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This report forms part of a contract placed with ITS by the Transport and Road Research Laboratory.

Contents

1. Introduction: Studies of Pedestiran Amenity

1.1 Study Objectives

1.1.1 Any new road, road improvement or traffic management scheme could affect pedestrian journeys in its locality or elsewhere. Some journeys may be affected directly, with severance caused where the new road or road improvement cuts across a pedestrian route, others may be affected indirectly with a new road causing changes in traffic levels elsewhere. To enable effects on pedestrians to be given proper weight when decisions are taken, techniques are required that forecast the effects of the scheme on the number and quality of pedestrian journeys. This is particularly true in urban areas, since effects on pedestrians may be one of the main benefits or disbenefits of measures to relieve urban traffic.

1.1.2 As a first stage of research in this area, TRRL placed a contract with The Institute for Transport Studies at the University of Leeds. The terms of reference were:

i) to review literature for currently available techniques and possible approaches and for any useful and general background information on:

   a) estimating numbers of pedestrian journeys
   b) assessing changes in pedestrian amenity;

ii) to make recommendations as to the best (if any) currently available techniques for (a) and (b) above, taking into account the availability of any data required as inputs to the techniques;

iii) if the literature review reveals that further work is necessary in these areas, either in the development or testing of existing methods, or in the development of new methods, to make detailed proposals to carry out the necessary research.

As well as the literature review (May et al, 1985) that study produced recommendations for further research (May, 1985). In 1986 TRRL commissioned the Institute for Transport Studies to conduct a research project based on those recommendations, whose detailed elements were designed to:

1) develop sampling procedures/expansion factors for pedestrian counts;
2) identify proportions of pedestrians by type;
3) test existing methods to predict pedestrian numbers and develop others if necessary;
4) develop dose-response relationships for overall nuisance and individual environmental effects;
5) explore evidence among residents of trip suppression and diversion in response to environmental conditions.

1.2 The Need for a Predictive Model

As one of the companion reports (Turvey et al, 1987) indicates, counting pedestrian numbers is a time consuming and relatively unreliable process. Pedestrian numbers are also likely to change in response to new developments, the introduction of pedestrian streets and the provision of new transport facilities. A model which could be used to predict pedestrian numbers with reasonable accuracy could avoid the need for expensive surveys, and overcome the problems of inability to count where changes were anticipated. However, such models need to be based on readily available, reliable and relevant data.

1.3 Study Reports

This report deals with item (3) above. Other reports based on this study provide an update to the original literature review (Turvey, 1987); a description of the survey design (Hopkinson et al, 1987a); and the results of work on items (1), (2), (4) and (5) above (Turvey et al, 1987, Hopkinson et al, 1987b, Hopkinson and May, 1987).

1.4 Study Method

The study method involved the selection of 15 centres, in five categories of three each. Of each set of three, one was to be set aside for validation purposes. The centres are listed in Table 1 and sketch plans of each location are included in Appendix 1. The procedures for site selection are described in Hopkinson et al (1987a).

The study programme involved the following fieldwork:

(1) manual classified counts of pedestrians;
(2) video data collection for pedestrian numbers and traffic flows;
(3) on-street pedestrian interviews;
(4) household interviews;
(5) noise and pollution monitoring;
(6) observation of site characteristics.

Of these items (1)-(3) and (6) were collected at all centres; items (4) and (5) were collected at two and three sites respectively as indicated in Table 1. This report uses primarily data from items (1), (2) and (6) above.

1.5 Report Outline

Chapter 2 describes the Coventry Model for predicting pedestrian numbers, on which this study is based. Chapter 3 outlines the data on which the Coventry Model was tested and alternative models were developed. Chapter 4 presents the results of tests of the Coventry Model in its original form. Chapter 5 indicates the results of tests of other model formulations. Chapter 6 presents conclusions from this study.

Table 1

Study Locations for On-Street Interviews and Pedestrian Counts

Type	Centre 1	Centre 2	Validation Centre
Large urban active	Manchester *	Aberdeen	Bristol
Large urban depressed	Lewisham *	Sheffield	Coventry
Small urban historic	Lanark **	Winchester	Guildford
Small urban other	Chesterfield	Kilmarnock	Epsom
District Centre	Hebden Bridge *	Twickenham	Hazel Grove **

* Pollution Studies ** Household Interviews

2. The Coventry Transportation Study Model (1973)

2.1 Basis of the Model

The Coventry Transportation Study (City of Coventry, 1973),included an attempt to determine numbers of pedestrians exposed to traffic conditions in different locations. Because of the costs involved in counting pedestrians, it attempted to develop models for predicting the numbers of pedestrians from readily obtainable land use and transport characteristics.

In our own work on counting and sampling procedures (Turvey et al, 1987) we have identified three types of pedestrian count:

i) pavement flow: pedestrians moving along the pavement per unit time;

ii) crossing flow: pedestrians crossing a given length of road per unit time;

iii) pavement concentration: pedestrians per unit area of pavement at a given instant.

The Coventry Model only produced relationships for the last two, but did so for different age groups. Our own work (Turvey et al, 1987, Table 20) has demonstrated that the proportions of pedestrians in different age groups in shopping streets are reasonably uniform across sites, and we have therefore concentrated, in this study, on estimating total pedestrian numbers.

The Coventry study suggested that it was impossible to predict pedestrian numbers in the Coventry CBD, due to the low correlation between numbers of pedestrians and land use variables, especially frontage shopping floor space. For district or suburban shopping centres the study revealed that the numbers of pedestrians present were highly predictable. This suggests that the Model might be expected to fit the smaller centres in our own study, more successfully than the larger ones.

2.2 The Pedestrian Concentration Model

The dependent variable which Coventry used was the average number of pedestrians on both pavements of a given street during specified times of day. This is equivalent to the average concentration for that time of day, multiplied by the street length and the sum of the two pavement widths. This assumes that concentrations on the two pavements are the same. It is necessary to use either real width and real concentration or effective width and effective concentration (see Turvey et al, 1987); either will give the same result.

The average numbers of pedestrians on pavements in streets were analysed by multiple regression against a number of variables:

(1) Net Retail Floorspace - convenience trades,
- durable goods trades,
- special attractors (supermarkets etc)

(2) Population within 440 yards of location
(3) Employment within 440 yards of location
(4) School places within 440 yards of location
(5) Employment within 100 yards of location
(6) School places within 100 yards of location
(7) Numbers of bus services stopping within location per hour
(8) Bus accessibility index (length of bus network within two miles radius connecting directly to the location)
(9) Weather conditions

While the retail parameter was defined as 'retail and service' it appears from later comments that only retail floorspace was used. The definition of area within which retail floorspace was measured is not clear; it appears to be that for the street in question alone. One additional variable included was an adjusted net retail and service floorspace parameter in which double weight was given to non-convenience shops in accordance with the findings of shopping models.

Table 2 presents the best predictive equations derived for each group of pedestrians for each time period where:

Peak Periods	=	Before 0930, 1530 - 1800
Off Peak Periods	=	0930 - 1530
Young Person	=	Under 12 years
Adult Person	=	12 - 60 years
Old Person	=	Over 60 years

The equations show that:

(1) shopping floorspace was the dominant explanatory variable;

(2) improved explanation was obtained by the adjustment of total floorspace to give greater weight to non-convenience shops;

(3) further improvements were achieved by the inclusion of a bus frequency variable; in the peak period, proximity to workplaces also has some significance.

In no case was the variable on the type of weather found to be significant (possibly reflecting the fact that during the survey no extremes of weather conditions occurred).

Overall, the results suggested that the number of persons in district shopping centres can be adequately predicted on the basis of total net retail and service floorspace. Separate predictions are valid for adult and old persons present on street, especially in the peak period where numbers of old persons tend to be low. In the off peak period numbers of young persons are low and often, out of term time, accompanied by adults. Correlations are poorer, particularly in the peak. The study recommends that the young be treated as part of the total number of persons present.

Table 2

Numbers on Footways: Best Predictive Equations from Coventry Model

Time Period	Age Group	Equation	Standard Error	R
Off Peak	Young	Y = 1.21 + 0.0036 TF	2.45	0.71
	Adult	A = 0.8 + 0.139 AF + 0.1907 Bus	7.34	0.88
		A = 0.6 + 0.159 TF + 0.227 Bus	7.48	0.88
		A = 2.52 + 0.18 TF	8.24	0.84
	Old	O = 0.00579 TF	2.88	0.82
	Total Persons	T = 1.48 + 0.025 TF + 0.263 Bus	11.50	0.87
		T = 3.7 + 0.027 TF		
Peak	Young	Y = 5.64 + 0.00465 TF	7.30	0.31
	Adult	A = 3.67 + 0.0126 AF + 0.237 Bus + 0.0013 E440	6.04	0.91
		A = 3.5 + 0.0143 TF + 0.272 Bus + 0.00113 E440	6.30	0.90
		A = 7.59 + 0.0168 TF	8.40	0.82
	Old	O = 0.61 + 0.0024 AF	1.80	0.74
		O = 0.64 + 0.0028 TF	1.85	0.72
	Total Persons	T = 11.16 + 0.02 TF + 0.32 Bus	13.10	0.80
		T = 13.87 + 0.0243 TF	14.00	0.77

where:

Y = Number of young persons) on both pavements of street,
A = Number of adults) averaged over time period of
O = Number of old persons) interest
T = Total number of persons)
TF = Total net retail floorspace) 'within location' assumed
AF = Adjusted net retail floorspace) to imply fronting street
Bus = Number of buses serving street
E440 = Number of jobs within 440 yards of street

2.3 The Crossing Flow Model

The dependent variable which Coventry used was the number crossing the road along the whole length of the street in a 10 minute period. The value predicted was an average for the time period under study.

Numbers crossing were tested by multiple regression against the same variables as used in the case of numbers on footways. The best predictive techniques are summarised in Table 3.

The same comments apply to these equations as for those for pavement concentration. The numbers of persons crossing proved highly predictable on the basis of retail floorspace. The only additional variable of any significance was in the case of the young, where the inclusion of school places within 440 yards provided an improved correlation. However, as with pavement concentrations the predictive power of the equations was lower for children and therefore it seems appropriate to limit prediction to adults, old persons and total persons (especially in the peak).

2.4 Conclusions

Provided that only total numbers are to be estimated, the only two parameters which contributed to the regressions were total retail floorspace and numbers of buses per hour. Equations for concentration are provided with and without the latter variable.

Table 3

Numbers Crossing: Best Predictive Equations from Coventry Model

Time Period	Age Group	Equation	Standard Error	R
Off Peak	Young	Y = 2.33 + 0.0049 TF	4.80	0.54
	Adult	A = 3.79 + 0.033 TF	15.74	0.83
	Old	O = 0.84 + 0.007 TF	4.75	0.72
	Total Persons	T = 7.4 + 0.0447 TF	21.90	0.83
Peak	Young	Y = 6.97 + 0.0063 TF + 0.028 S440	16.20	0.21
	Adult	A = 12.76 + 0.03 TF	14.30	0.83
	Old	O = 0.57 + 0.00356 TF	19.10	0.78
	Total Persons	T = 22.9 + 0.0398 TF	27.07	0.71

where:
- Y = number of young persons crossing for whole street per 10 minute period
- A = number of adults crossing for whole street per 10 minute period
- O = number of old persons crossing for whole street per 10 minute period
- T = total persons crossing for whole street per 10 minute period
- TF = total net retail floorspace fronting street
- S440 = number of school places within 440 yards of street

3. Data Sources and Values

3.1 Dependent Variables

As specified in the Coventry Model, two types of dependent variable were needed, average numbers of pedestrians on the pavements of the street, and average numbers crossing thoughout the length of the street in a 10 minute interval. These were derived from the count data reported in Turvey et al (1987).

Since that data was collected primarily for the period 0920-1650 it was used solely to test the off peak Coventry Model, which was derived for the period 0930-1530. Since the periods 0920-0930 and 1530-1650 have lower flows, the average values obtained for the period 0920-1650 will be slightly lower than those for 0930-1530, and can therefore be expected to be slightly over-estimated by the Coventry Model, which was derived for the latter time period.

The values for pedestrian concentration are taken from Table 33 of Turvey et al (1987), using the values for effective concentration. These need then to be multiplied by effective pavement width and by the length of street, and doubled to provide the total numbers on both pavements of the street. Street length was defined as in Hopkinson et al (1987a); the same definition was used for the land use data. These calculations are shown in Table 4.

The values for numbers crossing were derived from the total counts for the 0920-1650 period in Table 21 of Turvey et al (1987). These needed to be divided by 45 to give 10 minute average values and divided by the observation length and multiplied by street length to give totals for the street. To the extent that pedestrian crossing movements are concentrated on particular lengths of street this may be a somewhat approximate estimate. These calculations are also shown in Table 4.

While the Coventry Model did not attempt to predict pavement flows, it was decided to develop a model to do so. The dependent variable employed was pedestrian flow along the pavement per 10 minute period, averaged over the period 0920-1650. This data was taken from Table 21 of Turvey et al (1987), and is included in Table 4.

Finally, it was decided to use data for a standard 100 m length as well as data for the street as a whole. For this purpose average effective concentration was used, as already given in Table 4. Crossing flows were calculated per 100m of street. Pavement flows given in Table 4 were assumed to apply to the 100 m length.

3.2 Independent Variables

The Coventry Models for total numbers only require data on net retail floorspace and numbers of buses. However, it seemed likely that other variables might be needed to test alternative model forms. The additional variables considered in the Coventry study are listed in section 2.2. Of these, population, bus accessibility index and weather never contributed to the multiple regressions, and school places only contributed to the less successful regressions for young people, which are not being considered further here. It was therefore decided initially to seek information solely on retail floor area, employment and bus services.

Since 1973, most land use planning analysis has used gross rather than net retail floor area, and it was this which was sought. Its use in the Coventry Model may lead to an overestimate of pedestrian numbers. As noted earlier, floor area of service premises was omitted, following the definition understood to be used for the Coventry study. Data was sought both for premises fronting the street and for the centre as a whole. The former caused local authorities some problems, because land use data is not necessarily stored in this form, and some figures are therefore approximate. These are indicated in the data set in Table 5, as is the estimated floorspace per 100m of street.

Employment was specified as jobs within 440 yards of the street; the 100 yard catchment was found to be less useful in the Coventry study. Again this caused some problems for local authorities, and data is incomplete. Those available are noted in Table 5.

Bus flows could in many cases be determined directly from the video record; additional data was sought from local authorities to provide a check on the record.

In our proposal for the study, we also suggested the use of data on recreational facilities, restaurants, cultural facilities, parking facilities, pedestrian streets and covered shopping centres. The latter in particular are a feature which was virtually unknown in 1973. Most of these can be treated as dummy variables which indicate whether such a facility exists or not. At this stage it was decided not to trouble local authorities unduly by requesting further data.

The data which have been provided in this way are:

- (i) existence or otherwise of parking facilities within 100m of the street (PARK);
- (ii) existence or otherwise of a pedestrian street within 100m of the street (PEDS);
- (iii) existence or otherwise of a covered shopping centre fronting onto the street (SHPC);
- (iv) existence or otherwise of a protected pedestrian crossing facility in the street (PEDX);
- (v) existence or otherwise of a restaurant in the street (REST);
- (vi) existence or otherwise of a cinema, theatre or other entertainment facility in the street (CULT);
- (vii) existence or otherwise of an educational establishment in the street (EDUC).

Each of these was specified separately for the street as a whole and for the 100 m length in which observations occurred. It had been hoped to replace the parking variable by data on actual parking spaces, but several local authorities were unable to provide accurate data.

The final variable of this type tested was distance from a railway station. The parameter used was converted to a measure of proximity:

DIST	=	(2000-D)/2000	D < 2000 m
DIST	=	0	D > 2000 m

where D is the distance from the street to the station in metres.

One other variable which was readily available was population.

Table 5 indicates the values calculated for each of these variables.

3.3 Ease of Data Acquisition

While most of the variables listed in Table 5 were readily obtainable, considerable difficulty was experienced with the land use and employment data. Retail floor space data is often at least five years old, and varies in definition from authority to authority. Some include services and other non-retail floorspace; some include vacant floorspace. Employment data is often not readily available, and may well be aggregated to zones which are not wholly appropriate for a town centre study. Definition of either parameter at the level of the street or length of street presents further problems, since many authorities, and particularly the smaller ones, do not hold data in a form which permits ready disaggregation in this way. A further problem arises with new developments in which definition of the boundaries of a property fronting onto the street can present some difficulties. If retail floorspace data is found to be needed, care will be required to ensure that these problems can be overcome, and that the data has been recently updated.

<u>Table 4</u>

<u>Data for Dependent Variables</u>

	A	B	C	D	E	F	G	H	J
01 Chesterfield	2	35	200	0.107	85	8022	1015	305	89
02 Sheffield	5	50	275	0.059	162	13382	1634	267	845
03 Lanark	2.5	35	250	0.053	66	989	156	37	43
04 Hebden Bridge	2	35	150	0.055	33	281	26	11	32
05 Kilmarnock	2.5	20	750	0.117	439	2675	2242	178	100
06 Aberdeen	3	40	1200	0.140	1008	3083	2070	102	35
07 Lewisham	3.5	25	700	0.056	274	6034	3752	321	100
08 Epsom	1.5	45	225	0.102	69	3096	345	92	173
09 Winchester	2	30	175	0.040	28	2692	348	120	62
10 Guildford	3	25	75	0.167	75	14694	981	784	214
11 Twickenham	1.5	40	75	0.030	7	2915	124	97	44
12 Bristol	4	15	300	0.105	252	2913	1300	259	215
13 Manchester	2	10	500	0.140	280	1476	1650	197	200
14 Coventry	3	30	700	0.022	92	1911	1002	85	64
15 Hazel Grove	1.5	40	700	0.047	99	crossings not possible			60
	A	B	C	D	E	F	G	H	J

Key:
A = Effective Pavement Width (m)
B = Pavement Length from Study (m)
C = Total Road Length (m)
D = Average Effective Concentration (peds/m sq)
E = Numbers in Street
F = Crossings in Study Length 0920-1650
G = Total Street Crossings (peds/10 min)
H = Crossings per 100m (peds/10 min)
J = Pavement Flow (peds/10 min)

Notes:
C : estimated from maps
D : from Turvey et al (1987)
E : D x A x C x 2
F : from Turvey et al (1987)
G : F x C/(B x 45)
H : F x 100/(B x 45)
J : from Turvey et al (1987)

Table 5

Data Obtained on Independent Variables

Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14
01 Chesterfield	70000	4000	2000	5281	40	1/1	1/1	0/0	1/1	1/1	1/0	0/0	0.75	70
02 Sheffield	130000	14700	5345	N/A	162	1/0	1/1	1/1	0/0	1/1	1/1	0/0	0.60	477
03 Lanark	13069	7335	2934	N/A	27	0/0	0/0	0/0	1/1	0/0	0/0	0/0	0.80	10
04 Hebden Bridge	20000	1500	1000	N/A	10	0/0	0/0	0/0	1/1	0/0	0/0	1/1	0.70	11
05 Kilmarnock	76879	10713	10713	N/A	22	1/0	1/1	1/0	1/1	1/0	0/0	0/0	0.60	52
06 Aberdeen	263765	126992	39992	14000	143	1/0	1/0	1/1	1/1	1/1	1/0	1/0	0.80	200
07 Lewisham	99325	66825	9025	7500	119	1/1	0/0	1/1	1/1	1/0	0/0	0/0	0.60	232
08 Epsom	44680	30720	15720	5750	36	1/1	0/0	1/1	1/1	1/1	0/0	0/0	0.90	69
09 Winchester	24894	2250	750	N/A	25	1/0	1/1	1/1	1/1	1/1	0/0	0/0	0.80	30
10 Guildford	183654	22000	15000	N/A	52	0/0	1/1	1/1	0/0	1/1	0/0	0/0	0.80	57
11 Twickenham	40460	4250	4250	5250	30	0/0	0/0	0/0	1/0	1/1	0/0	0/0	0.70	32
12 Bristol	195079	52000	16000	N/A	102	1/0	1/1	0/0	0/0	1/1	0/0	0/0	0.25	388
13 Manchester	453897	10186	8186	48804	50	1/1	1/1	1/1	1/1	1/1	1/1	0/0	0.70	449
14 Coventry	146923	16069	10069	N/A	153	1/0	1/1	1/1	1/0	1/1	0/0	0/0	0.10	314
15 Hazel Grove	6611	6611	1611	N/A	35	0/0	0/0	0/0	1/0	0/0	0/0	0/0	0.25	42

Key:

1: RETC = Gross retail floor area in sq.m. for centre as a whole
2: RETS = Gross retail floor area in sq.m. fronting onto street
3: RETN = Gross retail floor area in sq.m. fronting onto 100m length
4: JOBS = Jobs within 400m of street
5: NBUS = Buses per hour using street
6: PARK = Parking space)
7: PEDS = Pedestrian street) Dummy variables; see text.
8: SHPC = Shopping centre) First value is for whole
9: PEDX = Pedestrian crossing) street; second is for
10:REST = Restaurant) 100m length
11:CULT = Cinema, Theatre)
12:EDUC = Education)
13:DIST = Proximity to railway station; see text.
14:POPN = Population of a town/city in thousands

4. Tests of the Coventry Model

4.1 Pavement Concentration

Table 6 indicates the average numbers of pedestrians in the street estimated using the Coventry Model. It is clear that the errors are extreme in both directions, but that in most cases the numbers are grossly overestimated.

4.2 Numbers Crossing

Table 7 provides similar information on numbers crossing the full street length in an average 10 minute period. Here the fit is slightly better, but the errors are still substantial.

It is clear generally that the Coventry Model is an extremely unreliable estimator of both pavement concentration and crossing flows.

Table 6

Pavement Concentration Observed and Estimated from the Coventry Model

Site		Pedestrians in Street Observed	Estimated	Error (%)
01	Chesterfield	85	112	+ 32
02	Sheffield	162	401	+ 148
03	Lanark	66	201	+ 205
04	Hebden Bridge	33	44	+ 33
05	Kilmarnock	439	293	- 33
06	Aberdeen	1008	354	- 65
07	Lewisham	274	1808	+ 560
08	Epsom	69	834	+ 1109
09	Winchester	28	64	+ 129
10	Guildford	75	598	+ 697
11	Twickenham	7	91	+ 1200
12	Bristol	252	1411	+ 660
13	Manchester	280	279	0
14	Coventry	92	438	+ 376
15	Hazel Grove	99	182	+ 84

Table 7

Numbers Crossing Observed and Estimated from the Coventry Model

Site		Pedestrians Crossing/10 min Observed	Estimated	Error (%)
01	Chesterfield	1015	182	- 82
02	Sheffield	1634	663	- 59
03	Lanark	156	334	+ 114
04	Hebden Bridge	26	74	+ 185
05	Kilmarnock	2242	485	- 78
06	Aberdeen	2070	585	- 72
07	Lewisham	3752	2983	- 20
08	Epsom	345	1377	+ 299
09	Winchester	348	108	- 69
10	Guildford	981	988	+ 1
11	Twickenham	124	152	+ 23
12	Bristol	1300	2327	+ 79
13	Manchester	1650	461	- 72
14	Coventry	1002	724	- 28

5. Alternative Models

5.1 Dependent Variables

In testing new models, it was decided to develop models for dependent variables for pavement flow, crossing flow and pavement concentration. The last two were determined both for the street as a whole and for the 100 m nearest to the observation point. This gave five dependent variables:-

PAVF : Pedestrian flow per 10 minutes averaged over the study period (column J of Table 4).

CRNO : Numbers crossing in whole street per 10 minutes averaged over the study period (column G of Table 4).

CROF : Crossing flow per 100 m length per 10 minutes averaged over the study period (column H of Table 4).

PEDN : Average number of pedestrians in whole street (column E of Table 4).

PAVC : Average effective pavement concentration (column D of Table 4).

However, early tests indicated that models to predict PEDN produced far lower correlations than those for PAVC, and PEDN was therefore abandoned as a dependent variable.

5.2 Models Tested

Each of these was regressed in turn against:

(i) the retail floor space in the centre (RETC) and the remaining variables (excluding RETS, RETN) in Table 5;

(ii) the retail floor space in the street, or in 100 m of street (RETS, RETN) as appropriate, and the remaining variables (excluding RETC) in Table 5.

Where dependent variables were expressed per 100 m of street, the appropriate values of the dummy variables were taken. After initial tests it was realised that variable JOBS could not be used because data was incomplete, and that variables REST, CULT, EDUC were closely correlated with size of centre and gave misleading results. These four variables were excluded from further tests.

These tests were initially conducted for the ten sites identified for this purpose (centres 1 and 2 in Table 1). The best model was then used to estimate the appropriate dependent variable for the five validation centres. This process highlighted the problems of using dummy variables. A final set of tests was conducted in which these were removed. The stepwise regression was then repeated for all 15 sites using the same independent variables as the best 10 site model.

5.3 Pavement Flow Models

Table 8 indicates the first three independent variables identified in a stepwise regression for each of the four data sets, for the ten sites, together with the resulting correlation coefficients. Existence of pedestrian crossings contributes to all equations, and floorspace to three. All correlations are high; the best, at 0.98, is for the 100 m street data and floorspace for the street. However, all equations are suspect in having high intercepts and high coefficients for dummy variables. This is exhibited in the test on the validation sites, for all of which the predicted values of PAVF, using equation (iv), are grossly in error. The equation for the 15 sites entering the same variables as for equation (iv) has a lower correlation at 0.74 and uses bus flow rather than floorspace. It again is suspect, with a large (in this case negative) intercept and a high dummy variable coefficient.

5.4 Crossing Flow Models

Table 9 provides similar results for crossing flow models. Bus flow contributes to three of the ten-site equations, as do proximity to a car park and existence of a pedestrian crossing facility. Correlations are slightly lower; the best is 0.87. Once again, all equations are suspect, with high intercepts and coefficients for dummy variables. This is again confirmed by the tests on the validation sites using equation (iv) which, while better than those for pavement flow, are still poor. The fifteen site regression equation entering the same variables as for equation (iv) demonstrates the same weakness and a much lower correlation.

5.5 Pavement Concentration Models

Table 10 presents similar results for pavement concentration models. Retail floor space contributes to all four ten-site models, and population and proximity to shopping centres to three of them. Correlations are lower again; that for the 100 m street data is substantially better than the others at 0.80. Tests for this equation on the validation sites provide estimates to within 10% at three of the five sites. The 15 site version of equation (iv) is, however, less convincing, with a negative coefficient for population.

5.6 Simple Three Parameter Models

All of the above models raised questions about the appropriateness of including several dummy variables. A final set of tests was conducted, for the type (iv) equations only (100 m street, street floorspace), in which only population, bus flow and floorspace (POPN, NBUS, RETN) were included. Tables 11-13 present the resulting models for ten sites, the ability of these to predict values at the validation sites, and the 15 site models.

For pavement flow the ten site model has a correlation of 0.76, but is negative in floorspace and has a large negative intercept. It gives a generally poor fit for the validation sites. The 15 site model is similar, but with a lower correlation.

Table 8

Pavement Flow Models

Equations : 10 Sites

(i) Whole street data; floorspace for centre

PAVF = - 374 PEDX + 2.8 NBUS - 143 PARK + 388
(r^2) (0.74) (0.90) (0.94)

(ii) Whole street data; floorspace for street

PAVF = - 706 PEDX + 0.0033 RETS + 86 PEDS + 710
(r^2) (0.74) (0.93) (0.95)

(iii) 100 m street data; floorspace for centre

PAVF = - 510 PEDX + 0.00036 RETC + 1.8 NBUS + 500
(r^2) (0.74) (0.89) (0.93)

(iv) 100 m street data; floorspace for street

PAVF = - 793 PEDX + 0.014 RETN + 3.7 DIST + 545
(r^2) (0.74) (0.97) (0.98)

Tests with Equation (iv)

	True PAVF	Modelled PAVF	% Errors
Bristol	215	770	+ 258
Coventry	64	686	+ 972
Guildford	214	755	+ 253
Epsom	173	- 25	- 114
Hazel Grove	60	569	+ 848

Equation: 15 sites

(iv) PAVF = 3.1 NBUS + 6.5 DIST + 221 PEDX - 278
(r^2) (0.44) (0.61) (0.74)

Key:

PAVF = pedestrian flow per 10 minutes averaged over the study period

For other parameters see Table 5.

Table 9

Crossing Flow Models

Equations : 10 Sites

(i) Whole street data; floorspace for centre

$$CRNO = 19.5\ NBUS - 94.8\ DIST + 2881\ PEDX - 4167$$

(r^2) (0.40) (0.56) (0.87)

(ii) Whole street data; floorspace for street

$$CRNO = -85.8\ DIST + 0.01\ RETS + 788\ PARK + 6741$$

(r^2) (0.40) (0.56) (0.84)

(iii) 100 m street data; floorspace for centre

$$CROF = -497\ PEDX + 137\ PARK + 1.07\ NBUS + 502$$

(r^2) (0.72) (0.81) (0.87)

(iv) 100 m street data; floorspace for street

$$CROF = -497\ PEDX + 137\ PARK + 1.07\ NBUS + 502$$

(r^2) (0.72) (0.81) (0.87)

Tests with Equation (iv)

	True CROF	Modelled CROF	% Errors
Bristol	259	611	136
Coventry	85	666	684
Guildford	784	558	- 29
Epsom	92	181	97
Hazel Grove	0	539	n.a.

Equation: 15 sites

(iv) $$CROF = 25.2\ NBUS + 50\ DIST - 1293\ PEDX - 333$$

(r^2) (0.31) (0.51) (0.66)

Key:

CRNO = Numbers crossing in whole street per 10 minutes
CROF = Crossing flow per 100 m length per 10 minutes averaged over study period

For other parameters see Table 5.

Table 10

Pavement Concentration Models

Equations: 10 sites

(i) Whole street data; floorspace for centre

1000 PAVC = - 2.05 SHPC + 0.0003 RECT - 0.067 PQPN8 + 62
(r^2) (0.56) (0.65) (0.68)

(ii) Whole street data; floorspace for street

1000 PAVC = 0.001 RETS + 67.5 PEDX - 3.9 SHPC + 4.0
(r^2) (0.17) (0.48) (0.61)

(iii) 100 m street data; floorspace for centre

1000 PAVC = 0.0002 RETC - 2.4 SHPC + 0.05 POPN + 57
(r^2) (0.55) (0.64) (0.66)

(iv) 100 m street data; floorspace for street

1000 PAVC = 0.09 POPN + 0.003 RETN + 27 PEDX + 27
(r^2) (0.42) (0.72) (0.80)

Tests with Equation (iv)

	True PAVC	Modelled PAVC	% Errors
Bristol	0.105	0.110	4
Coventry	0.022	0.085	186
Guildford	0.167	0.077	- 54
Epsom	0.102	0.106	4
Hazel Grove	0.047	0.051	9

Equation: 15 sites

(iv) 1000 PAVC = 0.0003 RETN - 0.121 POPN + 0.432 DIST + 34
(r^2) (0.38) (0.58) (0.63)

Key:

PAVC = pedestrians per sq.m. of effective pavement, averaged over whole study period

For other parameters see Table 5.

For crossing flow, the ten site model has a correlation of 0.80, but is negative in floorspace and has a high intercept. It gives a generally poor fit for the validation sites. The 15 site model is rather different in form, with a much lower correlation.

For pavement concentration, the ten site model has a correlation of 0.72, and is negative in bus flow. It produces a good fit for the validation sites, with four sites within ± 20% and three within ± 10%. Not surprisingly, the 15 site model is generally similar in form, with a correlation of 0.65.

Table 11

Simple Three Parameter Models

Pavement Flows

10 site equation

PAVF	=	0.03 NBUS	+	0.4 POPN	-	0.002 RETN	-	52
(r^2)		(0.71)		(0.76)		(0.76)		

Validation Tests

	True	Modelled	% Error
Bristol	215	74	- 66
Coventry	64	57	- 12
Guildford	214	- 59	- 128
Epsom	173	- 68	- 139
Hazel Grove	60	- 40	- 167

15 site equation

PAVF	=	68.7 NBUS	+	17.9 POPN	+	0.14 RETN	-	583
(r^2)		(0.43)		(0.47)		(0.48)		

Key:

PAVF = Pedestrian flow per 10 minutes averaged over study period

For other parameters see Table 5.

Table 12

Simple Three Parameter Models

Crossing Flow

10 site equation

CROF	=	0.3 POPN	+	2.9 NBUS	-	0.01 RETN	+ 76
(r^2)		(0.50)		(0.76)		(0.80)	

Validation Tests

	True CROF	Modelled CROF	% Error
Bristol	259	328	+ 27
Coventry	85	513	+ 504
Guildford	784	94	- 88
Epsom	92	44	- 52
Hazel Grove	0	174	n.a.

15 site equation

CROF	=	0.3 POPN	+	0.9 NBUS	-	0.0002 RETN	+ 115
(r^2)		(0.12)		(0.14)		(0.14)	

Key:

CROF = Crossing flow in 100 m of street per 10 minutes averaged over study period

For other parameters see Table 5.

Table 13

Simple Three Parameter Models

10 site equation

$$1000\ PAVC = 0.004\ RETN - 0.7\ NBUS + 0.17\ POPN + 60$$

(r^2)	(0.41)	(0.46)	(0.72)

Validation Tests

	True PAVC	Modelled PAVC	% Error
Bristol	0.105	0.098	- 7
Coventry	0.022	0.026	+ 18
Guildford	0.167	0.094	- 44
Epsom	0.102	0.110	+ 8
Hazel Grove	0.047	0.049	+ 4

15 site equation

$$1000\ PAVC = 0.005\ RETN - 0.7\ NBUS + 0.14\ POPN + 64$$

(r^2)	(0.38)	(0.53)	(0.65)

Key:

PAVC = Pedestrians per sq.m. of effective pavement, averaged over study period

For other parameters see Table 5.

6. Conclusions

6.1 The Coventry Transportation Study provided predictive models for numbers crossing the street in a 10 minute period, and average numbers of pedestrians on the street. In both cases a model based on retail floor area in the street was found to be the best predictor.

6.2 Both models were tested using data collected in the current studies, and found to be extremely poor predictors of pedestrian numbers.

6.3 The current study aimed to develop alternatives to the Coventry Models. Several dependent variables representing pavement flow, crossing flow and pavement concentration were tested against a range of possible explanatory variables based on retail floor space, population, public transport provision and adjacent pedestrian, parking and shopping facilities. Models developed for 10 sites were validated against the five validation sites; further models were developed for the full 15 sites.

6.4 While population data was readily available, problems arose in obtaining retail floor space data. Care was needed to ensure that definitions were consistent and data up to date. Data at the level of the individual street was often difficult to obtain. Similar problems arose with employment data, leading to its abandonment as a possible explanatory variable.

6.5 Apart from bus flow and distance from a station, the other variables were included solely as dummy variables. Most best fit models included one or more dummy variables with high coefficients, leading to inaccuracies in validation. Simpler models were therefore tested using the three parameters of population, retail floorspace and bus flow.

6.6 While the pavement flow models produced high correlations, validation was extremely poor. Similar results were obtained for crossing flow, although the validation results were slightly better. It has to be concluded that it is not yet possible to produce reliable predictive models for either of these variables. A wider range of sites and planning parameters will be required if such models are to be produced.

6.7 The pavement concentration models produced somewhat lower correlations, but much better validation results. Both the model including dummy variables and that without estimated concentration to within 10% at three of the sites. The model without dummy variables performed better at the other two sites, with errors of 18% and 44%; it also produced very similar 10 site and 15 site models.

6.8 The 15 site model for pedestrian concentration was:

$$1000\ PAVC = 0.005\ RETN - 0.7\ NBUS + 0.14\ POPN + 64$$

where:

PAVC = pedestrians per sq.m. of effective pavement, averaged and study period

RETN	=	floorspace in properties facing 100 m length of street
NBUS	=	average hourly bus flow
POPN	=	population of town or city

This model appears able to predict pavement concentration to within ± 20% at the majority of centres. However, it merits further testing, and it is clear that further work is needed on models for pavement flow and crossing flow.

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