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STUDIES OF PEDESTRIAN AMENITY

Report submitted to the Transport and Road Research Laboratory, Crowthorne, in partial fulfilment of a contract to Assess Current Literature Relating to the Pedestrian Environment.

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A B S T R A C T

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This report, produced for the Transport and Road Research Laboratory, summarises the results of an extensive literature search in two areas of pedestrian research:

(1) Estimating the Number of Pedestrian Journeys
(2) Pedestrian Amenity

The report identifies gaps in current knowledge from the revealed literature and makes recommendations for best practice. Research proposals are made, to help alleviate such revealed gaps, in a companion report.

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1. INTRODUCTION

1.1 Terms of Reference

In October 1984, the Institute for Transport Studies, at the University of Leeds, was awarded a contract by the Transport and Road Research Laboratory, Crowthorne, to undertake a review of current literature on the estimating of pedestrian numbers and on pedestrian amenity. The terms of reference of that contract were to:-

i) Review literature for currently available techniques and possible approaches and for any useful data and general background information on:-

   a) Estimating numbers of pedestrian journeys
   b) Assessing changes in pedestrian amenity.

ii) 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) Identify gaps in the current knowledge and make research proposals to fill such gaps, either in the area of development or testing of existing methods, or in the development of new methods.

This report covers the first two of these requirements; research recommendations will be contained in a companion report.

1.2 General Background

Walking is an extremely important mode of travel. If one counts all trips made by all people in the UK then trips wholly on foot represent more than 40% of the total (Rigby, 1977). The majority of walk trips are less than 1 km in length (Scott Rutherford, 1976) and as a result walking represents only about 9% of total person kms. Even so this is about 65% of the total distance travelled by bus (Skelton, 1982). Todd (1980) revealed that 98% of the population can go out on foot and on an average day 70% do. However, the reliance of other modes of travel on walking is shown by Hillman (1979) who found that 65% of all walk trips where the total distance travelled was greater than 50 meters, involved the use of another mode. For journeys of over 2 miles then only 2% were recorded as walk only trips.

Skelton (1982) argues that whilst considerations of vehicular traffic and vehicle congestion and delay are uppermost in traffic engineers' and planners' minds, pedestrian issues are rarely considered. She suggests three reasons for this:-

   i) Walking is regarded as a very low status mode of travel;

ii) Policy and practical decisions relate to the accommodation of traffic on the road network and are influenced by transport professionals (who tend to be very mobile, yet walk little);
iii) There is inertia in the current system of evaluation which favours the continuation of the status quo.

1.3 The Requirements for the Appraisal of Pedestrian Issues

Given the scale of pedestrian movement, it is important that transport planners, in seeking solutions to transport problems, should pay due regard to the problems faced by pedestrians. In addition they need to bear in mind the effects on pedestrians of policies designed to solve other problems. These considerations were reflected in the brief for this study, which noted that 'any new road, road improvement or traffic management scheme could affect pedestrian journeys in its locality or elsewhere'. The key inputs to the development of policy for the pedestrian and the assessment of pedestrian issues are

(i) an estimate of the numbers of pedestrians in the area of interest,
(ii) a knowledge of the problems which those pedestrians face, and
(iii) an ability to predict the extent to which proposed policy actions will relieve those problems or create new ones.

It is these issues, grouped together under the two headings of pedestrian numbers and pedestrian amenity, on which this report focuses. Given the emphasis in the brief, it concentrates on the effects of road construction and traffic management, but many of its findings are of more general relevance.

1.4 Past Reviews

Few attempts have been made to draw together current knowledge relating to transport issues and the pedestrian environment. In particular only two reports address both the issues of forecasting pedestrian travel and assessing pedestrian amenity. In 1972 the Institute for Transport Studies (Copley, 1972) sought to consider pedestrian movements in urban centres segregated into 3 inter-related subject areas:

1. Environmental aspects
2. Flow/concentration relationships, capacity and level of service
3. Pedestrian travel demand.

The study found that only the latter area had not been addressed to any great degree before. After reviewing current literature, the study concluded that it would be highly desirable to attempt to make forecasts of pedestrian travel demand based on a mathematical model. To this end the Institute for Transport Studies initiated survey, analysis and modelling exercises of pedestrian movements in Central Liverpool over the next four years (Copley, 1972).

The results of the ITS surveys were recorded in 1976 in what is certainly the most comprehensive appraisal of pedestrian issues in recent years, carried out by Transport and Environment Studies (TEST). Their report, entitled 'Improving the Pedestrian Environment' comprised 4 volumes of literature review, case studies and principal findings.

The study itself was commissioned by DoE to answer seven basic questions:

1) What do pedestrians do?
2) What number and types of trips do they make?
3) What are the characteristics of pedestrian trips?
4) How do trip characteristics vary with age, sex, socio-economic status etc.?
5) What are the needs of pedestrians?
6) What problems are faced by pedestrians?
7) What constitutes a good environment for pedestrians?

Eight specific data requirements were then sought to answer the questions above:

1) Speed/flow relationships
2) Numbers of pedestrians on pavements
3) Numbers of pedestrians crossing roads
4) Accident risk
5) Trip length and type
6) Inhibitions inflicted upon pedestrian behaviour
7) Catchment area
8) Severance index.

To meet these requirements a 3-stage exercise was planned:

1) An extensive literature search, to assimilate existing knowledge, review the content and identify shortcomings.

2) Five case studies exploring pedestrian behaviour problems and needs in different land use situations were planned
   i) A shopping street (Kentish Town)
   ii) A central area (Birmingham)
   iii) An area surrounding a major bus or railway station (Leeds)
   iv) An industrial estate (Slough)
   v) A residential area (Brockley)

3) A report stage drawing together the two previous strands of work and then attempting to:

   i) Evaluate the priorities and environmental needs of pedestrians;
   ii) Discuss the extent to which the case study situations were appropriate to the needs in (i);

iii) Identify the degree of suppression or diversion of existing potential pedestrian movement.

In the event time did not permit all of the case studies and only those in Kentish Town and Birmingham proceeded, together with similar work in the Putney area of Greater London.

The literature review outlined 6 subject areas:

1. Pedestrian activity
2. Accidents and road crossing behaviour
3. Pedestrian perception
4. The walking environment
5. Trip suppression and severance
6. Legislation and the pedestrian

The detailed findings under (1) and part of (2) are summarised in the present review of prediction and estimation of pedestrian numbers. Those for the remainder of (2) and sections (3) to (5) are covered in the present review of amenity issues. Section (6) is not relevant to the present review.

The TEST study concluded that in no area of pedestrian research could it be said that all was known. The exploratory nature of the project highlighted the need for further work in the following areas:

1) Accident prediction studies
   Data were often collected in insufficient detail and derived from too small a range of streets for use in accident prediction studies.

2) Speed flow relationships
   Further work was required in relation to crowding standards on footways.

3) Catchment area
   TEST identified a relationship between the catchment area of a particular shopping area and the role of walking as a mode of travel to it. Further work was deemed necessary however to test the transferability of the relationship to other areas.

4) Modelling pedestrian activity
   Previous models had been of two types:
   i) Models for predicting particular aspects of pedestrian behaviour e.g. volumes on footways or crossing roads;
   ii) Predictive models of network-wide travel demand. The study concluded that network-wide models were demanding in both data collection and computation and due to their apparent non-transferability and ignorance of behavioural issues, were of questionable value in most town or urban centres. Simpler models, relating numbers of pedestrians on footways to planning parameters were considered adequate for most central

area planning purposes, especially if enhanced by individual site studies e.g. at crossing points and termini.

5) Environmental index
Further development of a pedestrian environmental index was deemed useful specifically to help explain severance. TEST found that there was some evidence that pedestrians perceived main roads as neighbourhood boundaries. Further research was suggested to identify to what extent pedestrians crossed these boundaries or modified their behaviour because of them, and the environmental factors which led to these actions.

As will be seen in subsequent chapters of this report, little work has been done in most of these areas since TEST reported.

1.5 The Approach Adopted in the Present Study

Given the comprehensive approach adopted in the TEST study, we have concentrated our review on references appearing since 1976. Where these have in turn referred to material not covered by TEST we have reviewed those references. Otherwise we have based our review of pre-1976 material directly on TEST's. In seeking references, we have adopted three main approaches:-

i) The use of the IRRD abstracts catalogue and the Social Science Citation Index (SSCI)
ii) A search through all appropriate journals in the fields of
    1) Traffic engineering and control
    2) Accident analysis and prevention
    3) Transportation planning and technology
    4) Ergonomics
    5) Psychology and behaviour
    6) Environment
iii) A listing of references cited in articles identified under (i) and (ii) above.

In this way we were able to identify a total of 330 relevant references, all of which, with the exception of one or two theses which arrived too late to be studied, have been scanned. The listing at the end of this report includes all those references, and indicates those which have been referred to later in this report. Within the duration of the Study we were also able to review the procedures adopted in Greater Manchester County, with whom ITS has close links. This enabled us to gain some insight into the way that local authorities treat pedestrian issues.

1.6 Structure of the Report

The following chapters deal in turn with:

i) a discussion of the uses to which data on pedestrian numbers and amenity may be put, and the requirements which they impose (chapter 2);

ii) the review of recent literature on the estimation of pedestrian numbers (chapter 3);

iii) the review of recent literature on pedestrian amenity (chapter 4) and factors influencing pedestrian behaviour (chapter 5);

iv) a set of recommendations for best practice (chapter 6);

v) a summary of the main gaps in current knowledge, proposals for overcoming which are included in the companion report (chapter 7);

vi) the references (chapter 8).

2. USES OF DATA

2.1 General requirements

The process of policy formulation may be considered as involving the following stages:-

i) problem definition and identification;
ii) scheme development and design;
iii) assessment (modelling) of the effects of schemes;
iv) evaluation (appraisal) of modelled or implemented schemes.

At any of these stages it will be necessary to determine the numbers of pedestrians exposed to traffic or infrastructure-related problems, and the scale of, or change in, these problems.

The next two subsections describe briefly the ways in which such issues are currently incorporated into the policy formulation process at central and local government level. The final part of this section outlines the requirements which these uses of pedestrian data impose.

2.2 Central government requirements

The DTp's current approach to policy formulation with regard to trunk road schemes is based to a large extent on the recommendations of the reports of the Advisory Committee on Trunk Road Assessment (HMSO, 1977) and its successor the Standing Advisory Committee (HMSO, 1979). These reports developed the concept of an evaluation framework (the 'Leitch' framework) in which the effects of each of a number of options on a series of impact groups is identified. They suggest that the framework would be of use at the design stage in providing a checklist of design considerations and in alerting the designer to potential problems. The framework was, however, mainly orientated towards the assessment and evaluation stages, and particularly towards the requirements of public consultation and the public inquiry procedure. Interestingly neither report discussed the need for appraisal techniques to facilitate problem identification or ranking.

The most detailed guidance on the treatment of pedestrians in the framework is provided by the Manual of Environmental Appraisal (DTp., 1983). Part B, Section 9 includes advice on determining numbers of pedestrians. It is suggested that the main pedestrian routes crossing the proposed road and on roads likely to experience a doubling or halving of total traffic or of HGV flows be identified. Numbers of pedestrians directly affected on these roads can then be determined by spot counts or moving observer methods as outlined in section 3 of this report. Pedestrians affected as users of adjacent facilities (i.e. those within 300m of the new road or of roads on which flow will be doubled or halved) are obtained from information on membership and usage of those facilities. No guidance is given on the need to identify separately different types of pedestrian.

The impacts on pedestrians are identified in three broad groups; pedestrians as travellers are considered in terms of accidents, amenity and severance (but not travel time); pedestrians as users of facilities are considered in terms of vehicle/pedestrian conflict and, indirectly, severance. Impacts on policies for pedestrianisation and hence on pedestrians generally are considered separately. Part B, Sections 4 and 9 describe the treatment of these impacts in more detail. Section 4 considers the separate problem of severance, and suggests a series of thresholds in terms of types of crossing facility and increases in journey length (for both pedestrian and car journeys) which are set out in section 5 of this report. It notes, however, that the direct impacts in terms of journeys foregone are extremely difficult to ascertain, not least because they will affect different individuals, and particularly the young and elderly, in very different ways. For this reason it limits itself to providing broad descriptions of the scale of the problem and indications of numbers affected.

Section 9 considers amenity, and suggests that the most appropriate indicators are traffic flow, composition, pavement width and separation from traffic. In the absence of more detailed relationships, it suggests that adequate proxies for significant changes in amenity are a halving or doubling in traffic or HGV flows and an increase of 10m or more in the separation between pedestrians and traffic.

Traditionally, most trunk road schemes have been in rural areas, and the DTp's appraisal procedures have reflected this. With the impending change in local government responsibilities in the conurbations, the DTp has seen the need to extend its appraisal methods to reflect the issues which arise in urban areas. To this end it has asked SACTRA to recommend desirable and practicable improvements in methods for assessing options for the strategic improvement of urban roads with particular reference to the economic and environmental appraisal of a range of options from traffic management to major road construction. SACTRA in turn has sought comments from interested professionals. In our own report to SACTRA we argue that the DTp's appraisal framework should be used for problem identification as well as for scheme design and evaluation. Specifically on pedestrian issues, we highlight the need to incorporate changes in pedestrians' travel time, to develop techniques for estimating changes in pedestrian travel, to broaden the definition of amenity to identify explicitly the range of problems which pedestrians perceive, and to discriminate between the impacts on different groups of pedestrians.

2.3 Local government requirements

Inevitably, local government procedures for treating pedestrian issues vary widely. We have, however, been able during the course of this study to review the procedures adopted by one authority, Greater Manchester County, with whom we are associated in a separate study of the environmental appraisal of rail projects for British Rail. We have also drawn on our knowledge of a series of unpublished local authority highway scheme appraisal methods (Scotland, 1982) and on two published environmental evaluation methods developed by the GLC (Cohen, 1976) and West Yorkshire (Headicar, 1978) to provide guidance on the ways in which other local authorities incorporate pedestrian issues into their evaluations.

Many local authorities, both in the conurbations and the shires, have developed highway scheme appraisal techniques, usually based on the allocation of points for differing degrees of achievement of specified objectives (Scotland, 1982). Most of these methods were originally introduced to help in rationalising the long lists of highway schemes inherited by the new authorities in 1974. They were thus used initially for comparing schemes in different locations to solve different problems, as opposed to the DTp procedures, which are used to compare options for one scheme. However, some local authorities have since extended their use of these techniques to the comparative assessment of problems, and the comparison of alternative options. (Kent C.C., Surveyor, 1984)

While such methods are now widely used for broad highway scheme evaluation, they are generally considered inappropriate for providing a checklist of detailed design issues, or for detailed evaluation for public consultation, public inquiry and final decision-making requirements. Some authorities have developed more detailed environmental evaluation procedures to meet these needs, and have included pedestrian issues in them. These latter techniques have on occasion been used for assessing traffic management, traffic restraint and public transport improvement policies, although there is, interestingly, little evidence of their use to evaluate pedestrian street measures.

Some of the highway scheme appraisal techniques (notably those developed by South Yorkshire and Greater Manchester) require information on numbers of pedestrians, while others apparently assess the impact of pedestrian issues independently of the numbers affected. Greater Manchester mounted a detailed programme of count surveys for the purpose in 1976; their surveys at 43 centres used a combination of 10 minute samples and full counts between 10.00 and 16.30, but these have not since been updated. Of the two detailed environmental evaluation methods, the GLC's concentrates solely on building occupants in identifying the population affected, while West Yorkshire's estimates the numbers of pedestrians and uses the product of these and the severity of the problems to which they are exposed as an input to the aggregate disturbance index. Generally these estimates are obtained from a set of simple predictive equations (Headicar, 1979) derived from the 1973 Coventry Transportation Study, but in applying the method, direct counts were made in all major centres. None of the procedures appears to distinguish between types of pedestrian or to suggest a level of accuracy to which data are required and few of them specify clearly the area over which counts are required.

The methods also differ in the issues which they consider under the general heading of pedestrian amenity. Most specifically quantify pedestrian delay and changes in journey time. South Yorkshire's highway scheme appraisal includes consideration of footway standards, and West Yorkshire's the opportunity for formation of pedestrian streets. Greater Manchester used pedestrian delay and the logarithm of traffic flow as indicators of problem severity. The GLC's environmental evaluation only considers pedestrian delay (and weights it in terms of numbers of building occupants). West Yorkshire's assesses noise, smoke, carbon monoxide and visual intrusion as well, though the report notes that the pollution elements are rarely significant.

The only detailed evaluation of measures specifically for pedestrians revealed in this review was that for the major pedestrian street programme in Greater Manchester. Here there was little evidence of the schemes themselves being designed on the basis of detailed pedestrian surveys; however, after implementation a series of attitude surveys was conducted to identify changes in perception of noise, safety, appearance, crowding and accessibility.

This brief review of those local authority procedures known to us indicates that:

i) there is more emphasis on problem identification and ranking, but that this has typically been based on a one-off major survey;

ii) there is little guidance on the detailed requirements for estimating pedestrian numbers;

iii) there is considerable diversity in the lists of issues considered in assessing amenity;

iv) much of the consideration of pedestrians in design and evaluation is still left to officer judgement rather than formalised in specified procedures.

It is accepted that because of the lack of published material, this summary may be incomplete, and it is suggested that a further review may be merited.

2.4 Data requirements

The current procedures outlined above suggest a number of requirements for the data on pedestrian numbers and pedestrian amenity, only a few of which are adequately specified in those procedures. The issues which appear to us to be of importance, and to which we return in the following sections are:-

i) How should the area of interest for pedestrian effects be defined? The MEA suggests identifying the main pedestrian routes crossing the scheme, streets which both have a significant number of pedestrians and will experience a doubling or halving in flow and catchment areas within 300m of those streets. It is not clear, however, how 'significant' should be defined, or whether doubling and halving in flow represent satisfactory amenity thresholds. In urban areas, it is quite likely that a large area would be included by such definitions and it may be appropriate then to take sample locations from within that area.

ii) Over what time periods should pedestrian numbers and amenity effects be studied? The current DTp procedures concentrate on a 16hr day, and few local authority procedures are specific as to the appropriate time period. It seems likely that, in urban areas at least, different assessments will be justified for peak periods, when traffic flows are higher and pedestrians are more likely to be in a hurry, and the off peak, when more pedestrian shoppers will be on the streets.

iii) Which types of pedestrian, if any, should be separately identified? All current appraisal procedures treat all pedestrians as equal, yet it seems likely that their requirements will differ. Is it necessary, for example, to identify commuter pedestrians and shopper pedestrians separately to take account of differences in concern over delay and amenity? Should elderly and child pedestrians be separately identified, given their differing road crossing behaviour and accident propensity?

iv) Is it necessary to count pedestrians, or can their numbers be predicted, and to what level of accuracy is either required? Virtually all current procedures require pedestrians to be counted, yet it may be that simple predictive models would provide a more cost-effective approach. No procedure gives any guidance on the level of accuracy to which numbers are required, yet this is likely to influence substantially the costs of data acquisition or prediction.

v) How should amenity be defined for pedestrian appraised purposes? Some procedures include a list of environmental factors, but the lists often differ, and it would be unreasonable to attempt to cover all the factors listed. Which is the most appropriate shortlist? Or can all these factors be subsumed in a simple traffic flow related proxy of the kind used by DTp?

vi) At what levels do these factors have important influences on the pedestrian? The individual factors can have a wide range of effects on the pedestrian from annoyance to trip suppression. Are there clearly defined thresholds above which these effects occur? Should these thresholds be expressed in absolute terms, or on the basis of a percentage change? Can all the thresholds be related back to traffic flows, and hence simplify the analysis?

3. ESTIMATING THE NUMBERS OF PEDESTRIAN JOURNEYS

3.1 Data Requirements

Estimates of the numbers of pedestrians using, or crossing, specific lengths of street are required for problem identification and scheme assessment purposes. As noted in Section 2.4, the data may be needed for a range of locations, for different times of day and for different types of pedestrian. Some guidance will also be required on the accuracy with which pedestrian numbers can be estimated.

While counting is the most obvious method of data acquisition, it may be that predictive methods will produce adequate answers at lower cost. Subsection 3.2 reviews counting techniques, and 3.3 those for prediction.

3.2 Counting Pedestrian Numbers

The Manual of Environmental Appraisal (DTp, 1983) sets out three basic methods for the direct counting of pedestrian flows:

1) Film-based Spot Counts.
2) The Moving Observer Method.
3) Manual Spot Counts.

The method to be adopted, according to the manual, depends on the size of the survey and the availabiity of equipment rather than on any inherent superiority of one particular method. However, unless behavioural inputs are required to evaluation frameworks, the third method appears to be the most popular in terms of frequency of use revealed in the literature.

1) Film-based Spot Counts

In the UK a 1973 study of environmental issues (Coventry Transportation Study, 1973) evaluated survey techniques for use in estimating the numbers of pedestrians on street. Time lapse photography was considered with the camera to be mounted on a specially adapted bus for scanning the pavement as the bus was driven along the carriageway. The method was rejected for the following reasons:

1) Difficulties in providing suitable vantage points for the camera;
2) Analysis from photographs proved extremely time consuming, laborious and costly;
3) The view of the street observation was obscured from time to time;
4) There were difficulties in classifying pedestrians by age group from photographs.

Several studies have concluded however, that the time-lapse/video approach does have uses if a permanent record on film is required or if pedestrian behaviour needs to be studied. (Barnsley M.C. (1976), Fairhead (1975), Jamieson Mackay (1984)).

TEST (1976) used time lapse photography to provide a complete behavioural record of a limited section of street thus allowing repeated extraction of data. Again, however, problems of camera location and the time involved in analysis proved considerable. However, in analysing pedestrian delay, time lapse film provided the best results but at a high cost financially.

Jamieson Mackay (1984) utilised the time lapse approach to investigate behaviour of pedestrians at a number of sites in Cambridgeshire and Berkshire. The 2 hour duration films (15 in total) were selected to cover various aspects of behaviour including entry and exit, overtaking and junction negotiation as well as in an attempt to judge subjectively footway capacity. No attempt was made to quantify this capacity. The method offered the opportunity to replay incidents at slow speed and thereby analyse behaviour in some detail.

Fairhead (1975) used time lapse photography to observe changes, over successive years, in pedestrian flows along selected lengths of the footways of Oxford Street, London. He records no significant change between 1972 and 1973 but no details are given of the actual methodology used. Khisty (1982) also found photography of use in examining walkway cross flows but was able to have good visibility from the camera mounting position and only required to view corridors at schools where filming could be concentrated on periods of high activity.

2) <u>The Moving Observer Method</u>

In this the observer traverses a unit distance (say 100m) in one direction, counting every person he/she passes (in whatever direction they are travelling) and deducts the number of people overtaking. The count is then repeated in the opposite direction over the same stretch of road. The pedestrian density (in pedestrians per unit distance) is given by the mean of the two values.

The Coventry Transportation Study (1973) utilised this approach for counting the number of persons on the footway. The observer walked at an even pace along a footway using a three-bank tally counter (for young (<12), adult and old (>65) persons). No indication was given of the basis for making this classification and no classification by journey purpose was possible. 105 sites were observed in this manner and it was found that at a few locations there were so few pedestrians present that it was possible for the observer to stand at one point and take an instantaneous count of all persons present. In all cases the observation period was 10 minutes.

3) <u>Manual Spot Counts</u>

When counts of pedestrians are made from one particular fixed location, e.g. for crossing manoeuvres, it has been found that the use of tally counters and stop watches proved more effective than a photographic method (Barnsley MC, 1976). Again the

Coventry study, using manual counts for crossing manoeuvres, used a crude breakdown of person types by age, but did not specify how the observer judged age. 10 minutes appears to be the length of count which is most commonly used predominantly for the reason that this allows for a 10 minute period one way count at a site with a 5 minute break followed by a count for the other crossing direction or at another site, within a half hour time period. This keeps the observer interested and alert and so helps reduce error in data collection. Although enforced observer errors may invalidate results, TEST (1976) found that manual observation of pedestrian traffic flows, despite being costly on manpower, was an attractive method because of the reduced need for further analysis.

For both the moving observer method and for static counts the main determinant for pedestrian surveys appears to be the funding and resources available at any one point in time (Coventry, 1973). To this end recent developments in the production of portable event recorders (Polus, 1978; Green, 1979) may reduce the cost of data collection and increase the reliability, as well as providing a more permanent record.

In Barnsley (1976) it was estimated that due to staffing restrictions less than 0.5% of those crossing roads in the centre during the survey period were recorded. It was thought that a 1% sample would be more suitable and could possibly be achieved by use of a stratified sample of counts at a number of central area sites in the off peak period, supported by further counts in the peak. Counting was thought to be a simple technique and it was considered that a person could adequately handle pedestrian flows of 300-400 persons per hour (in 3 person groups).

3.3. Predicting Pedestrian Numbers

The prediction of pedestrian traffic has been approached in a number of ways. The literature indicates 3 approaches:

(1) A trip rate approach which seeks to identify the number of pedestrian movements at a point in time and at a particular location.
(2) Models which relate to transport planning and involve some element of trip generation, attraction, distribution and assignment for a time period.
(3) Crossing studies.

3.3.1 Trip rate approach

Although only a limited number of studies have attempted to determine pedestrian numbers, much research was carried out in the central area of Manhattan, USA by Pushkarev and Zupan (1971). The technique of regression analysis was used to establish a relation between pedestrian density and the following independent variables:

- walkways)
- office space)
- retail stores) floorspace (ft^2)
- restaurants)
- proximity to the nearest transportation terminus

Regression equations were developed to predict the number of pedestrians per block, at mid day and evening peaks as well as for central and suburban areas.

The work on the Manhattan road grid was well supported by Garbrecht (1969, 1970) who considered the theoretical implications of modelling pedestrian movements on a rectangular grid form of network and the earlier work of Oeding (1963), which showed that trip purpose affects walking speed as motivation varies depending on the type of trip.

Using the independent variables (above) Pushkarev formed a regression equation for each time period.

<u>For example</u>:

Streets midday:

$$p = 3.12 \text{ walkway} + 0.06 \text{ office} + 0.12 \text{ retail} + 0.74 \text{ restaurant} - 4.01 \qquad (R^2 = 0.61)$$

Streets evening:

$$p = 3.17 \text{ walkway} + 0.04 \text{ office} + D + 2.17 \qquad (R^2 = 0.52)$$

where:

1. p = number of pedestrians at an instant in time on the sidewalks of a particular specified sub-area (ft^2)
2. walkway = sidewalk area of sub area (1000's ft^2)
3. office, retail, restaurant = gross floor space of property in the sub area (1000's ft^2)
4. D = distance (100's ft) from centroid of nearest terminus.

Further equations looked at midday and evening estimates for avenues as opposed to streets in Manhattan but R^2 values are poorer at 0.36 and 0.23 respectively. They drew a distinction between business and residential conditions, but did not present separate relationships for them.

They also deduced that at midday retail uses attracted 2 to 7 times as many pedestrian trips as offices and that restaurants attracted up to 25 times the trips that offices did.

The model thus developed was of particular application to Manhattan and not intended as a general model to be applied in any central area.

Behnam (1977) aimed to develop a simple quantitative model that could be used for predicting pedestrian volume from land use data in the central core of the CBD of Milwaukee, USA. The study design placed a special emphasis on the selection of variables that could be quantified and obtained without difficulty from the existing data bank of a city. The following variables were chosen (with all the units being m^2), for the central core of the city. Each block was classified in terms of the land use at the mid block location.

1)	Commercial space (retail, restaurants etc)	[X1]
2)	Office space (offices, banks etc)	[X2]
3)	Cultural and entertainment space (parks, museums, theatres etc.)	[X3]
4)	Manufacturing space	[X4]
5)	Residential space	[X5]
6)	Parking space (multi-storey, surface parking)	[X6]
7)	Vacant space (all space not in 1-6)	[X7]
9)	Storage space/maintenance space	[X8]

A stepwise regression technique was used to discriminate and enter into the model the most significant land use variables that influenced the pedestrian volume. Several potential models were applied to the data before the final models were selected. Peak hour (noon) pedestrian flow per hour on a given street in the central core was described by:

$$Y = 5.128 + 0.000\,004\,03\,(X1) + 0.000\,001\,99\,(X2) + 0.053\,8\,\mathrm{LN}\,(X3) + 0.056\,\mathrm{LN}\,(X7) + 0.039\,8\,\mathrm{LN}\,(X8)$$

$(R^2 = 0.74)$

Average pedestrian flow per hour for a given street in the central core was given by:

$$Y = 5.159 + 0.000\,003\,57\,(X1) + 0.000\,001\,90\,(X2) + 0.032\,2\,\mathrm{LN}\,(X3) + 0.034\,2\,\mathrm{LN}\,(X5) + 0.038\,2\,\mathrm{LN}\,(X7) + 0.035\,9\,\mathrm{LN}\,(X8)$$

$(R^2 = 0.76)$

Notes:

(1) The coefficient of multiple determination showed that approximately 60% of the variation in pedestrian volume is explained by land use variables.

(2) X4 and X6, manufacturing and parking space respectively, do not figure in these equations.

Behnam states that the statistical evaluation of the two models indicated that they were good predictors of pedestrian flow in Milwaukee and hence would provide relatively accurate results. He goes on, however, to conclude that the study data was collected in central Milwaukee, USA, which is atypical of other urban centres in the USA. Geographical factors are, he suggests, important items in the development and use of such models.

Studies of pedestrian traffic generation at individual locations are also made to facilitate future detail design. Ranking and Hill (1972) looked at major office and retail buildings in Australia Square, Sydney. The method produced unit generation rates expressed as pedestrians per unit of floor area and per time period. These generation rates were found to depend on time of day, type of floor space etc. and as a result the form was derived

$$P = k\ (G.A)$$

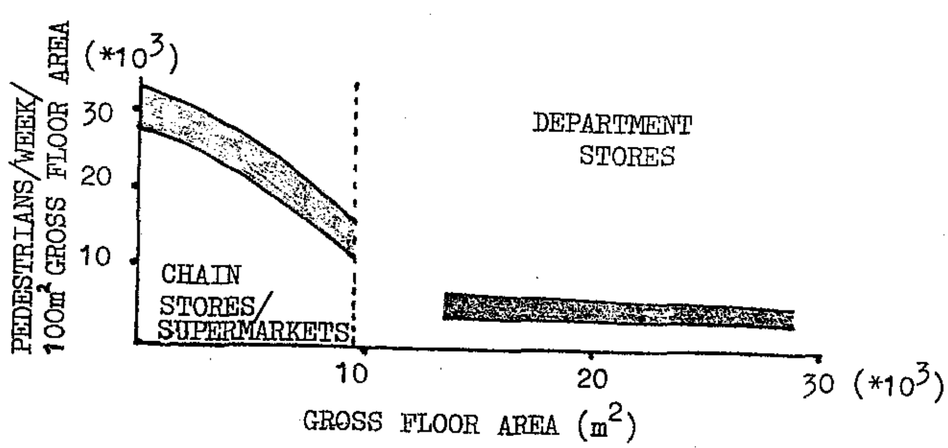
where:

k = constant for a particular establishment at a point in time, giving a weighting for lunch or evening conditions
P = number of pedestrian movements per hour
G = generating zone characteristics
A = attracting zone characteristics

Both G and A are indicators of office and retail floor space (1000 ft^2) per million ft^2 of the central area (Australia Square) in a given time period.

Similarly Hasell (1974) used a generation rate technique in his retail shopping work in Central London and based his rates on gross floor area (Figure 3.1).

Figure 3.1 Pedestrian Generation/Unit Floor Area (Hasell, 1974)



In the UK, few local authority studies have been revealed in the literature. Those that have (GMC, (1978); Barnsley MC (1976)) tend to rely on exhaustive work carried out in the early 1970's by the Coventry Transportation Team (1973), for the methodology.

For the Coventry study it was postulated that such was the nature of the CBD in Coventry that to attempt to predict densities would be impossible due to the difficulty in correlating numbers of pedestrians with land use variables, especially frontage shopping floor space (m^2). For district shopping however the study revealed that the numbers of pedestrians present were highly predictable.

The numbers of pedestrians on footways were analysed by multiple regression against the following variables using a method similar to that of Behnam (1977).

(1) Net retail floor space (m^2)
(2) Population within 440 yds of location
(3) Employment within 440 yds of location
(4) School places within 440 yds of location
(5) Number of bus services stopping within the location (per hour)
(6) Bus accessibility index (length of bus network within two miles radius connecting directly to the location)
(7) Weather conditions

The location was a length of shop frontage about 100 m long which embraced crossing facilities and free flow sites. Within each location a number of counting sites were positioned in relation to pedestrian flow chracteristics.

Separate analyses were conducted for young, adult, old and total persons, and a list of best predictive equations derived for each group of pedestrians for each time period (peak and off peak). Table 3.1 shows these relationships which were later used in the West Yorkshire WYTCONSULT evaluation (Headicar, 1979).

The results showed the numbers of pedestrians present and crossing roads in the shopping areas to be highly predictable, with shopping floorspace being the dominant explanatory variable of those tested.

It should be noted from this study that interviews play an important part in gaining land use data for use in the prediction of the numbers of pedestrians on street (also, Hasell (1974)).

Table 3.1 Numbers on Footways

Best Predictive Equations

Time Period	Adult Group	Equation	(R^2)
Off Peak	Young	$Y = 1.21 + 0.0036\ TF$	(0.71)
	Adult	$A = 0.6 + 0.159\ TF + 0.227\ Bus$	(0.88)
	Old	$AO = 0.00579\ TF$	(0.82)
	All	$T = 1.48 + 0.025\ TF + 0.263\ Bus$	(0.87)
Peak	Young	$Y = 5.64 + 0.00465\ TF$	(0.31)
	Adult	$A = 3.5 + 0.0143\ TF + 0.272\ Bus + 0.00113\ (E440)$	(0.90)
	Old	$AO = 0.64 + 0.0028\ TF$	(0.72)
	All	$T = 11.16 + 0.02\ TF + 0.32\ Bus$	(0.80)

Source: Coventry Transportation Study (1973).

where:

y	=	Numbers of young persons on footway within location
A	=	Numbers of adults on footway within location
AO	=	Numbers of old persons on footway within location
T	=	Total persons
TF	=	Total net retail and service floorspace within location (m^2)
Bus	=	Number of buses serving location per hour
(E440)	=	Number of jobs within 440 yds of location.

NOTE: Location = length of shop frontage including both sides of road normally 80 - 100 m long.

Also, if bus and employment factors are ignored then the following were found to apply:

Off Peak,

Adult	:	$A = 2.52 + 0.18\ TF$	(0.84)
All	:	$T = 3.7 + 0.027\ TF$	(0.85)

Peak,

Adult	:	$A = 7.59 + 0.0168\ TF$	(0.82)
All	:	$T = 13.87 + 0.0243\ TF$	(0.77)

3.3.2 Transport planning approach

Both simple and multiple regression techniques have been used in modelling trip generation. Ness (1969) and the Main Roads Department, Queensland (1971) employed a gravity model approach to undertake both trip generation and distribution simultaneously.

Ness (1969) employed the traditional gravity model technique to develop predictive tools for the journey to work and lunch hour pedestrian circulation demands in the central area of Toronto. The model was developed by treating the termini as transport zones and by dividing the central area into office zones. The generation and attraction rates of office and transportation zones were the main inputs to the model, along with a set of minimum path walking trees from all office centroids to all transportation zones. Similar gravity models have been used by Rutherford (1979) for predicting pedestrian travel, and the Main Roads Department, Queensland (1971) who postulated a model of the form

$$p = f\left(\frac{GA}{d}\right)$$

where :

p = pedestrian movement by purpose per unit time through defined precincts throughout Queensland
G = generating zone characteristic
A = attracting zone characteristic
d = distance between generating and attracting zones

This model was calibrated by plotting P/GA against d and assuming simple direct linear relationships between P, G and A. Population and employment were used as indicators of the purpose specific zone parameters G and A. 75% of pedestrian movements were found to be accounted for by 4 trip purposes: work, shopping, education and social.

This approach is mirrored by Scott (1974) who developed an entropy-maximizing model of a generalised theoretical pedestrian flow system. Scott assumed that there was a basic network representing a system of streets and carrying pedestrian traffic and that certain nodes represent gateways into and out of the system; other special nodes were designated arrival nodes or departure nodes. This theoretical model (based on a linear network) seeks to define a maximally likely (entropic) numerical pattern of flow, and utilised a complex spatial attractiveness function which related directly to various indices of retail activity (Sandahl and Percival, 1972). As a general model there are shortcomings with the approach. Scott assumes that pedestrians expend on average a constant quantity of time, money and energy and concludes that ultimately any really practical study of pedestrian flow patterns would probably have to be based on a series of more highly disaggregated models than the 'general' model considered.

Butler (1978) discusses the calibration and testing of a distributional model of pedestrian movement based on a series of studies conducted in Liverpool by the Institute for Transport Studies, University of Leeds from 1973-1977. The model used was based on the entropy maximising principle of Scott (1974) but did not record a particularly good fit. This may be due firstly to the nature of the network in Liverpool if compared with Scott's theoretical network and secondly, that pedestrian trips were fitted to an existing network and not vice versa. This underlines the insular nature of this approach in terms of application to one specific centre and the inherent difficulties in attempting to 'generalise' the model to cope with a variety of different locations.

Hass and Morrall (1967) conducted a survey of pedestrian tunnels between all major buildings and parking lots of Carleton University, Ottawa, Canada. The objective was to develop a pedestrian demand model for future design requirements. Data were collected by:

- origin/destination surveys
- screen line counts
- walking time - distance surveys using a 'floating pedestrian' technique
- peak hour was derived from the University timetable.

Trips were assigned to the network by a computer assignment program from the results of the surveys.

Ballas (1976) reports on the results of origin and destination surveys carried out at Montana State University from 1971 to 1973. Both person trip generation and distribution models for trips that had at least one end on campus were developed so utilizing generation rate and gravity model approaches.

Ballas used the gravity model to estimate the numbers of trips among the 18 zones that were most active in terms of origin and destinations. Data was collected and independent models were constructed for a two week period in December 1971 and similarly in 1973. The predictive accuracy of each model was then assessed by exercising the models for one year on the data of the other. In this way it was found that 72% of the variance in the 1971 sample of pedestrian volume at 3 defined interchanges was explained by the model. Similarly 52% of the 1973 sample was also explained. The interchanges between the two types of trip end which Ballas was interested in were School-School; School-Residential; Residential-Residential.

This model was developed and tested within Montana State University, USA. However, it was not operated in an actual planning context.

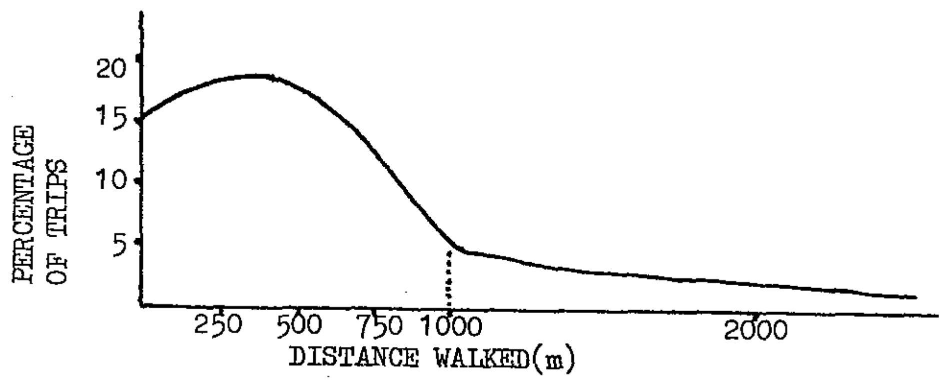
Little new research appears to have taken place over the past five years which seeks to develop further the predictive methods so far described. Indeed the only comprehensive model of note to emerge is that described by Bland (1983). The 'LUTE' model of travel by car, bus and on foot has been used to predict travel in a set of hypothetical towns with a wide range of sizes, shapes and population densities subject to

- o The average time spent travelling per day
- o The number of trips being held constant
- o Fares revenue covering a proportion of operating costs and allowing for the finite seating capacity of buses

The model is orientated towards public transport but walking remains an important mode in all areas, both in its own right and as an indispensible component of bus and car travel. As the majority of walk trips of all purposes are less than 1 km (see for example Figure 3.2), accurate modelling requires a spatial resolution of a few hundred metres or better.

Figure 3.2

Distance Walked by Pedestrians (Rutherford, 1976)



In 'LUTE' all origins and destinations are represented as spatially continuous distributions and Gaussian integration is used to estimate travel from one area to another (to a desired level of accuracy). Mode and destination choice are assumed to depend on a weighed sum of travel times and money costs called the 'behavioural cost'.

3.3.3 Crossing studies

It is in the area of behavioural research that more work has been done in looking at individual facilities or features of pedestrian movement. Williams (1982) and Cresswell (1979) both have looked at simulation models of pedestrians crossing the road (and are discussed more fully in section 5.6). From this work comes a direct comparison of the analytical techniques of measuring pedestrian delay identified by Tanner (1957), the empirical models of Goldschmidt (1977) and the simulation techniques of Cresswell and Williams.

Maher (1983) takes pedestrian crossing behaviour and attempts to develop a model to estimate critical gap acceptance based on both a 'least squares' and maximum likelihood approach. Polus (1983) also supports this work.

Bull (1980) looks at pedestrian arrival patterns and behaviour at pelican crossing sites in South Yorkshire and Khisty (1982) looking particularly at pedestrian conflicts regarding pedestrian cross flows in corridors identifies the need to introduce gap acceptance and density into simulation modelling. This concept of density along with crowding (Dean, 1978) and mode choice (Eyles, 1969) are reviewed in section 5.7 under factors influencing pedestrian behaviour.

One attempt to develop a transferable model at a specific facility, rather than area-wide, level has been made by Allos (1983) who aimed at developing a portable model capable of explaining the usage of a footbridge. The model considered pedestrian behaviour and attempted to reflect the choice that pedestrians make between convenience and safety in road crossing. A stochastic logit model was developed and initially included a time ratio between footbridge and surface route as a variable. This was found to be complicated to estimate and was rejected in favour of a distance ratio as a proxy for convenience and traffic flow for the effect of safety. Hence,

$$p = 1/(1 - \exp Z)$$

where

p = proportion of pedestrians using the footbridge
Z = linear function such that

$$Z = 4.14 + 3.86\ (DR) - 3.49\ (Q)$$

DR = distance ratio (footbridge distance:Roadway distance)
Q = vehicle flow (vehicles/sec)

In terms of prediction of numbers on links, not over the whole area, the development of research over the past decade highlights the need to disaggregate the general models of the early 1970's and to introduce parameters into pedestrian modelling that are not directly paralleled in the traffic field e.g. crowding, varying speed for varying trip purposes etc. Of the models that look at central areas then perhaps Behnam (1977) is the most comprehensive and economical though he does not consider behaviour or town wide implications. The literature reveals time and again the individuality of pedestrian journeys and outlines the difficulty in developing a predictive technique suitable for more than the location on which it is modelled due to demographic and land use variations both across and within urban centres. No literature, however, actually tests model validity across a range of centres. Perhaps experiences of local authorities' modelling exercises would reveal deficiencies of the current predictive techniques.

3.4 Conclusions

1) Disaggregation, Accuracy

From both revealed counting and prediction literature there is little information on the desired levels of accuracy or disaggregation required. It is generally agreed however that there is a need to treat the elderly and the young as separate components of all pedestrians. The separation of these age groups, however, is not well defined and is often left to subjective assessments by observers on street or from film, which tends to classify the young as those under twelve and the elderly those over 65 years of age. It is suggested that observed appearance may be deceptive so leading to errors in counts made and disaggregated in this way. Studies often state that models used correlate adequately with supporting counts. However fuller information tends to be sparse and fails to reveal either the anticipated or achieved accuracy of the counting methods or of the predictive techniques used.

2) Counting Methods

i) Cost

No detailed information on the relative cost of data collection methods has come from the literature. However, in terms of both finance and manpower it is generally thought that unless some behavioural input is required to an analysis then the moving observer and manual counting methods are preferable to the use of time lapse photography. Despite this the Coventry Study utilised film counts for movements along a pavement, where the mounting of the camera on a vehicle proved the main obstacle to use. However no reason was given for the choice of technique in conducting manual counts at a crossing point where both behaviour in crossing is an important factor and also the camera mounting would have been easier to secure and maintain. As with many pedestrian studies the main constraint on data collection may have been resource availability and the use of film at one location precluded its use at another.

ii) Count Periods

A 10 minute count period has been utilised in the majority of the studies reviewed. The Coventry Study in 1973 used this time period because it facilitated the co-ordination of counts at city centre sites where observers had to count pedestrians at more than one location. Such a count period was also found to minimise observer boredom and hence keep errors to a minimum. From this study the same count period has been used throughout the UK and whilst the latter point presumably still applies, the validity of always conducting 10 minute counts has to be questioned. In the case of Coventry, the time period was determined to a large extent by the numbers of staff available at any one time and the number of sites to be observed. This is not therefore the basis for determining a general rule on which all count periods should be based, and certainly the Barnsley Study (1976) showed that in utilising such a counting method a very low percentage of all pedestrians could be observed within each count period. Haynes (1977) indicates that perhaps a 15 minute count period would be preferable, providing resources are available. This, it is suggested, would reduce 10 minute count errors by 3%.

3) Predictive Methods

i) Land use variables

Ever since the early work of Morris (1962) studies have indicated that pedestrian traffic may be predicted with reference to certain quantifiable land use variables. In terms of the models reviewed then there appears to be a reliance on established methods (e.g. use of retail floor space as an indicator of pedestrian trip generation/attraction). This then could indicate either the adequacy of current techniques in crude forecasting or alternatively a major deficiency in current innovative research. Concerning the quantification of floor areas the trend seems to be to approach users of facilities in order to gain the appropriate data. This neglects the use of available standard land use surveys and may be responsible for increasing the cost of required data collection.

ii) Transferability

Models tend to be developed for use in design or evaluation at a particular centre and at a defined point in time. Thus, the 'general' area wide model in such a form does not exist. Here, further work on catchments is required to enhance understanding of the nature and spread of origins and destinations of varying journey purposes and of the scale of perceived or anticipated trip suppression. At street level, models tend to be more portable yet still restricted to streets comprising of similar facilities, for example, numbers, types and scale of facilities. The greatest development in obtaining portable models appears to be at the micro-level where behaviour orientated assessments of route choice and crossing behaviour may aid the estimation of the numbers of pedestrians affected by severance issues.

4. PEDESTRIAN AMENITY

4.1 The Definition of Amenity

The walking environment provides a large number of stimuli which the pedestrian receives and stores. The perception of these inputs is mediated by auditory, visual, olfactory and tactile senses from amongst other factors such as noise, appearance, fumes and vibration (Rosman, 1980). The individual refines and catalogues these inputs to produce a mental image of his or her environment. This image may be a simplified or distorted image of reality. Understanding these latent images is of crucial importance in assessing the likely impact of traffic and infrastructure on perceived environmental images, and in determining the likely success of improvement schemes.

4.1.1 What is Amenity?

The literature does not explicitly define amenity, being regarded as something that is easier to recognise than to measure. In searching for a practical definition of amenity or its close relative environmental quality, it is evident that the terms have social and cultural as well as physical dimensions (Ikelson, 1977).

The assessment of environmental quality can take a variety of forms. Much depends on what the term is being defined for and by which professional group. Nash, Pearce and Stanley (1975) argue that different assessment methods tend to be consistent within a set of values and that there is no uniquely proper way to carry out environmental assessment. It is important however that the value systems inherent in the design of a methodology and in the presentation of results are made explicit.

It is to be expected then that amenity studies will be done in many different ways. The basis of many amenity studies is environmental perception. The common thread running through these studies is the notion of image (Ikelson, 1977) which has been utilised to explore attitudes and behaviour. There are 3 complementary strands in the studies of images:

i) Physical correlation of environmental images (Cane, 1977)

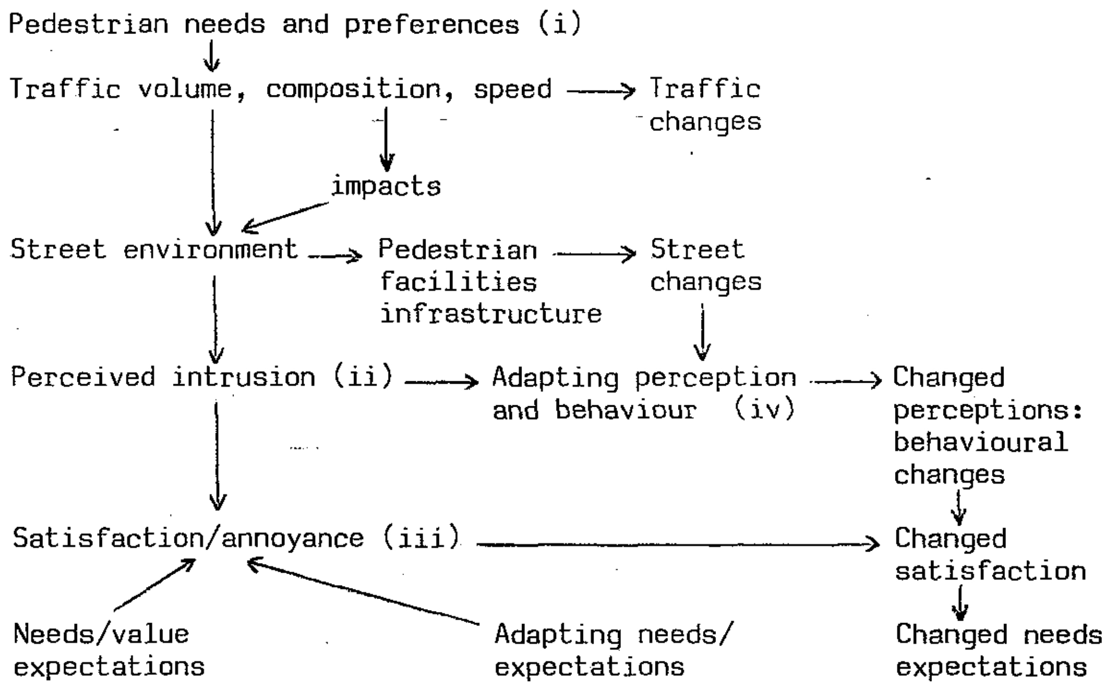
ii) The cognitive map (Pocock, 1977)

iii) Studies of landscape (Grigg, Huddart, 1977) and townscape preferences (Moriss, 1978).

In our literature search we have examined all 3 types of study. These will be discussed in subsequent sections.

Whilst these approaches all have their place and relative merits, in amenity studies it is not always apparent how the output from these applications of those techniques could or should be used. Appleyard (1981) offers a conceptual framework for systematically exploring the range of pedestrian/traffic/interractions (see fig. 4.1). We have added infrastructure effects, such as provision of pedestrian facilities, to the original diagram.

Figure 4.1 Conceptual Framework for Pedestrian Studies (After Appleyard, 1981)



It is obvious from this diagram that an amenity study requires a multi-disciplinary approach making use of study methods (i - iii) above where appropriate. In particular the techniques need to take into account people's capacity to modify their attitudes, behaviour, values and expectations to cope with their environmental conditions. We review the techniques and information currently used or available for the following areas in the Appleyard model.

i) Pedestrian needs and preferences for environmental conditions (section 4.2).

ii) To what extent traffic and infrastructure related environmental conditions are perceived by pedestrians (section 4.2)

iii) How people rate their satisfaction with those environmental conditions (section 4.3).

iv) How pedestrian behaviour may be influenced by those environmental factors (Section 5).

The following section describes in brief those techniques that have been found in the literature for measuring:

i) What people perceive as important elements in their environment and their attitudes to different levels of these elements;

ii) Behavioural response to those perceived factors.

4.1.2 Assessment Methods

The following section describes in brief those techniques that have been found in the literature for measuring:

i) what people perceive as important elements in their environment and their attitudes to different levels of these elements.

ii) Behavioural response to those perceived factors.

Environmental perception is a collective term for any of the various senses by which we apprehend that which surrounds us.

The two most common approaches to eliciting people's perceptions of their surroundings are either to ask them about their likes or dislikes in an area, usually whilst they are experiencing it (Hills, 1976); or to present visual material and ask people to specify their preferences (Grigg, Huddart, 1977), or identify similarities and differences between scenes (Stringer, 1977).

A third approach is to elicit the individual's spatial representation of their environment by getting them to draw a map or else provide information that enables a map to be constructed (Gould, 1974).

Verbal Response to Questions about Surroundings

Verbal response provides the most direct and potentially richest information on what people perceive as their environment. Techniques for eliciting verbal response are endlessly varied although the questionnaire remains the most popular method. Gaming techniques (Benibo, (1982)) and group discussions (Bruvold (1973)) have been attempted but have not found widespread use.

The 2 basic techniques used to probe for information are:

i) unprompted questions (e.g. Hills, 1976)

ii) prompted questionnaire (e.g. SCPR, 1978)

The former is likely to provide a less-biased impression of factors which cause concern. The responses are given in terms which have meaning to that individual but may not necessarily be of practical use to the study team. The technique can provide different dimensions to concepts such as danger or pleasantness - terms which often appear in prompted questionnaires - but which have ambiguous meaning. However non-standard responses may prove difficult to cluster into common concepts and may not have any correlation with physical environmental factors (Hills, 1976).

The prompted form of question remains the most popular technique in amenity studies. Rees, Dix and Clyde (1975) review in detail the development of an attitudinal questionnaire for use in the Liverpool study. The eventual method employed was an attitudinal matrix requiring respondents to rate their strengths of response to different environmental factors (semantic differential). The semantic differential has proved to be a popular measurement technique in environmental assessment where different levels of physical factors can be related to levels of responses. These can be used to establish levels for individual factors which could be regarded as thresholds triggering particular responses or as standards. The strength of the semantic differential and the prompted questionnaire is the ability to standardise questions and allow comparison of response across studies. The control and direction that is provided by the standardised approach may also be the weakness of the prompted questionnaire in that it may introduce the respondents to factors which they may not have previously considered. Further the technique makes the assumption that all people perceive the terms being used in the question, e.g. danger, in a similar way.

The extent to which different survey techniques produce a different emphasis on the importance of factors is not well documented. Harrison and Sarre (1977) in a survey found that different techniques (e.g. semantic differential, repertory grid) employed to elicit and analyse perceived environmental images gave markedly different emphasis on the primary factors of importance in defining respondents' images.

The questionnaire approach, whether using unprompted or prompted questions has limitations for application in amenity studies. The general comment that people can forget or have different levels of articulation about what they like or dislike about their environment automatically introduces an element of bias into the results. The source of bias in using questionnaire techniques is well documented (Oppenheim, 1968).

Further, not all amenity factors, notably air pollutants such as lead and carbon monoxide are perceived through any physical dimension and likely to evoke a response of nuisance. Judgements about health effects, which certainly contribute to the amenity issue, are usually made with reference to quality standards established through a wide range of empirical and experimental studies.

Verbal Response to Presented Images

More detailed and experimental approaches, albeit by reducing the level of reality, have been attempted by presenting individuals with images, often photographs, colour slides or maps, under controlled conditions and eliciting their response. Again the response can be elicited through unprompted or prompted questions, the advantage of the technique being the opportunity to alter the independent variables (images). This approach has been used in a variety of studies after incorporating a semantic differential scoring system for each image: visual intrusion (Grigg and Huddart, 1978), and crowding (Sadalla, 1981).

The ability to gain in-depth 'interviews' must be set against the disadvantage that the respondents are responding through only one sensory faculty - vision - making any linkage with actual behaviour more tenuous.

An alternative approach to the evaluation of environmental images through unprompted response is the repertory grid which has developed rapidly in the field of environmental studies (Stringer, 1977; Honikman, 1978). The grid system has been widely used in risk assessment (Royal Society 1984) and would appear to offer a useful technique for exploring concepts that have different meanings for different people.

The grid technique requires individuals to state similarities and differences between sets of 3 images presented say of street scenes. These discriminations are the individuals constructs. The individual is then asked to state which are his preferred constructs and to rank all other images on these constructs. At the end there is a matrix of ranking of images against all the constructs which have themselves been elicited through unprompted questions.

The theoretical and analytical differences between this approach and the semantic differential matrix, as used by Hills (1976), are discussed in Banister and Mair (1968).

Mental Maps

Mental maps may be derived by direct or in direct means. The three main methods of devising map information from respondents are

1) To get them to draw a map (Pocock, 1977)

2) To ask them to identify locations within or outside an are (Lee, 1975)

3) To identify trips crossing different boundaries.

4) To ask them to assess distances to locations (Lee, (1970)).

Map Drawing The 1976 TEST study asked pedestrians to draw the range and extent of the area they walked to for a variety of purposes. The results showed that the major shopping street formed a boundary for the extent of many walk trips. This may have been better because the street acted as a barrier to further movements or else satisfied pedestrian needs. The extent to which individuals' mental maps change over time and in relation to changes in amenity factors has not been found in the literature.

Location Identification The urban motorways project team (1973) examined the potential physical and psychological severing effect of new roads on pedestrian trips. They explored severance effects through a number of indicators including:

1) proportion of trips bridging a new road;
ii) perceived areal extent of home area;
iii) Number and location of landmarks considered to be in the home area.

The results from the study suggested that the effect of a new road reduces the number of cross-over trips (bridging) by pedestrians, although there is no evidence for a decrease in perceived neighbourhood area which was found to become relocated away from the new roadline.

Assessment of Distance Lee (1970) attempted to show the interaction between physical variables such as direction and location with human variables to derive perceived distance which is regarded as a prime factor in the probability of making a trip. The survey of perceived distances in Dundee found that they were related to direction of travel. Inward journeys were perceived as shorter than outward journeys.

Sadalla and Staplin (1980) found that the number of intersections along a route was crucial in explaining distortions of distance. Routes with more segmentation or information were recognised as longer than routes of equal objective length but less segmentation. This has important implications for pedestrian studies where changes in traffic conditions or infrastructure will alter the information input and stimuli impinging on the individual.

Behavioural Studies

Pedestrian behaviour research is concerned with the reactions of pedestrians in negotiating the road environment and the variables which influence those reactions (Frith, 1984). There are numerous methods used in the study of pedestrian behaviour and preference. Hoinville and Courtney (1978) review methods used in the measurement of consumer preferences, some of which have application in amenity studies. None of these are specifically behavioural studies since they rely on verbal response to ask people how they might behave in certain situations.

Methods used in exploring actual pedestrian behaviour fall into 2 categories:

i) based upon statistical evidence.

ii) observational approaches (e.g. Chapman, 1980).

Statistical Approaches

The inference of behavioural response on the basis of people counted in a particular activity is an appealing approach to assessing pedestrian amenity. If more people are found to be participating in a certain action e.g. crossing the road, then some interpretation of whether pedestrians are affected by that change can be made (GMC, 1978). The potential problems that such an approach can face are numerous. To make judgements on the benefits/losses of a scheme in terms of pedestrian numbers, ignores whether people find these conditions acceptable. However, to base an assessment of pedestrian problems entirely on numbers of people affected by different factors ignores whether people themselves find those conditions acceptable or unacceptable.

Observational Studies

Direct empirical studies on the actions performed by pedestrians is probably the most obvious starting point for studies of pedestrian behaviour. Observation may be performed in 2 basic ways:

i) Systematic recording
ii) Tracking/interviews.

Systematic Recording

Systematic recording has often been used in accident studies to monitor the number of the target group, such as young children playing in roads (Chapman, (1980)) or people having difficulty in crossing the road (TRRL, (1970)) technique involves 'reporters' either standing at particular locations or else walking through an area and counting the number of incidents over a given period of time.

Tracking

Tracking involves the following of specific individuals to monitor their route choice, pattern of activities or difficulties encountered. Video techniques have found increasing use recently for observing the pattern of movements along streets (McPhail and Wohstent, 1982).

Tracking has not found popular use in pedestrian studies (for examples see Routledge, 1974; Hills, 1984) mainly because it is a time-consuming operation to follow people. Hill (1984) suggests that asking people to recall their walk route at some point on their walk journey produces as reliable information for analysing route choice decisions as the tracking procedure.

A further development of the interview techniques to derive route choice decisions has been put forward by Khisty (1983). The author offers a behavioural circuit concept by which broad behavioural patterns of movements can be recorded, observed and compared. The methodology assumes an inextricable link between the physical environment and behaviour. A circuit is a regular pattern of activity. The information on these circuits may be collected through tracking but on a larger scale through interviews or questionnaires.

The approach takes into account the extent to which people adapt their circuits over a time period and their existing patterns can form a complete catalogue of behaviour indexed to locations, times, frequencies, populations and age groups. The main objective is to represent all aspects of the pedestrian journey within a single unit of analysis. The technique would appear to have many uses in assessing long-term effects of transport projects on pedestrian movements in complex urban environments.

4.2 Perception of Amenity

Tables 4.1 - 4.3 catalogue the likes and dislikes of people interviewed during two studies using unprompted questionnaires:

i) The National Environmental Survey (NES 1972)

ii) The TEST Kentish Town Road Survey (TEST 1976)

The National Environmental Survey which obtained responses from 5686 residents drawn randomly from England and Wales, revealed that 'good transport and access' was the most frequently mentioned 'like' about the area (29% of sample). 25% liked other residents in the area and 23% liked the appearance of the area. The most frequently mentioned dislike about the area was traffic (13%). 41% of the sample said that there was nothing that they disliked about the area.

The TEST Study which focussed one of its surveys on Kentish Town found that people gave overwhelmingly favourable response about the Kentish Town area but found the appearance of the area (to which traffic might be a contributory factor) unattractive.

Cane (1977), reporting on the likes and dislikes compiled from eight studies carried out in the early 1970s on environmental perceptions, suggested the following order of importance:

<u>likes</u>

1. people in the area
2. quiet/pleasantness
3. easy access to facilities

<u>dislikes</u>

1. poor appearance, dirtiness, noise, air quality
2. poor convenience to facilities

Cane reports that the different approaches adopted in the eight studies reviewed make comparisons difficult. The most obvious differences which may occur between studies are the levels of articulation of respondents, and their tendency to forget to mention certain likes/dislikes, and the effects of different groupings of responses. For example, poor appearance to a respondent in one situation may be comprised of an entirely different set of factors from that for respondents in another study. Equally the results do not give a clear indication of whether the different elements are liked/disliked because they are important or because of their scale. Thus some environmental factors might be of concern to pedestrians irrespective of the extent of the problem because they are considered sufficiently important; others will only be mentioned if they exceed a tolerance threshold or if the effect has been experienced recently.

Table 4.1 Percentages of Respondents Who Perceive Different Factors that they Dislike about their Neighbourhood Area

Percentages for:	Total sample	Very satisfied	Fairly satisfied	Dissatisfied with area
Base:	5315	2417	2399	497
	(%)	(%)	(%)	(%)
Traffic	13	11	15	19
Neighbours	10	6	10	30
Poor transport facilities	10	8	12	11
Shopping facilities	9	6	11	15
Entertainment & amenities	9	4	12	18
Neglect of streets	7	5	8	14
No facilities for children	6	3	7	13
No atmosphere	5	3	6	1
Smell in fumes (not traffic)	4	3	5	7
Unattractive appearance	4	2	4	11
Vandalism	3	2	3	8
House or flat	3	1	3	9
Noise (not traffic)	3	2	3	6
Other answers	11	9	11	14
Nothing	41	54	34	8

Source: NES (SCPR, 1978)

Table 4.2 Percentages of Respondents who Perceive Different Factors that they Like about their Neighbourhood Area

Percentage for:	Total sample	Very satisfied	Fairly satisfied	Dissatisfied with area
Base	5315	2417	2399	497
	(%)	(%)	(%)	(%)
Good transport & access	29	33	28	16
Other residents	25	34	19	9
Appearance	23	29	19	10
Shopping facilities	22	26	20	13
Countryside	21	27	18	6
Peace and quiet	21	27	18	5
Work - convenience and availability	11	9	13	8
Ties with area	10	12	9	4
Atmosphere	10	13	8	3
Entertainment & amenities	8	10	7	4
Healthy fresh air	7	11	5	2
Good schools & access	6	7	6	4
House or flat	6	8	6	3
Absence of traffic	5	6	5	1
Streets kept clean	4	4	3	1
Sports facilities	3	3	3	2
Away from industry	3	4	3	1
Vague replies	3	4	3	0
Other answers	3	4	3	3
Nothing	15	4	18	50

Source: NES (SCPR, 1978).

Table 4.3 Percentages of Pedestrians who Listed Favourable and Unfavourable Comments about the Kentish Town Road

Comment	Frequency	% all answers	% all respondents
Generally like	48	12.0	6.3
Generally dislike	18	4.5	2.3
Like shops	70	17.5	9.1
Shopping could be better	53	13.2	6.9
Dirty	72	18.0	9.4
Too busy, crowded	38	9.5	5.0
Renovate, squalid	83	20.7	10.8
Negative references to people	16	4.0	2.1
'Disorderly', too may pubs etc.	3	0.8	0.4
TOTALS	401	100	52.3

Source: TEST (1976)

The interaction between levels of environmental factors and general satisfaction with an area has been studied but the relative importance of different perceived factors in determining overall quality is still unclear. Langdon (1976) and Aubree (1971) have found that people's perceptions of environmental quality are related to their annoyance with noise levels. Mackie and Davies (1981) found that reactions to specific environmental factors such as noise and fumes were more closely correlated with levels of traffic than to objective measures of those factors. These study findings combined suggest that general satisfaction with traffic-related environmental quality may be more closely correlated with traffic volumes than with levels of individual environmental factors.

However there are clear indications from these studies that when people are asked generally about their perceptions of an area, traffic is rarely mentioned among the dislikes, while access related issues are important in influencing both likes and dislikes.

Conversely at a more detailed level there is evidence that individuals do react to the effects of specific traffic and infra-structure induced factors. These effects are considered in the next sub-section.

4.3 Perception of Traffic/Infrastructure Factors in the Walking Environment

This section reviews several studies that have investigated specifically pedestrians' perception of the walking environment and the difficulties encountered in it. The factors likely to be perceived may be dependent upon:

i) the characteristics of the pedestrian
ii) the interview 'setting'
iii) levels of road traffic
iv) attitudes to walking in general.

The extent to which these different aspects do influence perceived factors has not been explicitly researched and one must be cautious in making general interpretations about what people perceive as sources of road traffic nuisance must be cautious.

Among the studies reviewed elements of the environment which concern people have been identified either by unprompted or prompted questions.

(1) TEST Study (1976)

Pedestrians in Kentish Town High Street were asked about specific improvements that they would wish to see in their walking environment or any likes and dislikes that they had about conditions experienced when walking in the area. The questions were open-ended and the responses fell into 3 broad categories:

i)	traffic conditions:	volume, noise, road width, hgvs
ii)	pedestrian facilities:	crossing facilities, difficulty in crossing, footpath condition
iii)	amenities and social aspects:	building squalor, dirt, crowding, shops, undesirable people, behaviour.

The majority of comments made were negative.

A further survey of Putney High Street produced favourable comments on:

i) shopping facilities
ii) compactness of shopping centre
iii) accessibility
iv) atmosphere and friendliness.

Dislikes fell into 2 broad categories:

<u>Pedestrian Facilities</u>

(i) difficulty in crossing the road
(ii) need for a pedestrian precinct
(iii) pavements too narrow
(iv) insufficient time at traffic lights

<u>Traffic Conditions</u>

(i) too much traffic
(ii) noise
(iii) road too narrow
(iv) parking facilities inadequate
(v) too many lorries.

(2) <u>Liverpool Pedestrianised Street Study (Hills, 1976)</u>

As part of an assessment of pedestrians' attitudes to conditions on a Liverpool Street before and after pedestrianisation a wide variety of subjective responses were collated to the question of what people liked or disliked about the street. Of the grouped impressions, both favourable and unfavourable, eight attributes emerged as predominant, accounting for 78% of all responses. These attributes were (in rank order)

i) shops
ii) noise
iii) crowds
iv) freedom to cross
v) safety for pedestrians
vi) personal safety
vii) access by transport
viii) overall appearance

Any differences in perception by journey category, age and sex were not explored.

Table 4.4 Percentages of Pensioners Identifying Problems when Walking (PSI 1976)

Proportions with at least one problem	41%
Of those who state at least one problem, the problem is due to:	(%)
uneven pavement	37
mud/grass pavement	5
narrow pavement	5
no pavement	4
changes of level - hills/ramps	42
speed/volume of traffic	20
other traffic issues	14
not enough pedestrian crossings	10
no seats	5
no/poor lighting	4
kerbs/steps	3
n (with problems)	125

Table 4.5 Percentages of Young Women Identifying Problems When Walking (PSI, 1976)

	travelling with children youngest child is: under three	three to four	five & over	travelling alone
	(%)	(%)	(%)	(%)
proportion with problems	42	36	27	29
n	118	78	161	357
Of those with problems, the problem is due to:	(%)		(%)	(%)
traffic/crossing roads	38		53	39
narrow pavement	32		14	21
uneven pavement	21		9	15
hills/ramps	14		7	14
no pavement	12		26	16
mud/grass pavement	8		12	8
kerbs/steps	8		2	2
places too far away	6		5	7
other	17		14	19
n (with problems)	77		43	103

Table 4.6 Percentages of Respondents who Experience at Least one Difficulty in the Walking Environment

Aspect of pedestrian environment	Registered disabled (%)	Elderly, physical difficulties with walking (%)	Non-elderly housewives, physical difficulties with walking (%)	Elderly, no difficulty with walking (%)	Non-elderly housewives, no difficulty with walking (%)
	percentage of people reporting difficulty				
kerb	12)	5	4	4	2
ramps	58)				
rails/ramps	59	45	30	19	12
uneven/narrow pavements	21	19	13	14	8
crowds	50	4	0	5	2
traffic/ crossing roads	35	31	22	16	17
other difficulties	2	23	43	54	67
Sample	143 disabled people in Coventry who made walk trips	366 from total sample of 825 in Guildford	23 from total sample of 195 housewives in Guildford	459 from total sample of 825 elderly in Guildford	172 from total sample of 195 housewives in Guildford
Source:	Hopkin et al (1978, table 14)	Hopkin et al (1978, table 14)	Unpublished	Hopkin et al (1978, table 14)	Unpublished

(4) Study of Pedestrian Traffic in Helsinki (1973)

1000 responses to a request to name places that were good or bad for pedestrians in Helsinki were treated to factor analysis to highlight the following 4 factors (after Katz, 1978):

1) city factor - shop windows, shops, neon signs, young people.

2) traffic disturbance factor - difficulty of moving, difficulty of moving with children and pram, high density.

3) traffic arrangement factor - location of facilities, particularly pedestrian crossings, barriers, signs, transit stops.

4) social factor - tranquility, trees, plants, colourfulness, atmosphere, unsocial or violent people.

Again there appear to be distinct groupings of factors by which we might analyse pedestrian amenities. The relative importance of different factors is reviewed in section 4.4. The following studies have investigated pedestrian perception of walking conditions using prompted or more structured questionnaire techniques.

(5) The mobility of old people. TRRL LR 850 (1978)

Several surveys carried out by TRRL show problems for pedestrians resulting from traffic and infra-structure effects. Table 4.6 illustrates these findings.

The results indicate that obstacles (kerbs, ramps, rails) in the walking environment are a major difficulty for pedestrians who have difficulties in walking. This became more apparent for elderly people. Crowds are a source of difficulty for registered disabled but less so for other groups.

Pavement condition is less of a difficulty for all groups listed than obstacles but follows the similar pattern of being more of a problem for those who have difficulty in walking in general.

Road traffic and road crossing is mentioned by about one third of the registered disabled and the elderly infirm as a difficulty in the pedestrian environment, less frequently by other groups.

Altogether infrastructure effects appear to be more dominant factors in the walking environment than traffic effects for those people with walking difficulties.

(6) Pedestrian transportation for retired people (1971)

A survey of 709 retired people revealed the following problems and perceived advantages of walking indicated in Table 4.7.

Table 4.7 Percentage of Elderly Pedestrians Identifying Perceived Advantages and Problems of Walking

Likes	
Good for health	92%
Inexpensive	90%
Independent	85%
Convenient	82%
Contact with people	81%
Disadvantages	
Destinations too far	83%
Depends on weather	78%
Hills	72%
Fears	65%
Tired, feet hurt	55%
Takes too long	52%
Health problem	37%
Traffic confusing	36%

Source: CARP, 1971.

(7) Environmental impact of road traffic
Ludlow - TRRL 1978

This set of surveys of pedestrian reaction to traffic conditions following removal of traffic reveals those main aspects of traffic which bothered people before traffic was removed. Table 4.8 indicates these results. Figures are compared with results from the NES survey results (SCPR, 1978) where respondents were asked to rank order the problems they identified in the walking environment.

Table 4.8 The Importance of Individual Environmental Factors Encountered in the Walking Environment

	Percentage of Respondents Identifying Factors as Main Problems Encountered in the Walking Environment	Problem Factor Identified as Most Important Problem in the Walking Environment	Problem Identified as Second Most Important Problem Encountered in the Walking Environment
Danger	68	29	16
Noise/vibration	23	12	18
Smoke/fumes	8	9	17
Dust/dirt	3	9	18
Visual	1	13	13
No problem		29	

Both sets of results show that pedestrian danger is perceived as a more major problem than noise. In the NES study pedestrian danger incorporates difficulties in crossing the road. Visual effects include the visual impact of parked vehicles and relate to residents' views as well as pedestrians'.

(8) Tyne and Wear Study 1979

As part of the Tyne and Wear Metro Study (Bennison, (1980)), pedestrians likely to be affected by changes in the public transport system in Central Newcastle were asked for their attitudes to walking (see Table 4.10). The majority of pedestrians did not perceive any difficulties in walking around the city centre. Pedestrian congestion was regarded as the major difficulty of walking around the city area. Difficulty in crossing roads was offered by 56% of pedestrians as a problem, whilst over half of pedestrians interviewed found pavement conditions unsatisfactory (see Table 4.9).

Table 4.9 Percentage of Pedestrians in Central Newcastle who Identify Difficulties in walking around the city centre (Bennison, 1980)

	Number	%
None	499	57.5
Long distances	9	1.0
Pedestrian congestion	319	36.8
Vehicular traffic	11	1.3
Other	22	2.5

Table 4.10 Response to Prompted Questions about Walking Conditions by Respondents in Central Newcastle (Bennison, 1980)

	Agree strongly	Agree slightly		Disagree slightly	Disagree strongly
WALKING					
It's tiring	2 (6)	7 (19)	4 (11)	9 (22)	15 (42)
It can be difficult in bad weather	11 (31)	10 (28)	3 (8)	8 (22)	4 (11)
Pavements are narrow or uneven	7 (19)	12 (33)	3 (8)	9 (25)	5 (14)
It's difficult to carry shopping	13 (36)	9 (25)	3 (8)	6 (17)	5 (14)
It's difficult to cross roads	11 (31)	9 (25)	5 (14)	5 (14)	6 (17)

Percentages in parentheses

(9) User response to pedestrianised streets (Stewart, 1981)

Pedestrian responses to pedestrianised facilities in four cities in the United Kingdom were examined. From the nine variables that were provided to establish a respondent's overall rating of street design characteristics, the most important were found to be those with a strongly functional element:

	% of respondents identifying the following factors as important street design elements
i) safety	83
ii) cleanliness	76
iii) ease of walking	75

Width of street, brightness and relaxation were terms ranked lower as important attributes.

4.4 Nuisance ratings to environmental factors

The previous sections have looked at those factors that are mentioned as being noticed in the walking environment. This subsection considers the relative importance of these different factors in terms of nuisance rating.

A number of studies have examined pedestrians' attitudes to different aspects of the walking environment. These studies have generally identified those problems which are considered to be the most important sources of nuisance rather than trying to determine the levels of those factors which trigger particular responses.

As noted in the previous section, care has to be taken in the interpretation of statements of attitudes since they may obscure the process of adaptation and selection which may underlie the stated attitudes.

4.4.1 Relevant Studies

(1) TEST Study (1976)

The 1976 TEST study of pedestrians' reactions to conditions in Kentish Town High Street where traffic flows were between 1000 - 2000 vph rated attitudes to the factors on a 7 point semantic differential scale (see 4.1.2) where a score of 1 means that the respondent has strongly unfavourable comments to the factor and 7 means a strongly favourable comment. Scores for individuals are summed to produce the following aggregate scores.

Table 4.11 Aggregate Rating Scores of Pedestrians Interviewed in Kentish Town Road to Different Environmental Factors (TEST 1976)

Noise and vibration	2.3
Traffic dust & fumes	2.4
Litter	3.3
Overall appearance	3.5
Ease of crossing the road	3.7
Crowding of pavements	3.9
Public transport	3.9
Feeling of safety	4.3
Shopping facilities	5.1

Equal numbers of people gave positive and negative ratings to the ease of crossing Kentish Town High Street. Ratings of fumes, dust and safety were generally unfavourable. The effects of crowds produced strongly polarised comments. Age and sex differences in the ratings were investigated for each of the variables. Females tended to find noise and vibration more disturbing than men. Older people (65+) were generally more disturbed by feelings of safety and reactions to noise.

(2) SCPR Roads, Traffic and the Environment (SCPR, 1978)

The 1972 Survey, Road Traffic and the Environment, examined a wide range of attitudes to the area in whch people live and to road conditions outside the home. The factors that people considered to be the most disturbing from road traffic were, in order of priority:

- pedestrian danger
- noise and fumes
- dust and dirt
- vibration
- parking.

Respondents were asked to state whether they experienced each of the factors listed in Table 4.12 and how much they were bothered by it. About half of the respondents were disturbed by traffic noise. The proportions seriously disturbed by noise outside the home were significantly different from the proportion seriously affected inside the home. A majority of nearly 2:1 claimed to experience greater disturbance when out in their area than they did at home.

Fumes were a much bigger source of nuisance for people outside than when at home. 54% noticed them when out, 47% found them a nuisance. Although fewer people were disturbed at all by fumes, than by noise when outside it was fumes that evoked stronger responses.

Difficulty and danger of walking or crossing roads in their area was of at least some concern to more than two thirds (72%) of the sample; over a quarter were bothered 'quite a lot' or 'very much'. Disturbance due to visual intrusion arising from traffic was difficult to evaluate. The nature of the disturbance for pedestrians was not segregated from all other effects.

Table 4.12 Percentages of Respondents from the National Environment Survey who Identify the Following Factors as a Source of Nuisance in the Walking Environment (SCPR, 1978)

Bothered:	Noise		Fumes	Pedestrian danger
	At home	Out	Out	
very much	2	5	10	10
quite a lot	7	11	13	18
not very much	40	38	24	41
Not at all	51	46	7	31
Not experienced	0	0	46	0

The rank order attributed to the shortlist of five items by the respondents is given in Table 4.13. 29% did not rank the items at all because they were not bothered by any of them. The remaining 71% ranked them but not necessarily in a full sequence. They might pick out the two most annoying aspects and then give the others equal ranking.

Table 4.13 Rank Order of Pedestrian Difficulties Experienced in the Walking Environment (SCPR, 1978)

	Noise & vibration %	Dust & dirt %	Fumes %	Road crossing %	Parking - visual %
Ranked as most bothering	12	9	9	29	13
Ranked as second most bothering	18	18	17	16	13
Ranked as third most bothering	16	18	18	11	9
Ranked as fourth most bothering	15	16	17	9	9
Ranked as least bothering	10	10	10	7	27

From Table 4.13 it is apparent that road crossing problems rank first. This data has been summarised by inverting rank order scores (most bothering = 5, 1 = least bothered) to obtain the following mean ranks and scores. (Table 4.14)

Table 4.14 Aggregate Scores of Pedestrian Difficulties Experienced in the Walking Environment (SCPR, 1978)

	Rank mean (71% respondents)	Score *
Road crossing	3.7	68
Noise and vibration	3.1	53
Dust and dirt	3.01	50
Fumes	2.97	49
Parking	2.67	42

where:

$$\text{Score} = 100\ \frac{(\text{rank} - 1.00)}{4}$$

Those effects that were not experienced do not appear in the tabulated results. From the results it is evident that pedestrian danger, a shorthand term for a set of disturbances based on, but not only concerned with crossing the road was the most serious problem.

The SCPR Study indicates that road traffic is a major source of disturbance for pedestrians and that the wide range of problems are rated at a higher level of annoyance than those experienced in the home. This is not to suggest however that individuals would choose to seek improvements in walking conditions before improvements in the home.

(3) TRRL By-pass Schemes (TRRL, 1980)

The TRRL measured pedestrian reactions to conditions in high streets before and after the removal of traffic from a number of towns. From these attitude studies a range of mathematical equations was derived by which general nuisance from traffic conditions could be predicted. Some of these results are shown below. (Table 4.15).

Before removal of traffic danger was ranked the most important nuisance factor by pedestrians followed by noise, smoke and fumes, with dust and dirt least important. In the after situation danger was ranked the most important factor again although marginally ranked lower than before. Smoke and fumes and noise were ranked about equal in the after situation with dust and dirt ranked least important.

Table 4.15 The Rating of Pedestrian Problems in 13 Town High Streets Before and After Removal of Traffic (TRRL, 1980)

	Before	After
Danger	1.4	1.6
Noise	2.2	2.4
Dust/dirt	4.2	3.2
Smoke/fumes	2.4	2.0

where:
Factors ranked 1 - 5 in order of importance.
1 = most nuisance. Total scores divided by total responses.

In total traffic in the after studies appears to cause less nuisance to pedestrians than in the before situation, although this was not made explicit in the report. The extent to which pedestrians rated the overall change in conditions was not explained in depth.

On the basis of all residents' attitudinal reactions to conditions at all survey sites, predictive expressions for the percentage of residents bothered by traffic was derived. The expression using 16 hr traffic flow and number of heavy lorries was found to give the highest level of significance.

Hence,

$$Y = 14.4 + 0.002\ X1 + 0.0027\ X2$$

where :

Y = percentage of residents bothered by traffic
X1 = 16 hr traffic flow
X2 = 16 hr flow of heavy lorries
SE = 12%
r = 0.89

Although pedestrians were identified in the TRRL studies as the gro up most disturbed by traffic conditions it is somewhat strange that a similar modelling approach was not attempted from the pedestrian group reactions. It would be unlikely that 16 hr traffic flow would be a suitable measure in this respect - a shorter time period reflecting the shorter exposure period of pedestrians to those conditions might be appropriate.

It would be anticipated that these expressions are valid only for large scale traffic changes. It was not reported in the TRRL report whether different age, sex or pedestrian journey variables accounted for any differences in reported nuisance.

The studies by TRRL (1980) found that people in general expected more improvement from the effects of by-pass construction than actually occurred whilst measurements soon after the traffic changes were similar to repeat measurements made more than a year later. This suggests that longer term adaptation either does not exist or takes place over a period longer than a year.

4.4.2 Discussion and Conclusions

Table 4.16 illustrates from the literature reviewed those factors that have been mentioned by pedestrians as likes or dislikes about the walking environment. This Table illustrates the wide range of physical factors that people perceive. The numbers in the table refer to the factors that appear to be most important to pedestrians, based on frequency of response and ranking of effects.

Comparisons across studies require assumptions to be made regarding the questions that were asked, and the relative magnitude of the different factors and the way in which the results were compiled.

However the factors that appear to be dominant in defining amenity fall into 3 broad groups:

i) traffic conditions
ii) pedestrian facilities and infrastructure effects
iii) amenities and social aspects.

Traffic Effects

Traffic effects appear to predominate in the ranking of problems. This is especially true for response to unstructured questionnaires. Noise, danger, difficulty in crossing the road and fumes, together with the volume of traffic generally and of

HGVs are the physical factors that need to be considered further in a pedestrian study.

Pedestrian Facilities

Pedestrian facilities, notably the conditions of pavements and the presence of obstacles such as railings, steps and kerbs are rated as major difficulties in several studies, particularly for people with any physical difficulties in walking.

Amenity and Social Aspects

The appearance of an area and the presence of shops are cited as major factors liked or disliked about areas where people walk. Crowding is cited as an important effect in three studies.

A number of those factors cited as being important factors in the walking environments such as danger, convenience and accessibility are not well defined terms and likely to be construed in different ways by different groups.

A more thorough investigation of these factors is required to identify the appropriate dimensions for those factors from which to establish the relationship with pedestrian perception.

The studies reviewed have shown that different groups perceive different problems, sometimes related to their own physical capacities.

Differences in what factors people perceive as nuisance, for different journey categories or traffic levels have not been found in the literature.

The Manual of Environmental Appraisal (DTp 1983) uses traffic volume changes as indicators of amenity changes. As has been noted in this section amenity studies are complex and that traffic volume is but one factor that contributes to overall satisfaction or dissatisfaction with environental quality. Further different groups identify different problems when walking. MEA does not recognie the need to treat different groups separately.

The following section looks in more detail at the range of response to those factors experienced in the walking environment, and identifies thresholds of those factors which might be more appropriate for defining amenity standards.

Table 4.16 Factors that were Mentioned by Respondents from Different Studies as Being Important Likes

Factors perceived	CARP (1972)	LAUTSO (1973)	TEST (1976)	HILLS (1976)	PSI (1978)	SCPR (1978)	TRRL (1978)	T/WEAR (1984)
Traffic conditions								
Volumes			✓(1)		✓	✓(1)	✓	
HGVs			✓			✓		
Diff.crossing		✓	✓	✓(4)	✓		✓(1)	✓(1)
Danger/safety	✓(3)		✓	✓(4)		✓(1)		
Noise	✓(4)		✓(2)	✓(2)		✓(2)		
Delay			✓					
Fumes			✓			✓(3)		
Parking			✓			✓	✓	
Pedestrian factors								
Crossing facs.		✓	✓					
Gradients	✓(2)				✓(1)		✓(2)	
Subways/bridges	✓(2)				✓(1)		✓(3)	
Road width								
Visual intr.								
Pavement cond.			✓(4)	✓	✓(2)		✓(4)	✓(3)
Obstacles					✓			
Amenities/ Social Aspects								
Street furn.		✓	✓	✓				
Crowds		✓	✓	✓(3)	✓		✓	✓(2)
Appearance		✓	✓(3)	✓(1)	✓			
Shops		✓		✓(1)				
Distance walked	✓(1)							

where:

CARP = (1972)
LAUTSO = (1973)
TEST = Transport and Environment Studies (1976)
HILLS = (1976)
PSI = (1978)
SCPR = (1978)
TRRL = Transport and Road Research Laboratory (1978)
T/WEAR = Tyne and Wear County Council (1984)

5. FACTORS INFLUENCING BEHAVIOUR

5.1 Studies of Pedestrian Behaviour

5.1.1 Types of behaviour

The previous section has discussed the factors that pedestrians like or dislike in the walking environment and their relative importance in terms of nuisance ratings. Sections 5.2 to 5.7 consider in turn the most important of these factors, and the levels at which each of these factors engenders different responses is reviewed. Firstly it is useful to list the types of behavioural activities that might be modified by environmental factors.

There would appear to be eight types of response to changes in environmenta quality that could be quantified in a pedestrian amenity study. A number of these can be evaluated using conventional techniques; others might require the development of different approaches. The eight types of response are:

(i) No change noticed
(ii) Annoyance
(iii) Loss of time
(iv) Change of route
(v) Change of destination
(vi) Trip supression
(vii) Health effects
(viii) Accidents

Most recorded work has concentrated on responses (i), (ii) and where relevant (iii), (vii) and (viii). The extent to which the other responses have been studied in the literature is discussed in the following paragraphs.

5.1.2 Scope of pedestrian behaviour studies

Generally studies of pedestrian response to new schemes, such as pedestrianisation, have focussed on individuals' ratings of satisfaction with the changes in conditions (Stewart, 1981) or else counts of changes in pedestrian flows on selected routes (Weisnop, 1981). Few studies have analysed any changes in pedestrian routes or the impact of the changes in environmental quality on pedestrian health, other than accidents.

Assessments of existing pedestrian behaviour in the walking environment have tended to concentrate on how far people walk for different journey purposes (TEST, 1976; Rutherford, 1981). There have been no detailed micro-scale analyses of the factors that might cause variations in the propensity to walk.

Waldman (1977) studying inter-urban variations in the propensity to cycle found that weather conditions, gradients and safety were the 3 major factors which helped to explain differences between towns. Such a study might be usefully employed for analysing pedestrian travel behaviour.

5.1.3 The effect of environmental factors on walking distance

Two general studies have looked at the association between environmental factors and walking patterns.

Hills (1976) found that after pedestrianisation of a shopping street in Liverpool the numbers of people attracted to the central shopping area had fallen slightly. The proportion using buses had risen slightly although the walk distances for those using buses had increased. Bus users avoided using one of the central bus stations (although it was cheaper) because they disliked crossing the road and roundabouts. 36 per cent of respondents revealed that they disliked crossing by the footbridge provided.

Lovemark (1972) reviewing a series of pedestrian problems found that willingness to walk varies with the environment and means of transport. In two environments with similar standards of delay in crossing the road and public transport provision but different standards in width of pavement and aesthetic interest pedestrian walking trips for the same purposes differed by up to 30% in length. There has been relatively little follow up work to this important funding and the extent to which environmental quality affects trip length, walking speed and other behavioural response has been neglected.

5.1.4 Pedestrian route choice criteria

Two studies have examined the role that environmental factors have in influencing pedestrian route-choice. The TEST Study (1976) found that the majority of pedestrians' routes were selected because they were the most direct - rarely to avoid crowds or because they were perceived as pleasant, unless they happened to be the most direct as well.

Seneviratine and Morrall (1985) studied pedestrian route choice selection criteria amongst pedestrians at 36 locations in Calgary. Over 50% of the 2685 interviewed indicated the primary criterion to be "quickest route" except when the trip purpose was walking between shops. In this case most attractions was ranked as the most important criterion. Attractions were defined in the study in terms of shopping facilities and general aesthetic quality of the surroundings. The three highest ranked criteria for virtually all trip makers, journey purposes and journey times were all distance-related: quickest available route, route always used and only available route.

Environmental criteria were almost always ranked below distance criteria. "Number of attractions", "least crowded" and "least number of street crossings" were ranked as the fourth, fifth and sixth most important factors in determining route choice. When the purpose of visit was shopping or involves a trip from a bus to the shops then the "number of attractions" became the second most important criterion. The level of crowding was ranked fourth for journeys to work or associated with busness in the morning peak. Noise and crowding were ranked more highly by men than women. Noise and air pollution criteria generally ranked seventh or eighth. The main objective of pedestrians thus appears to be to minimize distance or more precisely perceived distance.

The influences of environmental factors on other pedestrian activities have not been significantly followed up since the work of Lovemark (1972). The following section describes in more detail studies of the different responses engendered by individual environmental factors.

5.2 Air Pollution

5.2.1 Effects of air pollution

Pedestrians are exposed to a wide range of gaseous and particulate vehicular emissions that occur at a variety of concentrations and which may have different effects on different types of pedestrian.

Pedestrian exposure to such pollutants is intensified by exercise and their proximity to the source compared with people in buildings but is lessened because the exposure period is typically low. Table 5.1 shows the potential effects on pedestrians of each pollutant on typical congested urban street levels.

Table 5.1 The Potential Effects of Air Pollution on Pedestrians

		Health	Odour	Visual	Secondary Reactors
Gaseous	Carbon Monoxide	✓	x	x	x
	Nitrous Oxides	✓	x	✓	✓
	Sulphur Dioxide	x	x	x	x
	Ozone	✓	✓	x	✓
	Hydrocarbons	✓	✓	x	✓
Particulates	Smoke	✓	✓	✓	x
	Lead	✓	x	x	x

Some of these effects, for example the brownish haze caused by nitrous oxide and the odours and haze effects of ozone tend to occur as an area-wide problem rather than as a localised effect.

It must be noted that health effects are normally evaluated by reference to air quality standards (see 5.2.3) and that there are no precise standards for assessing the aesthetic effects of vehicular air pollution.

Secondary reactions refer mainly to the formation of acid rain and photochemical smog which whilst in this country having little direct impact on the pedestrian may as a result of media attention affect general attitudes towards air pollution.

The Manual for Environmental Appraisal (DTp, 1983) uses the concentration of Carbon Monoxide as a general indicator of the level of vehicle pollution. The manual specifies that only when the effects of a new trunk road are likely to result in a breaching of the 9 ppm (8 hr average) carbon monoxide standard, is a special air quaity report needed. Carbon monoxide is a colourless and odourless gas and therefore unlikely to generate annoyance on its own. It is produced mainly from petrol engines whilst smoke, which is a major cause of visual and odour problems is produced largely from diesel engines. Further, it is produced at the highest rates under different engine operating conditions from nitrous oxides and particulates. For all these reasons carbon monoxide may well be an inadequate proxy for other pollutants.

5.2.2 Nuisance ratings

Several important pollutants, particularly carbon monoxide and lead are generally not perceived through any physical dimensions. Other pollutants may be visible or odorous, and this may alert the pedestrian to potential health hazards of air pollution in general, as well as creating nuisance. Therefore we may consider nuisance ratings to air pollution in general, as well as to those pollutants that are perceived as polluting.

There is little consensus in the literature for the factors which best explain nuisance. Candidate units include concentration, colour, size of plume and frequency of emissions, but for none of these have satisfactory relationships with nuisance been derived.

The WYTCONSULT study (1977) adopted the following thresholds of noticeability and undesirability for pedestrian exposure to smoke and carbon monoxide (Table 5.2). These thresholds, for carbon monoxide were derived from those used by the GLC (1975) which in turn derived them from World Health Organization recommendations. These standards are heath related rather than nuisance-based and the threshold descriptions might therefore be misleading. In the analysis roads were graded according to their sensitivity to the environmental effects of traffic and higher thresholds were used for less sensitive links.

Table 5.2 Thresholds for Pedestrian Exposure to Smoke and Carbon Monoxide Concentrations (WYTCONSULT 1977)

Link Sensitivity Grade	Noticeable Smoke	Undesirable Smoke	Noticeable Carbon Monoxide	Undesirable Carbon Monoxide
1 - 3	60	80	5	8
4 - 6	70	100	5	9
7 - 9	80	140	5	11

Smoke concentrations in microgrammes per cubic metre
Carbon monoxide concentrations in ppm - 8hr average.

No other studes have been found which specifically attempt to provide nuisance thresholds for "aesthetic" effects of vehicular-related air pollution. It is however highly unlikely that in every situation where people find smoke annoying, the smoke concentration would correspond to the values included in Table 5.2. It is not clear what the appropriate unit of analysis for evaluating the visual effect of air pollutants should be.

5.2.3 Health effects

Air quality standards are based upon extensive research in a variety of disciplines. These normative standards are applied to safeguard public health. Air quality standards recommended by the Department of Transport for assessing the possible air pollution impact of a new trunk road have been dopted from the US Federal air quality standards (MEA, 1983). These standards are listed in Table 5.3.

Table 5.3 US Federal Air Quality Standards

	Average Period	Concentration ppm	g/m^3
Carbon Monoxide	1 hr annual maximum	35 *	
	8 hr annual maximum	9	
Nitrogen Dioxide	1 year arithmetic mean	0.05 *	
Particulate Matter	24 hrs annual geometric mean		75
Hydrocarbons	3 hrs annual maximum	0.24	

Standard adopted by DTp *

Recent USA research has suggested that the Carbon Monoxide 1 hr Standard should be reduced from 35 ppm to 25 ppm (EPA, 1984) to safeguard public health. There is strong evidence to show that the 8 hr Co standard of 9 ppm is breached on many streets in London (GLC, 1981).

The Lawther report (DHSS, 1980) reviewing the contribution that lead in petrol makes to the body burden recommended that the annua mean concentration of air borne lead should not exceed 2 micro grammes per cubic metre in places where people might be continuously exposed for long periods. The GLC has suggested an undesirable and an action threshold for particulate lead of 500 pphm and 5000 pphm respectively (Burningham, 1982).

Little work has been carried out to study the health risks of pedestrian exposure to different levels of air pollution concentrations typically found on urban streets. This would appear to require increasing priority in vew of the demographic trend towards an ageing population in this country.

5.2.4 Thresholds

The only available pollution thresholds are health-related ones. Most of these are cited in Table 5.3; that for lead is an annual average of 2 g/m^3.

No thresholds can be quoted for nuisance or behavioural responses, and this appears to be an important area for research, particularly given the widespread concern with diesel smoke.

5.3 Noise

5.3.1 Noise measurement

The impact of traffic noise on residents has been extensively studied (Langdon, 1976; TRRL, 1980). The effects on pedestrians exposed to traffic noise at different levels has not been extensively studied.

Generally the L10 measure - the noise level exceeded for 10% of the time, has been shown to be well correlated with residents ratings of annoyance with noise. The Manual of Environmental Appraisal (DTp, 1983) indicates that a change in the L10 18hr measure of 3dBA or higher is significant and that the number of households affected by such noise changes should be calculated.

Pedestrian exposure to traffic noise is generally for a shorter period of time than for residents.

It is unlikely that pedestrians will discriminate noise level changes in the range of $\pm$ 3dBA L10 dBA 18hr, but will make judgements about whether they find noise levels on any particular street acceptable. It is appropriate therefore to establish an absolute rather than a relative noise threshold for evaluating the significance of noise impact on pedestrians.

Expressions for predicting noise levels under congested conditions have been derived (Langdon, 1976; Gilbert, 1980) but have not been used for relating pedestrian annoyance to prevailing noise levels. These predictive expressions give little weighting to motor-cycle noise which as reported in the SCPU study "Road Traffic and the Environment" (1978) is rated the most disturbing source of traffic noise by 19% of householders when out in their local area. L10 values derived using these expressions however by Langdon and Gilbert may have a weak correlation with pedestrian annoyance when their traffic flow contains some proportion of motor cycles.

5.3.2 Nuisance ratings

The WYTCONSULT (1977) used the following thresholds for noise impact on pedestrians (Table 5.4).

Table 5.4 Thresholds for Pedestrian Noise Exposure (Source: WYTCONSULT 1977)

Land Use Sensitivity	Noticeable	Undesirable
1 - 3	68	72
4 - 6	70	74
7 - 9	72	76

All values L10 18hr dBA.
Note L10 1hr values are approximately 3dBA higher than the L10 18hr values.

The noticeable thresholds are based on background external noise levels found typically in urban areas.

The undesirable thresholds were derived from the traffic volume and composition characteristics which represent the desirable maxima which might normally be expected for streets of the different land use types with pedestrian access (the assumed environmental capacity) viz;

	Vph	% HGV	dBA * L10 18 hr
Residential	400	5	72
Shops, Offices	600	10	74
Industrial	600	25	76

* Assuming kerbside-noise level; assuming a carriageway width of 33 ft and a traffic speed of 30 mph.

The TEST study (1970) found that over one-third of pedestrians found noise levels in the L10 1 hr range 70-80dB(A) to be disturbing.

They did not however identify any thresholds at which a certain proportion of people were affected by the noise level or significant increases in nuisance ratings were triggered.

A survey of shopping streets in the West Midlands (Junue, 1977) reported that across the entire County the average L10 1 hr dBA values at kerbside sites along major shopping streets were between 72-74dBA. This study found that increases in nuisance with incremental increases in noise were greater at higher noise levels (above 74dBA L10 1 hr) than in the lower regions.

5.3.3 Behaviour response

The extent to which road traffic noise modifies pedestrian behaviour; and how the cause of any modification have not been extensively explored in the literature. Noise levels at which conversation becomes difficult often refer to indoor levels. The Committee on the Problem of Noise (HMSO, 1963) stated that at L10 1hr 60dBA conversation becomes difficult.

Two detailed studies have been found which have explored the effect of noise levels on pedestrian behaviour. Karte and Grant (1980) have examined the effect on traffic noise on environmental awareness. They hypothesised that a person subjected to an excess of environmental stimuli would adopt tactics to reduce these inputs to be more tolerable. 80 pedestrians were observed under different noise conditions. Noise readings were taken 2 metres away from the kirb and 3 minute recordings were made of the traffic noise. This procedure was repeated after an interval of 3 minutes. The traffic noise level was establishd from these measurements and divided into a high category 74dBA and above, and a low category below 70dBA. The exact unit of measurement has not been specified.

The patterns of activity and length of residence on street of the two groups were not significantly different. Respondents interviewed were aware of 3 test items planted on the survey street 56% of the time in the low traffic noise conditions, 35% of the time in the high traffic noise conditions. The higher traffic noise conditions led to faster walk speed, and more straight ahead gazing. The survey tentatively offers evidence that noise could be a contributory factor to these differences in behaviour. The paper concludes that as yet there is no clear indication of the physical and mental toll suffered by pedestrians who have to cope continuously with congested conditions. Page (1982) offers further eivdence that high intermittent noise levels have a signficant effect on pedestrains' willingness to help other pedestrians. Several hundred pedestrians in the USA were observed to see whether they would assist a researcher pick up some parcels she had dropped. In the "low-noise" situation respondents were more likely to pick up the parcels.

5.3.4 Thresholds

There has been relatively little study of pedestrian annoyance to different levels of traffic noise. The only precise threshold that has been quoted in the literature is the "undesirable" noise level 74 dBA L10 18hr (WYTCONSULT, 1977). It appears that changes in noise levels in this range cause a greater increase in noise ratings than at lower noise levels (Jurue, 1977). Traffic noise appears to have an effect on pedestrian behaviour but the results from the studies found remain tentative.

5.4 Danger

5.4.1 Measurement

In theory danger can be measured in terms of the objective probability of injury, physiological reactions to fear or attitudinal expressions of anxiety. Unfortunately none of these is an ideal measure. The first appears to have little direct relationship to expressed danger while the others are difficult to measure on a regular basis. As a result it is difficult to define or measure danger adequately, or to separate out the ndividual causes of a sense of danger.

5.4.2 Nuisance

Broome (1984) carried out a study of the extent to which HGV's in a traffic stream contributed to residents' an pedestrians' rating of danger. The study found that noise was not a good indicator of Lowry nuisance but that low frequency noise (<63 Hz) might be if it could be easily measured. Fear was the most important pedestrian reaction to the presence of lorries but the direct assessment of fear proved difficult. Smoke and fumes which were also identified as a source of nuisance from lorries and contributed to the sense of danger were also difficult to assess. The nuisance rating of lorries was more pronounced when people were walking along a road than when they were at home. The studies carried out by local authorities provided little firm data from which to develop any meaningful dose-response relationships. The model suggested by Broome for predicting pedestrian nuisance was based on a form suggested by the Merseyside County Council is as follows:

$$I = a \cdot \frac{Q}{W} (1 + b.H\%)$$

I = is a measure of intimidation
Q = traffic flow per standard lane
W = path width
H% = proportion of multi-axled HGV's in the traffic flow
a and b are constants

The concept of "intimidation" is not particularly useful unless there are clear indications of what its dimensions are and what it is that is causing the intimidation. The expression has not yet been calibrated.

An extensive study of pedestrian annoyance with road traffic conditions was performed by Crompton (1978). The aspects which appeared in the final report and are of relevance here are difficulty in crossing the road (5.5.3 and 5.5.4); worry about safety in crossing and assessment of hazard.

The proportion of people interviewed who were worried about the safety of crossing the road showed little variation for different types of crossing.

	Random Crossing	Pelican Crossing	Zebra
% Worried			
Mean	35	27.1	35.2
S.D.	9.1	9.6	16
Range	17.2-50.9	12.8-42.9	12.9-62.5

Figures are in percentages.

Levels of delay or traffic volume were not factors which affected the proportion of people who were worried.

Accompaniment, especially of young or elderly people, was the only factor affecting the worry rate. The following expression was found to have the best fit with the subjective response date.

$$P = 10 \log HGV + 0.93\ C \cdot \frac{(PX)}{(PR)}$$

P = percentage worried
h = flow of heavy goods vehicles per hour
L = length of street surveyed

PX = Numbers of pedestrians along (L) per hour
PR = Numbers of pedestrians crossing street (L) per hour

Such results whilst of some interest need to be related specifically to traffic levels in order to derive more generally applicable dose-response relationships. Further the expression tells us nothing about the strength of the worry or how this might contribute to behavioural responses.

A field site survey using students to rate how hazardous they perceived road crossing conditions as pedestrians was carried out at a number of sites in London. This was reinforced by a series of laboratory studies using slides of traffic scenes to test those students' reliability in predicting hazard and how their rating of conditions was related to different traffic densities. The students' ratings of hazard at the different sites were aggregated to derive the following hazard categories:

Assessments	Vehs/hr
slight	< 700
moderate	700 - 1300
great	1300 - 2000
extreme	> 2000

5.4.3 Behaviour

Adaptive behaiour to perceived danger may take the form of:

(i) Greater use of road-crossing facilities
(ii) Route changes to avoid conflict
(iii) Trip abandonment
(iv) Restriction of vulnerable pedestrians.

Item (i) is dealt with in the subsequent section.

The SCPR study (1978) asked householders to state which roads in the area they would allow children under their care to cross unaided. The flows at which the sample would be equally divided as to whether they would allow the child to cross the road are as follows:

Child aged	4	0
	6	85
	8	400
	10	1500

Fears of walking along a road with no pavement were expressed by 29% of those interviewed. Over half the sample were sometimes worried about the safety of other people.

The vehicular flow at which 25%, 35% and 50% of respondents had difficulty in crossing the road were as follows:

% respondents	Occasionally	Often
25	200	700
35	300	900
50	600	1800

Crompton (1978) whilst exploring in detail many aspects of pedestrian delay and annoyance with crossing the road did not specifically look at the extent to which people adopt their behaviour to minimise delay (such as choosing alternative routes) or whether trip supression is a possible outcome of perceived or expected delay. Ina complementary study however the extra distance that people might be prepared to walk to a "service" to avoid having to cross a busy road was investigated in a trade-off study. The expression for willingness to walk extra distances was as follows:

$$P = 24.76 + 0.74\ EWD - 7.2 \times 10^{-6} \times Q^{2}$$

P = percentage crossing to point A

where

EWD = extra walk distance in feet to nearside service

Q^2 = hourly traffic flow

This expression predicts that for a 13' increase in walk distance to the service on the nearside pavement would result in a 100% increase in the proportion choosing to cross. This expression takes no account of people who have difficulties in walking, the presence of crossing facilities or other activities that the pedestrian may pursue.

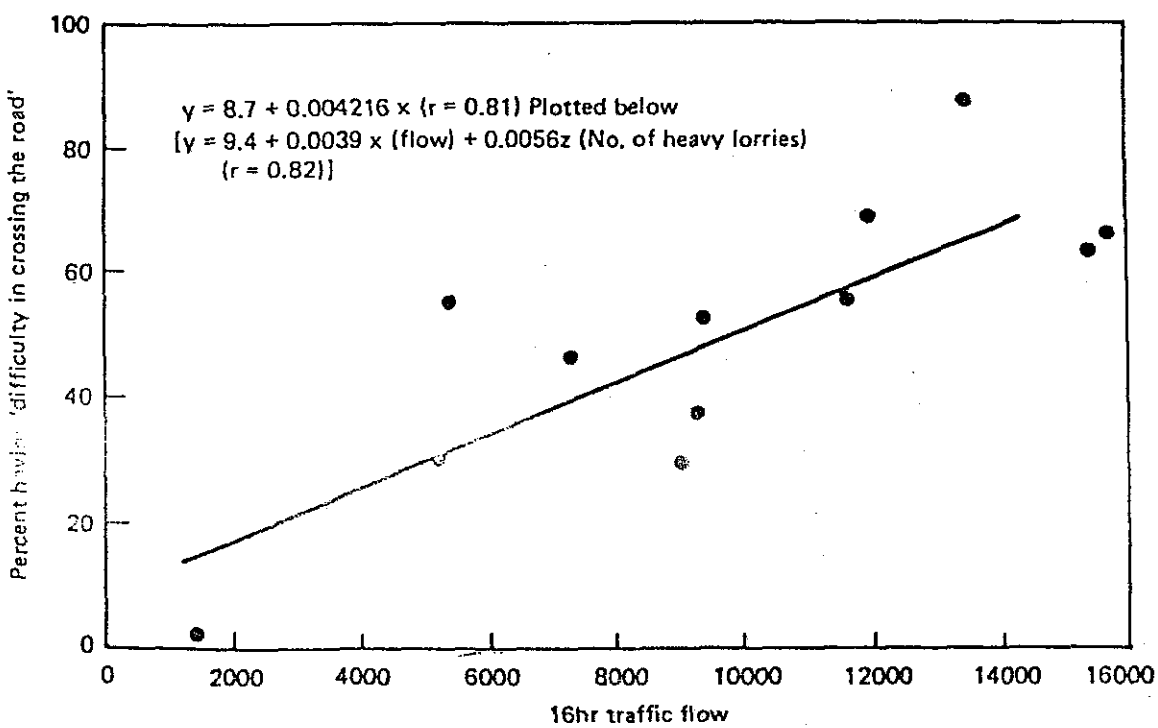
Katz (1978) found that road crossing behaviour was affected by concern over safety but that path deviation of more than 30 m (from a straight line distance) are resisted by pedestrians. Mohammed (1983) studied the distances that people were prepared to walk to use footbridges to cross busy roads, but did not indicate to what extent perceived danger contributed to this. Lovemark (1972) suggested that the willingness of pedestrians to walk further to reduce danger is overestimated.

5.4.4 Road crossing difficulty

Difficulty in crossing the road is treated as a separate section because of the difficulty of assigning the activity to either the nuisance or the behaviour category.

The TRRL by-pass study which made systematic observations of pedestrian road crossing difficulty and correlated this to prevailing traffic conditions derived the following relationship (Fig. 5.1).

Figure 5.1 The Percentage of Pedestrians Observed Having Difficulty Crossing the Roads with Different Traffic Flows



It is apparent from this diagram that there is no appropriate flow or change in flow which can be used as a threshold figure. The 16hr flow at which 50% of pedestrians are observed to have difficulty crossing the road is about 10,000 vehicles (= 600 vph) although the scatter of this median point ranges between about 6000 and 12,000 veh. per 16hr flow (375-750 vph).

The TEST study (1976) revealed that over a quarter of respondents in Kentish Town Road had some difficulty in road crossing during the day of the survey. 64% were observed to have difficulty or delay crossing the road.

The SCPR study (1978) derived a set of relationships between reactions to road crossing difficulties and fears and traffic flow. Residents were asked about difficulties that they encountered when walking. It was found that the 18hr traffic flow measures were the most important independent variables in predicting scores on the index of general annoyance. The reactions to some perceived difficulties are shown in Figure 5.2.

The figure shows that the percentage of respondents claiming to have difficulty crossing the road outside their home increases proportionately with increase in traffic below 500 vph, the slope of the line being approximately as follows:

$$\% \text{ finding difficulty often} = 0.035\,Q$$

where Q is the hourly flow.

The traffic level at which trip diversion or trip abandonment might be triggered was not explored.

Crompton (1978) developed the following provisional predictive expressions for the percentage of all respondents who found crossing the road difficult:

Random sites = 26.1 + 2.1 (mean delay) ($r^2 = 0.69$)
Pelican sites = 13.3 + 2.0 (mean delay) ($r^2 = 0.75$)
Zebra sites = 10.4 + 2.6 (mean delay) ($r^2 = 0.87$)

The study involved observations at 31 different sites with different crossing facilities and traffic conditions. The percentage having difficulty crossing at the three different types of facility are shown below but these are not however correlated with traffic flows.

		Random	Pelican	Zebra
% having	mean	44.3	24.6	22.8
crossing	s.d.	16.5	17.5	12.5
difficulty	range	0-71.7	0-55.9	12.5-47.5

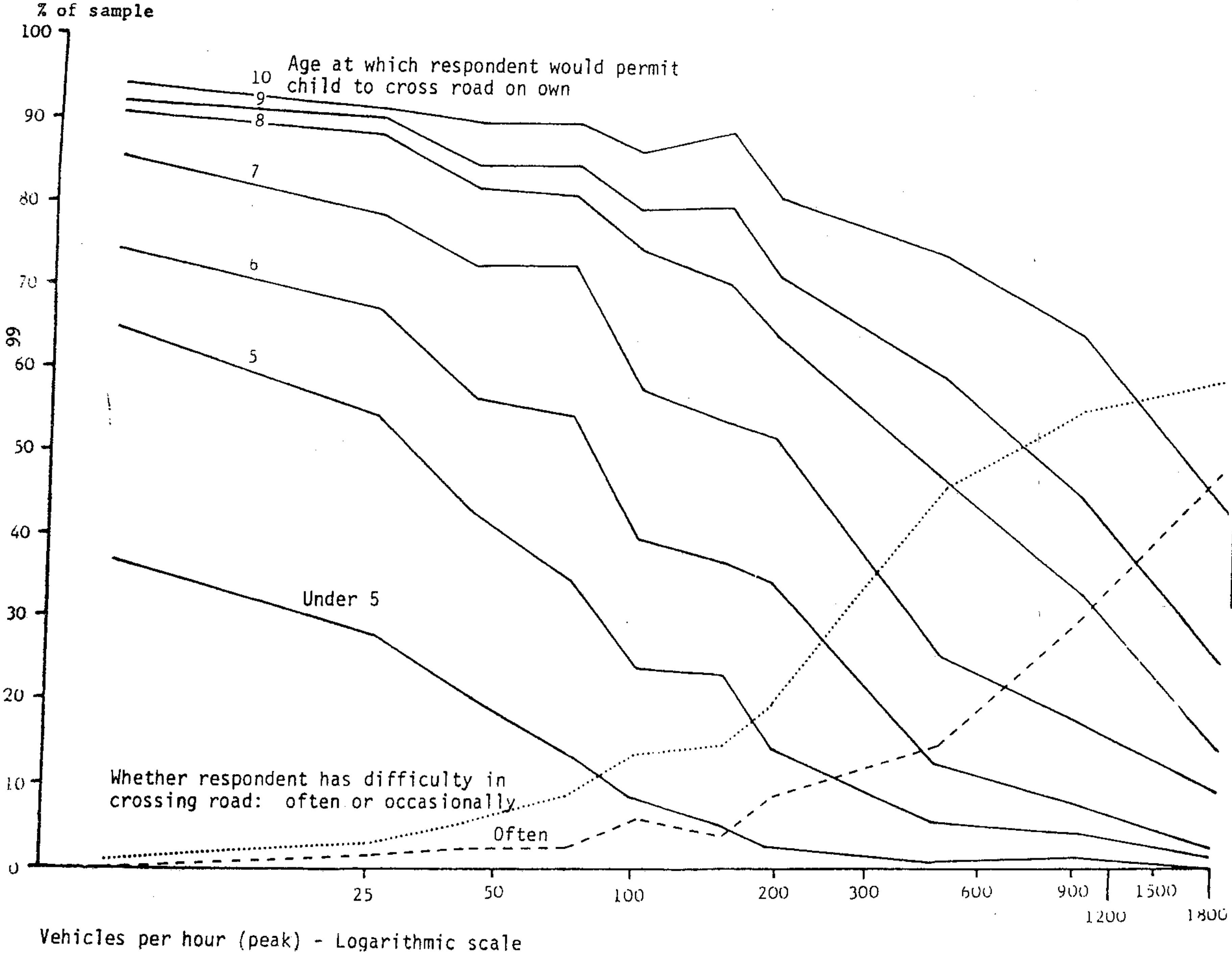
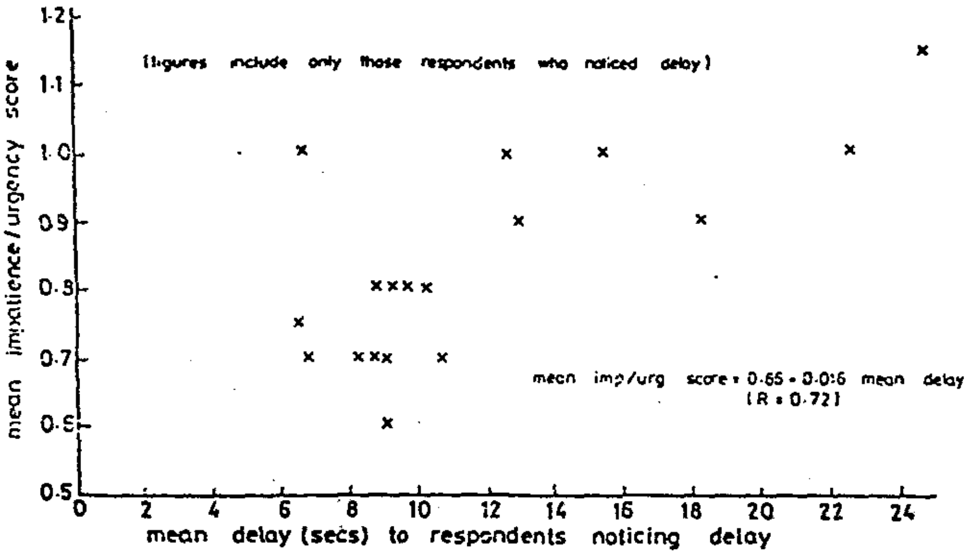


Figure 5.2 Perceived Difficulties in Crossing Roads

These results indicate that with an increase in delay with crossing the road there is an increase in the percentage of people reporting difficulty in crossing the road. It appears therefore that a change in delay, which may arise from a change in traffic flow, will lead to a series of other behavioural and attitudinal changes. Unfortunately the data presented makes it difficult to establish any clear thresholds for road crossing difficulty. Figure 5.3 indicates for the relationship between impatience in crossing the road and mean delay experienced the diffuclty in establishing appropriate or reliable thresholds.

Figure 5.3 Percentage of Respondents Who Noticed Delay and were Impatient v Mean Delay



Source: Crompton, 1980.

5.4.5 Thresholds

Although danger itself cannot be measured, a series of traffic flow thresholds can be identified above which danger is felt, or leads to changes in behaviour.

700 veh/h represents the onset of 'moderate' danger an 1300 veh/h 'great' danger. However, the majority of respondents did not often experience difficulty in crossing at flows below 1800 veh/h. At 600 veh/h, 50% of respondents would not permit a child of 8 to cross the road unaided.

5.5 Pedestrian Accidents

In 1983 over 61,500 pedestrians were killed or injured on the roads of Great Britain. This represents about 20% of all road users who were killed or injured during the same year. Fatalities, however, were of a higher percentage for pedestrians than for all road users; 3% of pedestrians involved in an accident were killed in 1983 compared with just less than 2% for all road users. Although the numbers killed have dropped by over 30 percent since 1965, with a corresponding decrease in the numbers of pedestrians injured, this does not indicate the total situation. Goodwin (1977) indicates that the actual accident figures say little about the risk involved in walking. Per mile travelled, he estimates the pedestrian is six times as likely to be involved in an accident as is a car driver. Goodwin also correlates accident rates with sex and age and concludes that whilst women under 60 years of age are less likely to be involved in an accident than a man of the same age, the very young and the old are almost twice as much of a risk as those in the range 20 years to 60 years. Todd (1980) supports this view and attempts to explain such accident rates by looking at road crossing behaviour. For example, 93% of pedestrian accidents were found to have occurred on the highway with 85% associated with a road crossing manoeuvre. Todd found that the location of the crossing was also important in that 80% of pedestrian road crossing accidents were not near a crossing facility. Of those on or within 50 yards of a pedestrian crossing 45% of accidents occurred not actually on the crossing, suggesting that it may be 5 times as dangerous to cross within 50 yards of a pedestrian crossing as on the crossing itself. No clear relationship was developed to link pedestrian and vehicle flow to accident rates save to say that 25% of all pedestrian accidents occur on about 2% of urban roads.

Chapman (1982) indicates that although annual accident statistics are broken down by age and sex, these variables are not the only relevant contributing parameters. Important also are temporal factors such as season, day of week and time of day, as well as spatial factors governing the characteristic location of accidents. It is in the latter areas however where perhaps least research has been conducted, especially in recent years. Accident studies then, fall into the following four categories:

(1) Temporal studies
(2) Spatial studies
(3) Road crossing studies
(4) Pedestrian exposure to accident risk

5.5.1 Temporal studies

The DTp Road Accident statistics give an annual breakdown of accident statistics analysed by time of day and by day of week. Data are presented separately for child and adult pedestrians. From these statistics temporal variations can be observed for both children and adults. For example, the within-day pattern is different for children and adults and weekends show a different within day pattern for both age groups. Also, for adults the pattern of Friday accidents can be distinguished from the pattern of the other weekdays. Peaks of accidents also occur:

For children the main peaks are at 4pm weekdays and to a lesser extent 8am-12 noon. At weekends the distribution is more even. Adults experience the largest peak at 5pm weekdays (4pm Friday) with smaller peaks of equal dimensions at 81m, 12 noon and 11pm. However the 11pm peak increases in size at weekends, thus becoming much more significant.

Grayson (1975) conducted a survey of 474 child pedestrian accidents in Hampshire and concluded that journeys to and from school accounted for a similar proportion of accidents. Also, 35% of school children injured between 4pm and 5pm were coming from school and only half the children injured during this period were going home. Therefore it appears that a substantial proportion of child pedestrian accidents during the late afternoons of weekdays occur as a result of journeys other than those undertaken for the purpose of going to and from school as is often postulated - for example, playing, running errands and visting.

One possible factor contributing to the late evening peak in the adult pedestrian casualty statistics is the alcohol-intoxicated state of some pedestrians at that time of day. Clayton (1977) found that 33% of fatally injured pedestrians had been drinking alcohol and 15% had an alcohol level in the blood in excess of 150 mg per 100 ml. If the role of alcohol is significant however, it may be confounded to some extent by the effects of darkness. In Britain, about one out of four pedestrians sustain their injuries of all severities during the hours of darkness. Swedish data from insurance company records (Sandels, 1979) is more dramatic. Half the accidents to 25-64 year-old pedestrians took place during the hours of darkness. Sandels notes however, the effects of weather and seasonal changes within this figure, and acknowledges that further analysis is required.

5.5.2 Spatial studies

From the Accident Statistics 1983 (DTp, 1983) it is revealed that 97% of child pedestrian casualties and 93.5% of adult pedestrian casualties incur their injuries in 'built-up' areas. It is now well documented that pedestrian accidents to young children (under 10 years) occur predominantly on minor roads in residential districts, and within a short distance of their homes (Grayson, 1975; Chapman, 1979, 1981). Studies have tended to be orientated towards the child pedestrian however and further work is required looking at a variety of road types and ages of pedestrians. The occurance of high percentages of pedestrian accidents on a small section of any road network has implications for the development of urban road appraisal.

5.5.3 Road crossing studies

Since most pedestrian fatalities occur at or near urban intersections, engineers and planners have tended to conclude that pedestrian signals would improve pedestrian safety. Khasnabis (1982) conducted a review of current pedestrian signal literature.

Williams (1978) discussed the evolution of the pelican crossing in England and Australia. He was unable to concude that pelican crossings significantly increase pedestrian safety and mentions that at sites where positive safety benefits were indicated, the results were often masked by other factors such as the installation of anti-skid surfaces and/or guardrails. Williams evauation of pelican facilities does not, however, indicate any adverse effect of the devices.

Inwood (1979), in a study conducted for the Transport and Road Research Laboratory analysed injury accident data, pedestrian counts and vehicle flows for lengths of road on or near pedestrian crossings. The prime objective of the study was to compare pedestrian accident rates at zebra and pelican crossings located at similar sites in terms of visibility and proximity to busy intersections. The study showed no evidence of a difference in pedestrian accident rates between pelican and zebra crossings. However, pelican crossings tended to have a lower total injury accident rate than zebras when the road length in the vicinity of the crossing was taken into account. For injury accidents then pedestrian-activated signal crossings were found to be more effective than zebras.

Limited information is reported in the literature regarding the use of actual pedestrian accident data for crossing movements. Some studies have looked at accidents in relation to specific intersections but the data base used in such studies is too small to permit the development of general conclusions. Work by Zegeer (1982) relates to pedestrian accident experience rather than pedestrian behaviour to compliance measures. Zegeer looked at two situations:

- o The analysis of pedestrian accidents before and after the introduction of a pedestrian signal.
- o A comparative analysis of accidents at locations with and without pedestrian signals.

Zegeer found that certain levels of pedestrian and vehicle volumes relate to increases in the numbers of pedestrian accidents at the sites which he studied. Data was compiled from accident, traffic and roadway data files and regression analysis indicated that pedestrian volume is the single most important variable in explaining the variation in pedestrian accidents. Critical steps appear to be at 1200 and 3500 pedestrians/day and at traffic levels of 27500 and 18000 vehicles/day. The study is not based on an analysis of accident rates at specific locations and although acknowledging that other variables infuence the occurrence of pedestrian accident rates it is not specific about their nature. Considering other types of facility, Lalani (1977) found that the provision of refuges, which are often thought of as pedestrian facilities, decreased the vehicle accidents at 52 out of the 62 sites which he studied. However it was revealed that pedestrian accidents rose at all 62 sites with the introduction of a central-refuge.

5.5.4 Pedestrian exposure to accident risk

Accident studies rely largely on exposure data for an assessment of accident risk. The following studies have been carried out not as accident studies for an assessment of potential remedial measures but as attempts to evolve a methodology for the collection of exposure data which may then be used in future studies.

Over recent years distance (Howarth, 1982), traffic volume, vehicle hours and vehicle-miles have been used as a basis for estimating accident rates. Chang (1982) identifies these parameters as inadequate if other factors such as geometric layout and infrastructure obstruction to pedestrian movements (guardrails, bollards etc.) are not taken into account. Chang argues that it is the aggregation of all such factors which determine the risk of accidents occurring and it is this risk potential that should be used as a proxy to the implementation of road safety measures.

Cameron (1982) describes a method of collecting exposure data with the objective of measuring pedestrian accident risk, by comparing the exposure data with the occurrence of pedestrian accidents. Based on the study, exposure was defined as the product of the numbers of all pedestrians and vehicles passing through (or observed within) a specified 40m road section in the same 5 minute interval. The analysis was based on 26 variables ranging from sex and age to pedestrian alcohol condition, speed limit, lighting and pedestrian behaviour. The model developed produced accident rates (accidents divided by exposure) and was found to agree with expectation and past research. High accident risks were found for pedestrians under 11 and over 60, especially for males. The young, more frequently, were found to run across the road than pedestrians in general, and have a particularly high risk in this activity. Also, this risk is increased if they cross a road alone, as is the risk for the elderly. The study concludes that at signal lights and other pedestrian crossings, the differences in risk with respect to age are diminished and that relative to distance travelled, pedestrians as road users have a casualty accident rate second only to motorcyclists. This relative order is in agreement with Goodwin (1977). However, in the Cameron study accidents involving pedal cyclists were not counted despite being shown by Goodwin to have potentially a greater risk of accidents than the pedestrian.

Van der Molen carried out a study to develop an educational policy for reducing child accidents. He attempted to evaluate the performance of 26 tasks from walking along the street to crossing a wide multi-lane intersection. Using observation and interview techniques developed elsewhere (Routledge, 1974) Van der Molen identifies a number of factors important in exposure analysis, namely:

(1) Individual behaviour
(2) Individual exposure

(3) Psychological abilities and limitations

No results are available at present. However what is relevant is the scope of such a project which aims to analyse appropriate pedestrian behaviour for a number of traffic situations in relation to accidents, exposure and behaviour, not just one isolated variable.

Jonah (1983) took the work of Howarth (1982) and Routledge (1974) and looked at accidents, exposure data and accident rates for a number of sites to produce indicators of relative risk. Results revealed that children (3-12 years) and the elderly had the highest accident risk but only when distance travelled, duration and number of streets crossed were used in the exposure index. Jonah concudes that his results demonstrate that exposure data is critical in defining target groups for pedestrian safety programs.

Indeed data on pedestrian exposure have considerable value for understanding pedestrian accidents and designing remedial measures for them. The data is often expensive to collect however. For example accident data may be collected by police reports (Stats 19A) or on site interviews but only the former may be cost effective. For exposure data, Jonah indicates that retrospective interviews and roadside observation studies are both required demanding resources of finance and manpower in large quantities.

Cameron (1982) highlights two particular requirements for further work in this area, in the light of deficiencies in the model of pedestrian exposure which he developed, and this is supported by Jonah (1983). Firstly in looking at accident statistics and police reports a clearer definition of operational terms is required to avoid the use of obscure and misunderstood terminology such as 'boarding' public transport and 'pedestrian visibility'. Secondly, in the development of modelling techniques further studies need to be conducted which look at a range of sites, stratified by traffic controls and other site variables. This will overcome problems of having to analyse site variables which may not be representative of the area as a whole.

5.6 Pedestrian Delay

5.6.1 Measurement techniques

There are at least three components of delay which the pedestrian can experience when undertaking a walk trip

(1) Geometric delay
(2) Level of service delay
(3) Road crossing delay.

Wright (1982) defines geometric delay as the practical minimum walking time minus the minimum walking time unimpeded by vehicles, street furniture, or other pedestrians. The delay may be caused by street layout, street furniture, control devices, physical barriers to movement or irregularities in the kerb or carriageway. Geometric delay is just as important to the pedestrian as to the driver, in the sense that it accounts for an appreciable proportion of the pedestrian s journey time, especially when taken alongside road crossing delay. Wright concludes however, that it is not so clear to what extent pedestrians actually perceive geometric delay as an important factor in their decision making process.

Levels of service delay on busy pavements often results from a real reduction in pavement width from road widening or more generally from infrastructure obstructions and slow moving window shoppers. Several studies (Polus, 1983; Fruin, 1971) have attempted to measure such delay and relate it to typical pavement densities at a variety of locations. The relationships derived in a series of studies which look in more detail at the behavioural effects of crowding on footways are set out in 5.7.2.

Road crossing delay is perhaps a more tangible and therefore easily modelled form of pedestrian delay. It depends on the minimum gap in the traffic which the pedestrian is willing to accept and also the time taken for a gap of at least this size to appear. The latter depends in turn on the flow of traffic and the characteristics of that flow, and of any controls on that flow.

The literature shows that pedestrian delay is able to be predicted for a number of situations, and is most frequently expressed as the average delay per pedestrian. Delay may also be presented in the form of the percentage of pedestrians delayed or the percentage of pedestrians experiencing greater than a given threshold of delay, but there appears to be a clear relationship between these parameters and average delay. For economic evaluation purposes, of course, total delay will be required.

GMC (1976) indicate the variation in mean delay experienced at a variety of crossing facilities, ranging from 3.4 seconds at zebra crossings to 9.4 seconds at traffic signals and 16.9 seconds at pelicans (Table 5.5).

The measurement process is considered in 3 stages.

(a) Gap measurement

It was suggested by Ashworth (1971) that the majority of pedestrians have critical acceptance gaps in the range of 2-6 seconds and that they normally accept gaps in the traffic to cross a road in the region of 5-7 seconds, depending on road width (DoE, 1968). The individual's ability to measure gaps of this size depends on his judgement of vehicle speeds. Bergman (1982) studied the accuracy of pedestrians' speed estimation. He found that lighting, sex and age had no significant effect on speed estimation and that overall slow speeds (10-20 mph) were estimated the most accurately, while higher speeds were overestimated. Both the earlier empirical models of Tanner (1951) and the later simulation modelling techniques of Hunt (1982) depend heavily on the ability to estimate the critical gap in traffic flow which is acceptable to pedestrians. The measurement of critical gaps is made difficult because pedestrians often disguise the gaps which they reject, and conversely more cautious pedestrians are more likely to reject gaps, thus biasing the results. Ashworth (1971) discusses these problems and suggests ways of overcoming them. Goldschmidt (1977) adopts a different approach in which an observer judges whether he would be able to cross. Maher (1983) attempts to show some of the benefits which might be gained from a more general approach to the problem of estimating gaps. Maher suggests that least squares regression may be an overworked and often an inappropriate method, but it used because it is conveniently available in package form on most computers. Such a method may include gaps into which no pedestrian entered and this creates bias. By omitting such gaps, much of the data becomes redundant. Maher concludes that a maximum likelihood estimation (consisting of writing down the probability, or likelihood, of obtaining the observed values of the data as a function of the model parameters and finding those values of the parameters which maximise this likelihood function), has very desirable unbiased properties especially when applied to very large data sets.

(b) Crossing studies

Hunt (1982) developed a simulation model of delays in crossing the road at random points and at zebra and pelican crossings. Output was in the form of mean delay, the proportion delayed and the proportion of pedestrians with a delay greater than a specified level. Accurate prediction of these parameters is shown to depend primarily on the ability to model pedestrian crossing behaviour and vehicle arrival distribution adequately at a particular site. For this reason the model is limited to a consideration of a restricted range of crossing types. He concludes that pedestrian delay is lowest at zebra crossng (1-2 seconds) for a given pedestrian flow. Clearly a full quantitative comparison of crossing types can only be made in a situation where influencing factors can be controlled as in a simulation model of the form used by Hunt.

King (1977) utilizes the analytical techniques of Tanner (1951) to explain the case for pedestrian signal warrants. He bases these on a consideration of the average or maximum delay for both pedestrians and vehicles. King accepts the theory of critical gap acceptance and suggests that if the pedestrian 'threshold' of delay is violated then it will become necessary to introduce traffic control devices to create artificial gaps in the traffic flow. To vindicate this approach studies by Pye (1983), show the benefits of the introduction of signalised pedestrian facilities on delay. Pye found that the introduction of an overlap period reduced the harrassment of pedestrians by motorists without significantly increasing either pedestrian or vehicle delays, provided that a maximum overlap period of 4 seconds is implemented. The exact figure depends on crossing width.

(c) Derived relationships for delay

A number of expressions have been developed from empirical, anaytical and simulation techniques, which seek to enable pedestrian delay to be predicted.

Tanner (1951) used an exponential arrival distribution to derive a formula for the delay caused to a randomly-arriving pedestrian at an isolated location:

$$d = \frac{2e^{N} - N - 1}{N} \quad \text{for two directional flow}$$

where:

N = traffic flow in each direction (veh/hr)
= gap required to cross one stream (secs)
d = mean delay (secs)

Unlike Tanner, Goldschmidt (1977) used a multiple linear regression technique to develop predictive equations of delay to pedestrians at random crossing points in one and two way London streets of 6-10 m width such that:

$$d = 1.26 + (4.54 \times 10^{-6} \times Q^{2})$$

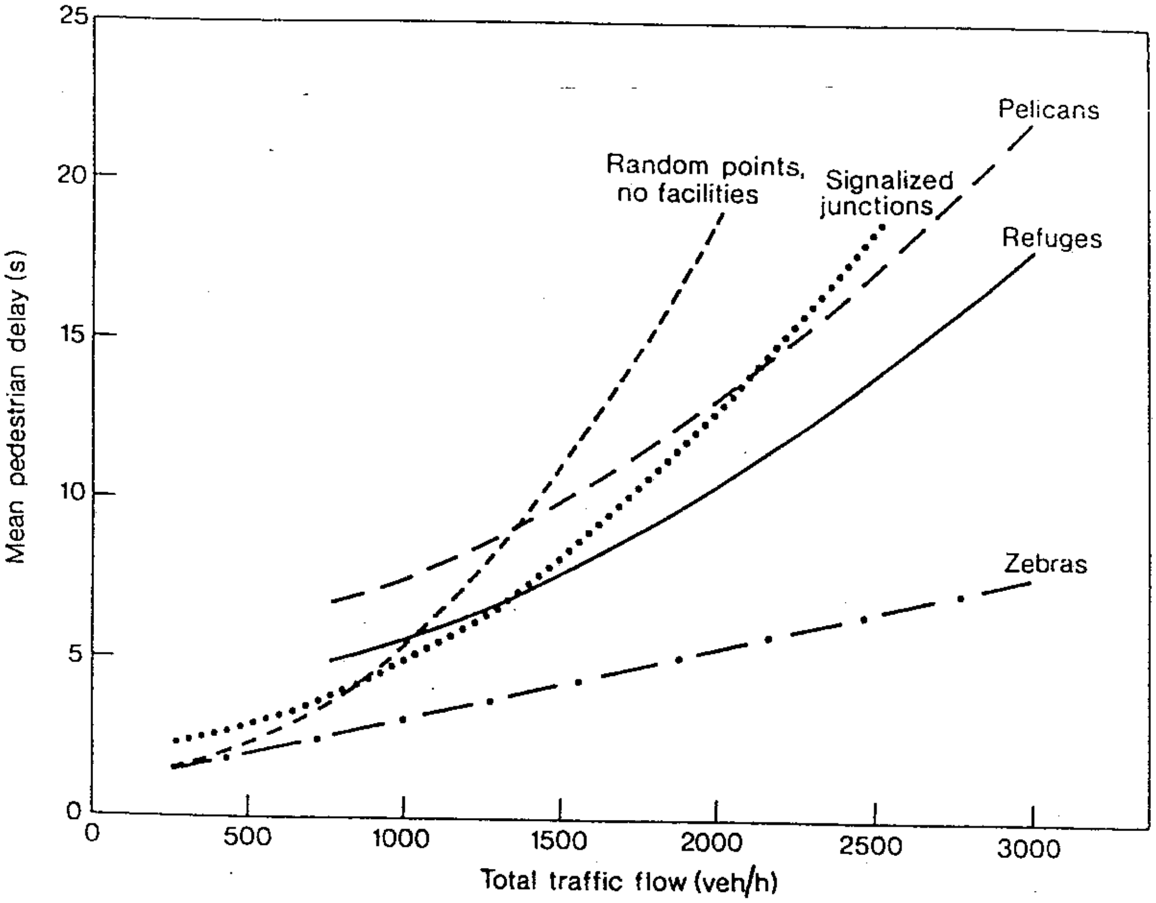
$$\text{and, } p = 1.01 - e^{-1.03 \times 10^{-3} \times Q}$$

where:

d = mean delay
p = proportion delayed
Q = traffic flow (vehicles/hr)

These relationships are used in the Manual for Environmental Appraisal (DTp, 1983) as shown in Figure 5.4.

Figure 5.4 Pedestrian Delay at Crossing Facilities (Goldschmidt, 1977)



The simulation modelling techniques of Creswell (1978) have shown that fixed time pelicans inflict a mean delay of the order:

$$D = \frac{(a + b + k)^2}{2\,(k + a + b + c)}$$

where

$$k = d + e + f$$

and, in figure 5.5

a = amber phase (3 seconds)
b = red man in red phase (1 + seconds)
c = green man (4 + seconds)
d = flashing green man (6 + seconds)
e = red man in flashing amber phase (1 + seconds)
f = red man in green phase (20-40 seconds)

Figure 5.5 Signal Phases

VEHICLE ASPECT

Green	Amber	Red		Flashing Amber		Green
<— f —>	<— a —>	< b>	<- c ->	<— d —>	<- e ->	<— f —>
Red man			Green man	Flashing green man	Red man	

PEDESTRIAN ASPECT

5.6.2 Tolerable delay

A study of pedestrian annoyance with road traffic conditions and in particular delay was carried out by Crompton (1978). The study looked at:

(1) percentage noticing delay
(2) annoyance with delay
(3) impatience with delay.

Crompton (1978) makes the point that to notice delay is not necessarily to object to it. From his studies it is observed that for a mean delay of 5-7 seconds 40-85% of respondents at random sites were annoyed with one of the following three factors:

(1) Impatience
(2) Difficulty in crossing

(3) Worry about danger.

This compares with 30-75% at pelicans. At both types of sites only 10% of respondents were annoyed by all three factors. Also, for mean delays of up to 10 seconds a 2 second increase will increase the proportion noticing the delay significantly. However, for longer delays 5-6 seconds in needed to make a significant change in the proportion noticing the delay. Crompton also found that the ge of respondent was related to the degree of annoyance resulting from pedestrian delay. For respondents 15-24 years old, at all sites, 60% noticed being delayed whilst for those over 45 years of age only 47% noticed a delay. Hence a relationship between noticeability and average delay was identified along with a weak link between difficulty in crossing the road and mean delay.

A range of mathematical expressions were derived for random crossing points and pelican crossings such that

(a) Random sites

$$\% \text{ annoyed} = 45.7 + 1.89 \text{ (mean delay (secs))} \qquad r^2 = 0.66$$

(b) Pelican crossings

$$\% \text{ annoyed} = 11.8 + 1.9 \text{ (mean delay (secs))} \qquad r^2 = 0.77$$

The intercept for (a) is surprisingly high, and inconsistent with other results from the study. At random sites between 40% and 80% of respondents were annoyed by the delay which they had experienced. With mean delays of 18 seconds about 50% of respondents were annoyed. From this work it appears that a delay of between 18 and 20 seconds is unacceptable to the majority of pedestrians. However no disaggregation by sex, age or trip purpose was performed and although the study looked at risk and impatience in crossing roads no criterion was defined for tolerable delay which embraced all these factors.

Greater Manchester County (1978) utilized a series of delay thresholds used by the Greater London Council (1975). In this average pedestrian delays in crossing a road (not on a crossing facility) of above

(1) 7.5 secs was deemed acceptable
(2) 15 secs was deemed undesirable
(3) 30 secs was deemed highly undesirable
(4) 120 secs was deemed totally unacceptable (crossing would be virtually impossible)

GMC also looked at the mean delays at several types of crossing facilities. The results are shown in Table 5.5.

Table 5.5 Mean delay at crossing facilities

	mean delay (secs/person)	
zebra crossing	3.4	(cf Hunt (1982) 2 secs)
uncontrolled crossing	6.3	
traffic signals	9.4	
traffic signals/with pedestrian phase	11.9	
pelican	16.9	

The figures are consistent with similar comparisons made in the Crompton study and highlight the difference between zebra crossings and pelicans in terms of the delay imposed.

GMC conclude from behavioural studies that pedestrian perception of delay does not appear to be linear, so that a 12 second delay is perceived as more than twice a 6 second delay.

WYCC (1975) considered that even a 1 sec. average delay was noticeable. They developed a series of thresholds above which delay was considered undesirable, depending on link sensitivity. For residential streets, 2.7 secs was used, while for shopping streets the value used was 13.4 secs.

There is no similar set of relationships between geometric delay and annoyance. The MEA (DTp, 1983) recommends thresholds of 250 m additional distance for moderate severance and 500 m for substantial severance. No source is quoted for these values, which seem remarkably high given the additional travel time which these imply.

5.6.3 Effects on risk and accidents

The link between pedestrian delay, risk, and road crossing behaviour is not well defined in the literature, and few studies attempt to address all these factors. However, Crompton (1978) conducted a study of pedestrian road crossing behaviour and attempted to link aspects of measured pedestrian delay with risk and annoyance perceived by the pedestrian.

The study of accidents within Crompton's work was based on the collection of accident data over a period of 5 years at various crossing types and in a variety of types of streets. For example, 31 shopping streets in Greater London were studied which were representative in terms of:

(1) Distance from central London
(2) Traffic volume
(3) Size of shopping facilities

For road crossing in general, correlations between difficulty in road crossing and delay, traffic volume, number of HGV's and carriageway width were all very poor and no general relationship was validated.

5.6.4 Delay thresholds

In defining thresholds for pedestrian delay disaggregation by journey purpose is desirable as is the amplification of the relationship between risk and delay. More important than the degree of annoyance which they perceive is the relationship between impatience and delay, whereby the pedestrian is at some point willing to risk taking gaps in the traffic stream which may be dangerous. However there is no basis for identifying such thresholds at present.

Overall, a mean delay of 5-7 secons is regarded as acceptable whilst a delay in excess of 18-20 seconds is generally thought to be undesirable. However the acceptability of pedestrian delay varies from site to site and by trip type. From the literature no thresholds can be given for different trip purposes or ages.

5.7 Crowding and Pedestrian Level of Service

5.7.1 Measurement

Traditionally speed, flow and density relationships have been developed to study vehicular traffic. Due largely to the ease of data collection these parameters have also been used within the pedestrian sector. Older (1984) investigated the relationship between the speed of pedestrians and density on Oxford Street in London. He found a decreasing linear relationship between the speed and density of pedestrians on pathways. The highest pedestrian speeds at the lowest densities under free flow conditions were 1.4 m/s. Wheeler (1969) found a decrease in flow and speed of pedestrian traffic with a rise in density and with an increase in pedestrian traffic from the opposite direction. Fruin (1971) explored the application of traffic flow theory to pedestrian flow, average speed and density. He found that pedestrian speeds tended to be less variable as density increased, since this restricted the individuals ability to pass slower moving pedestrians and maintain an individual desired walking speed. Therefore, density has tended to be used throughout the literature as the variable which can best describe the level of service concept.

5.7.2 Crowding (Nuisance)

Crowding has been identified in several studies (reviewed in 4.2.1) to be a factor that people perceive in the walk environment. The factors affecting the perception of crowding have not been explored in any explicit study. Those factors that might be expected to influence the perception of crowding are:

(1) numbers of people
(2) individuals expectations; values; needs
(3) individual physical, psychological characteristics
(4) social and amenity aspects.

The work on the perception of crowding has tended to remain somewhat subjective rather than providing any quantified data that can help in the evaluation process.

Numbers of people

Crowding and density are often used synonomously although it is clear that crowding has come to mean much more than merely numbers of people. Fruin (1972) and Polus (1983) have categorised pedestrian levels of service in terms of pedestrian density.

The TEST study (1976) reported that in the Kentish Town Road survey there were few strongly polarised views about the effects of crowding on pavements. Even on the highest observed footway densities few people commented upon any feeling of crowdedness. This absence of strong reactions may however be due to the form of question asked.

Individuals expectations

The MEA (1983) includes a section on driver stress which is measured by amongst other things the inability of road users to drive at a speed that they expect to or wish. Thus it is held engenders frustration and stress. The same might be true for pedestrians although no research has been found which considers these factors. The conceptual problem with the level of service concept is that we do not know whether the physical categories of "satisfaction" equate with pedestrians own expectations and values. For example the literature has shown that people with difficulties in walking are prone to experience problems in crowded areas (Hopkins, 1978; Hillman, Whalley, 1976). In some situations such as pedestrianised areas the prescence of large numbers of people would probably be perceived as beneficial by the majority, being associated with liveliness and atmosphere. These were terms highlighted in many studies as items of importance by pedestrians.

Social and amenity factors

The literature on factors other than numbers of people which might affect the perception of crowding have been based on experimental evidence and have been concerned with the perception of space in rooms and the effect of different variables on this perception. It is worth reporting on those factors that have been suggested as affecting crowding. Literature on the ways that people cope or adapt to crowding has not been found. McClelland and Auslander (1978) presented individuals with a series of slides depicting street scenes with varying numbers of people engaged in a variety of activities. Individuals were asked to rate their reactions to different questions relating to crowdedness. It was found that it was the number of people in close proximity which was the primary determinant of crowding. In other words, spatial density was not a true measure of crowding.

Other studies have shown that perceptions of crowding are related to the amount of information on display, regarding directions and locations, and that improvements in information can reduce levels of frustration in getting between two points (Wener, Kaminoff, 1983).

TEST (1976) reported that there were few polarised views about crowding and that research tends to remain suggestive rather than informative. Stokols (1969) made the distinction between density as a physical index and crowding as a phenomological state, suggesting that perceived crowding is affected by changes in variables other than density.

There is further evidence that factors such as the amount of light entering a room and its seating pattern can affect the perception of whether a room appears crowded (Wener, 1977; Schiffenbauer, 1977). It is not too great a leap to extend this to a pedestrianised street or area for pedestrian where the presence and arrangement of street furniture may not only help to avoid hindering pedestrian movement (and thus avoid crowding) but also to make an area appear less crowded.

It is clear from our review on crowding that there is still the need for much clearer empirical evidence on how people perceive crowding; under what conditions this is perceived and how this contributes to overall annoyance with pedestrian conditions in different settings.

5.7.3 Pedestrian level of service (Behaviour)

Fruin (1971) defined service levels for pedestrians based on average area occupied per pedestrian (the inverse of density). Six levels of service were defined as indicated in Table 5.6.

Table 5.6

Pedestrian levels of service

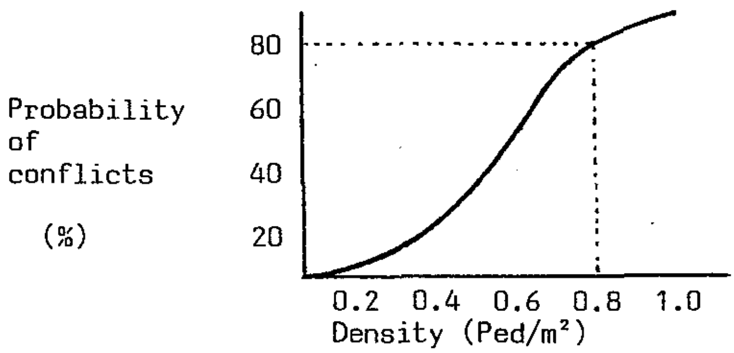
OEDING (1963)		FRUIN, J. (1971)			POLUS, A. (1983)			PUSHKAREV (1975)		
Level	ped/m^2	Level	ped/m^2	Design for Walkways	Level	ped/m^2	Design for Walkways	Level	ped/m^2	
A	< 0.30	A	< 0.29	Squares, concourses	A	< 0.60		A	< 0.2	Open flow
B	< 0.60	B	< 0.40	Public buildings, terminls	B	< 0.75	Shopping centres, public buildings	B	< 0.4	unimpeded flow
C	< 0.90	C	< 0.67	Peak conditions at terminals	C	< 1.25	High rise offices	C	< 1.0	dense flow
						< 2.0	Sports centres, central termini			
D	< 1.43	D	< 1.0	Crowded public areas	D	< 2.0	Not recommended	D	< 2.0	jammed flow
E	< 1.43	E	< 2.0	Congested conditions						
		F	> 2.0	Queues						

Fruin based his 6 levels of service on work conducted by Oeding (1963), and found a significant difference in the behaviour of pedestrians between one directional and two directional traffic such that pedestrians in the main flow tend to occupy the entire walking path space and leave the free clearance space between them to the pedestrians in the secondary flow. At densities greater than 2 ped/m^2 this may result in pedestrians in the secondary flow being forced to walk in the roadway. Fruin found that pedestrian behaviour was affected not only by the amount of pavement space allocated to the pedestrian but also by level of service attributes and characteristics of physical that influence the quality and ease of pedestrian traffic flow, e.g. the chance of conflicts, the existence (or not) of two directional flow etc. Pushkarev and Zupan (1975) offered a level of service definition similar to previous studies. The defined levels of service of Oeding (1963) tended to be closely mirrored by Fruins (1971) work. Pushkarev (1975) looked in particular at the low density conditions ignored by Oeding and Fruin (above 0.2 pedestrians per m^2).Similar level of service definitions result however beginning with open flow and unimpeded flow, to dense flow and jammed flow, in which progress is nil (see Table 5.6).

Polus (1983) conducted a survey in the central business district of Haifa, Israel using video tape recorders. Walking speeds of men were found to be significantly greater than speeds for women and all speeds were found to be negatively correlated with density. However, Polus noticed that the effect of density on speed is higher at higher densities. He identified three regimes - low (< 0.6 ped/m^2), medium (0.6 ped/m^2 - 0.75 ped/m^2) and high density (0.75 - 2 ped/m^2). For this reason a 3 regime linear regression model was used to represent the relationship between pedestrian density and speed, and Polus then made proposals for level of service definitions and suggestions for their use as shown in Table 5.6.

Another strand to the understanding of pedestrian level of service may lie in the development of techniques to study the effects of minor pedestrian flows crossing a major flow and attempting to link such work with perceptions of crowding, unpleasantness and accessibility. Khisty (1982) undertook a study at Washington State University, USA to examine the characteristics of pedestrian cross flows in corridors, passageways and hallways and then to determine the effect of one pedestrian flow crossing another. Time-lapse photography was used to study pedestrian crossing movements and hence to derive speed/density/flow relationships and conduct conflict and gap acceptance studies. The relationship between probability of a conflict and density was found to have the form shown in figure 5.6.

Figure 5.6 Cross flow traffic conflicts
(Source: Khisty (1982))



It was found that up to a pedestrian density of 0.8 - 1.0 pedestrians/m^2 there is no significant difference in speed between the major and minor fows. However, as the density increases above 1.0 pedestrian/m^2 the speed in the minor flow decreases and the time lapse photography revealed that the speed and density of the major flow were more or less independent of the minor flow. In fact, the minor flow was heavily dependent on the characteristics of the major flow such that as the critical level of 1 ped/m^2 was achieved then queues started building up in the minor flow, and conflicts rose to as high as 80%, of all crossing incidents.

Here, conflicts were analysed by counting the number of collisions or near collisions between the crossing flows at varying densities. Table 5.7 gives the relationship between major and minor flows indicated in the gap acceptance analysis.

Table 5.7 Capacity of pedestrian cross flows

Capacity of pedestrian cross flows (Pedestrians/min/m) *A	B	Total capacity (Pedn/min)
30	30	60
40	28	68
50	25	75
60	22	82
70	19	89
80	17	97

* A Major flow
B Minor flow

Based on these figures Khisty concluded that the following values should be applied to design criteria for such cross flows:

1. Minimum speed of 1.0 m/sec
2. Maximum flow of 75 ped/min/m (for the sum of both flows)
3. Maximum density of 0.8 ped/m^2

This value of 0.8 pedestrians/m^2 relates to Fruin's level of service D (Polus (C)) and would exclude public buildings such as sports centres, transportation termini and other crowded public areas from design under such conditions. Clearly the introduction of behavioural concepts into the understanding of level of service will affect its definition and remove some of the subjectivity currently employed. The greater the understanding of behavioural issues then the more useful will become the concept of level of service.

However, more recent research suggests that factors other than conventional traffic engineering measures of pedestrian movement should be considered in defining levels or quality of service. Morrall (1985) reported on pedestrian travel studies carried out in Calgary; these studies included the collection and analysis of data relating origins, destinations and routes to walking speeds, flows and densities. Morrall observes that speed, flow and density may not be the best measure of quality of service. The surveys show that over 50% of the people interviewed were seeking to walk the shortest distance. Therefore that the directness of a route may be a better indicator of route choice. From the study he concludes that whilst level of service is considered as important in the planning of pedestrian facilities, the actual pedestrian perception of level of service remains subjective and therefore there may be a danger that the concept reflects just the views of planners rather than of pedestrians.

Morrall goes on to say that people's perceptions of attractiveness are likely to be dependent on factors such as delays, levels of congestion, surface treatment, visual quality, level of noise, quality of air, safety, environmental protection and commercial/retail activity. The Calgary studies showed that whilst route selection would not depend on all such variables at every location, such parameters may provide a better understanding of level of service than the conventional characteristics of movement such as speed, flow and density which may not be perceived by pedestrians.

With particular reference to the understanding of the concept of level of service, behavioural studies on perceived distance and spatial behaviour (Nasar, 1983; Lee, 1970) and perceptions of crowding (McClelland, 1978; Dean, 1978) have highlighted the fact that crowding is perceived as a potential source of nuisance by pedestrians. This is supported by Hills, (1976) and Bennison (1980), but no data are quoted. Also the condition of pavements, pavement width and other factors pertaining to width and spaciousness are cited as problems by pedestrians. Elderly, infirm and disabled pedestrians are particularly prone to these factors (Hopkins, 1978; Hillman, 1976).

What appears to be lacking in our understanding of pedestrian level of service is clear empirical evidence of how people respond to the influence of other people in different situations and at different densities.

5.7.4 Thresholds

From the review of level of service literature the density threshold at which pedestrians cease to experience free flow conditions on footways appears to lie in the range 0.75 ped/m^2 - 0.8 ped/m^2. Above this figure then pavements became crowded and congested and unrecommended queues start to develop.

6. CURRENT BEST PRACTICE

6.1 Introduction

This section attempts to answer the questions on data needs outlined in subsection 2.4 in the light of the literature reviewed in sections 3 - 5. In doing so it recommends best practice where it exists and indicates uncertainties associated with the recommendations. These uncertainties form the basis for a series of research recommendations in section 7. In practice, as will become apparent, many of the questions raised in 2.4 have not been addressed in the literature, and many of the methods used seem to have been adopted unquestioningly. It would be easy in these circumstances to conclude that no recommendations can be made in the absence of further research. Yet the application of evaluation methodology cannot await the outcome of research programmes. To avoid unnecessary delay we have used our own professional judgement to suggest 'best practice' but would emphasise that our recommendations should be subject to further review in the light of the research which is clearly necessary.

6.2 Defining the area of study

In terms of the MEA's framework inputs, six types of location need to be identified:-

i) those where significant flows of pedestrians cross a proposed route which can be expected to induce significant severance;

ii) those where significant flows of pedestrians cross a route where a proposed increase in flow can be expected to induce significant severance;

iii) those where significant flows of pedestrians cross or are deterred from crossing an existing route which induces significant severance;

iv) those where significant numbers of pedestrians use the pavements alongside a proposed route whose infrastructure or traffic can be expected to induce significant environmental intrusion;

v) those where significant numbers of pedestrians use the pavements alongside a route where a proposed increase in flow or change in infrastructure can be expected to induce significant environmental intrusion;

vi) those where significant numbers of pedestrians use, or are deterred from using the pavements alongside an existing route whose traffic induces significant environmental intrusion.

Of these, (iii) and (vi) relate to existing pedestrian problems which might be relieved by specific schemes, and which might contribute to the ranking of individual problem locations; (i), (ii), (iv) and (v) relate to potential adverse effects on pedestrians of proposed schemes. Provided that these sixlocations and their pedestrian numbers can be identified, it does not seem necessary as MEA proposes to identify users of facilities within 300m of such routes, since these users will already have been accounted for among the pedestrian numbers at the locations identified.

The key requirements are, of course, to define 'significant' and to determine those situations in which pedestrian numbers or conditions are significant. There is no guidance in the literature on the minimum number of pedestrians who should be considered, and this is clearly to a large extent a matter of political judgement. The answer will also depend on the severity of the impact. At one end of the spectrum any pedestrian involved in an accident should clearly be considered while it might be argued that even 1000 pedestrians per hour slightly annoyed by noise should have little effect on the final decision. Very tentatively we suggest that:

i) severance and pedestrian delay effects should be considered where crossing flows exceed 100 pedestrians per hour;

ii) amenity effects should be considered where there are in excess of 250 pedestrians using the pavements alongside the route in question at any time.

A conscious decision has been taken to use flow as the parameter for the first of these, since it is the act of crossing and the crossing rate which cause the problem; and density x pavement width x link length for the second, since it is presence which causes the problem, and similar problems can arise anywhere along a homogeneous link. The thresholds are, however, arbitrary, and need to be checked in the light of experience in evaluating specific schemes. In particular there is a danger that the numbers actually observed in an area of existing severance or intrusion are reduced because of that severance or intrusion. If this is the case, the thresholds for existing problems will be too high. It will be important to assess the scale of this effect in any further research and modify the thresholds accordingly.

Again the literature gives little guidance on significant severance levels, and we see no reason for modifying the MEA's guidelines in advance of further research. We suggest below (in subsection 6.7) a series of thresholds which can be used to identify significant potential intrusion.

As noted in 2.4, such definitions may lead, in dense city centres, to the identification of most links in a traffic network. Where this happens it seems wholly appropriate to sample on the basis of flow and land use, among the links

.dentified for detailed analysis and to estimate the total impact from this sample. We are aware, however, of no examples of this being done in practice. This again is an area where the methodology should be reassessed in the light of evaluation experience.

6.3 Defining the time periods of study

The appropriate procedures here depend on whether it is necessary to determine the total numbers of pedestrians affected or simply to indicate the scale of the problem. The former is more appropriate for severance and pedestrian delay effects, while the latter may be sufficient for environmental intrusion. In either case it will be necessary to identify times of day at which there are different numbers of pedestrians, different types of pedestrian and different levels of environmental intrusion. This suggests concentrating on the morning and evening peak and the intervening off peak period as separate situations, but ignoring the evening and night, since pedestrian flows will then be small (Goodwin, 1977). For environmental intrusion, it may be satisfactory to exclude the morning peak if, as seems likely in shopping streets, the pedestrian density then is low. For the morning peak it seems reasonable to take one sample peak hour for analysis while the evening peak may require separate consideration of the hour at the end of the school day and the hour at the end of the shopping and work days. For the inter peak period, it may be possible to take a sample hour and factor up on the basis of pedestrian flows. While it is probable that several studies have collected sufficient data to enable appropriate expansion factors to be determined, there is no information in the literature on suitable values. It may be possible to determine such values from video records from past surveys.

6.4 Defining types of pedestrian

Different pedestrians can be expected to be affected in different ways by traffic and infrastructure because they are physiologically more vulnerable, psychologically more responsive, or more directly affected because of their needs. The contrasts are greatest for severance, danger and delay, where it is possible to identify two vulnerable age groups and two vulnerable trip purposes. Younger children are more likely to be at risk in heavy traffic and to be restrained from crossing roads by their parents, while the elderly are less likely to accept smaller gaps in the traffic stream, and may well be further delayed or discouraged from crossing as a result. It is recommended that these two groups of pedestrians be separately identified and that pedestrians' apparent abilities rather than specific age bands be used as the basis for identification. Among purposes, there is a case for identifying travel to work and on business separately since gaps accepted are likely to be smaller, delay will be more important and conversely trip suppression less likely. However, pedestrians are not easily identified on this basis, and it may be more appropriate to use delay and cost estimates for the average pedestrian which reflect the distribution of purposes and of purpose-specific costs. The other category which justifies separate treatement is those pedestrians who are encumbered by small children, baggage or disabilities. All of these are separately identifiable and, since their proportion almost certainly varies by location and time of day, may be worth treating separately.

6.5 Counting and Prediction

There are as yet no predictive methods for either pedestrian flows or densities which have been shown to be transferable. Local authorities have tended to use the methods developed in the Coventry Transportation Study (see 3.3) without, apparently, testing the validity of their application. Some, such as West Yorkshire, have accepted the need for additional counts on heavily used streets. In the absence of further development and testing of predictive methods, we recommend using the CTS methods, for land uses for which they are appropriate, to produce a first estimate of numbers, and to decide whether the thresholds in 6.2 above are likely to be exceeded. Where flows or densities in excess of those thresholds are predicted, we recommend that sample counts be made. In this way experience with the transferability of the CTS methods will rapidly be gained, and refinements can be made where necessary.

Where counts are needed, there seems no reason to count for the whole of the periods identified in 6.3 above. Ten minute sample counts appear to be accepted practice, and although no standard grossing-up factors are available, these could readily be derived from existing data. The appropriate counting method will depend on the type of data required. For crossing flows, stationary counts are required, whereas for numbers of pedestrians on a street the moving observer method is more appropriate. There appears to be no benefit in using film unless a permanent record or a study of behaviour is required.

There is no guidance in the literature on levels of accuracy that are required in estimating pedestrian numbers, yet these are critical to the costs of data collection. The thresholds suggested in 6.2 above may also be appropriate as maximum levels of accuracy of measurement or prediction, although for very high pedestrian numbers an accuracy of $\pm$ 10% may be more appropriate. As elsewhere, these suggestions need to be reassessed in the light of actual evaluations.

6.6. Travel and Amenity Factors

From the literature review there is a clear justification for considering more than simply noise as an intrusion into pedestrians' environments. It is recommended that, where they exceed thresholds identified in 6.7 below, the following factors be considered in the evaluation of travelling conditions and amenity:-

i) traffic induced delay
ii) geometric delay and other causes of severance
iii) noise
iv) atmospheric pollution
v) danger
vi) crowding.

As a separate issue, there is evidence of concern with visual aspects of infrastructure and street layout, and with the condition of the pavement. These however seem more appropriately to be dealt with in considering the aesthetic aspects of a scheme, rather than by attempting to quantify an inadequate proxy such as visual intrusion or delay.

6.7 Factor Thresholds

It is harder to specify the thresholds above which each of these should be considered, partly because there is a wide range of responses which can be induced, and partly because there is insufficient information on many of the relevant dose-response relationships. The main responses can be considered to be

a) annoyance and fear
b) health effects
c) accidents
d) time losses
e) trip rerouteing, diversion and suppression

In most cases there is a gradual increase in the response as the factor 'dose' increases, and it is hard to identify obvious thresholds. In certain cases (e.g. fear leading to suppression) one response will, above a certain level, lead to another. In certain cases (e.g. the effects of noise on time loss or accident), the response will not be significant or relevant. Some responses (e.g. health, accidents) will generally be agreed to be more important than others. Where dose-response relationships have been obtained from attitude surveys, they have tended to concentrate on existing users, thus excluding the specific responses of trip rerouteing, diversion and suppression, and the more general process of adaptation. All of these considerations make precise specification of thresholds difficult, and likely to lead to inequities.

The most appropriate parameter for the 'dose' may also not be obvious. In some cases, as with noise a relative (percentage change) parameter is often adopted, but it seems more appropriate generally to use absolute values, qualified, where necessary, by a minimum significant change. In some cases the units in which the factor is measured (e.g. dB, ppm) may be the most useful unit for the threshold; in other cases traffic (or HGV) flows may be more appropriate, and will certainly reduce the analysis task. In the light of these comments, many of the following recommendations must be extremely tentative, and require further research before they can be confirmed or modified.

i) Road Crossing Delay

Reactions to delay depend on the type of crossing facility provided. Since they are most severe at sites with no control, it is recommended that thresholds be based on such situations. Where a zebra or pelican crossing is provided, Crompton's results (section 5.6) can be used to determine the likely levels of annoyance.

For uncontrolled sites, Crompton's results suggest a level of 18 secs. mean delay as the point at which half the respondents were annoyed. The GLC's undesirability threshold of 15 secs. is consistent with this and is recommended as the appropriate threshold above which annoyance is likely to be of concern. In typical urban conditions this threshold will not be reached until average flows of 1700 veh/hr are obtained (Goldschmidt, 1977). This seems surprisingly high and may merit further assessment. It is considerably higher than the MEA threshold for moderate severance of 800 veh/hr (8000 veh/day). It will certainly be necessary to identify a lower threshold above which time losses from pedestrian delay are assessed. The MEA threshold is approximately the point at which (Goldschmidt, 1977) the mean delay to those delayed exceeds 10 sec., and this seems an appropriate point at which to start assessing time savings.

There is no evidence on which to base a threshold above which pedestrians are more likely to take risks, and hence increase accident rates, or to change their journey patterns. The only thresholds which have been quoted are those for the GLC's evaluation method (30 secs. as highly undesirable and 120 secs as totally unacceptable) and there is no apparent basis for these. No recommendations can therefore be made, and this is an issue on which further rersearch is urgently needed.

ii) Geometric Delay

The only thresholds which appear in the literature are those recommended in the MEA (DTp. 1983) which suggest that severance is slight for increases in journey length of up to 250m, moderate between 250m and 500m and substantial above 500m. No justification is given for these thresholds in the Manual, and it is interesting to note that they represent walk times of around 150s and 300s, which are far in excess of the critical thresholds for road crossing delay. While we have doubts about their adequacy, we have no basis for recommending different thresholds at this stage.

iii) Noise

Annoyance appears to be felt by a majority of respondents in a range of kerbside one hour L10 values of 70dB to 74dB. As with residents' responses, there is almost certainly a wide range of tolerances. West Yorkshire use an undesirability threshold of 75dB for shopping streets. Health, accident and time loss effects do not arise, and there is no evidence of trip suppression. On this basis a threshold of 74dB (1h L10) is recommended. This cannot readily be converted to equivalent traffic flows, because composition and operating conditions influence noise, but at typical urban speeds and compositions this is equivalent to a flow of around 1000 veh/hr. It is suggested that it is more appropriate to use an absolute threshold of this kind, rather than one based on the minimum perceived $\pm$ 3dB change, since most pedestrians will experience traffic noise occasionally rather than continuously.

iv) Atmospheric Pollution

Conversely for pollution there is no basis in the literature for deriving annoyance thresholds; all the analyses have been bsed on health effects, and the two pollutants usually used are CO and smoke. For CO, the GLC and West Yorkshire both use an undesirability threshold of 9 ppm (8hr average) which is equivalent to a one hour average of around 35 ppm, and was initially imposed by the USEPA to avoid adverse effects on health. It is difficult to relate this to traffic flows because of the effects of congestion and buildings, but such evidence as there is suggests that this threshold may be exceeded at flows of around 1500 veh/hr.

For smoke, the GLC and West Yorkshire use undesirability thresholds of 40 and 100 g/m3 respectively (as an annual average) but the basis for these is not clear, and the discrepancy between them suggests that they are unlikely to be reliable. No threshold is suggested for smoke at this stage, but given people's concern with the polluting effects of diesel engines further research to develop a threshold is clearly desirable.

v) Danger

It is difficult to separate the effects of delay and danger on annoyance, but several studies suggest that perceived difficulty in crossing becomes a matter of concern above around 700 veh/hr, if no dedicated facilities exist. It appears that pedestrians perceive a significant hazard at flows above 1300 veh/hr. It is extremely difficult to determine the relationship between these perceptions of danger and accidents (or, indeed, health), since heightened awareness of danger my well lead to a site being safer. There is little information on trip suppression by adult pedestrians, but children's travel can be restrained at flows in excess of around 400 veh/hr. This suggests the need for three thresholds:

a) 400 veh/h for locations where substantial numbers of young children cross;
b) 700 veh/h generally for danger;
c) 1300 veh/h for significant danger.

vi) Crowding

Crowding is related to pedestrian flows and densities, rather than traffic. Annoyance appears to become significant at densities in excess of 0.8 peds/m^2. At levels above 2.0 peds/m^2, pedestrians are more likely to walk in the road, thus contributing to accidents. At levels above 0.8 peds/m^2 travel times increase markedly. There is no evidence to suggest thresholds for trip suppression.

This suggests the use initially of two thresholds:

a) 0.8 peds/m^2 for annoyance and travel time effects
b) 2.0 peds/m^2 for potential accident risk.

In the light of further research, it may be appropriate to add a further threshold for densities above which suppression occurs.

vii) Traffic Flow

Figure 6.1 summarises the traffic flow related thresholds identified above. It should be noted that in most cases thresholds are only available for annoyance. Higher thresholds, above which the more serious effects of accidents and changes in trip making can be expected, still need to be identified, and are likely to be of considerable importance in appraisal. It is notable that the thresholds indicated vary considerably; it appears that for the average pedestrian, the effects of traffic do not need to be considered at flows below 700 veh/hr, and that even flows in excess of 1000 veh/hr are only likely to induce concern over danger and noise and significant time losses from delay. These conclusions must however be treated with caution; not only do these thresholds at present focus on annoyance, but they exclude annoyance with fumes, the effects of heavy goods vehicles, and (except in one case) the specific needs of different groups of pedestrian. Further research is needed on all of these aspects.

Figure 6.1 Recommended Traffic Flow Related Thresholds for Typical Urban Speeds and Compositions

veh/h		
2000	:	
1700	*	Annoyance (delay)
1500	*	Health (CO)
1300	*	Suppression (danger)
1000	*	Annoyance (noise)
800	*	Time/severance (delay)
700	*	Annoyance (danger)
400	*	Suppression (children) (danger)
0	:	

7. THE NEED FOR FURTHER RESEARCH

The previous section indicates several points on which advice on best practice is uncertain. Each of these suggests an area on which further research may be needed. These are reviewed in turn, and proposas for the research are set out in a companion report. A final subsection attempts to suggest an order of priority for the research topics identified, in terms both of need and ease of completion.

7.1 Sensitivity tests

There are several recommendations in section 6 whose validity can only be tested in the light of experience of their use in specific scheme evaluations. The main ones are:-

i) the thresholds for determining whether pedestrian numbers are significant (6.2);

ii) the sampling method adopted for streets in extensive study areas (6.2);

iii) the sample hours used for identifying the temporal distribution of effects (6.3);

iv) the levels of accuracy required (6.5).

We recommend that, as the opportunity arises, the sensitivity of the evaluation outcome to each of these recommendations be tested. This is probably best done by slightly extending the evaluation process for a number of forthcoming schemes, which should include ones in differing sizes of urban area.

7.2 Disaggregation by Person Type

Subsection 6.4 recommends the separate identification of the young and the elderly, those making work and business journeys, and those who are encumbered. In a subsequent subsection we recommend attitudinal surveys to confirm that such a disaggregation is necessary. At a more basic level it will be important to know, for sampling purposes, what proportions of pedestrians are in each of these categories in different locations and at different times of day. With the exception of work and business journeys, this information could readily be recorded during normal counting surveys; all items could be collected as part of the attitudinal studies recommended later.

7.3 Predictive Techniques

We note in subsection 6.5 that there has been no attempt as yet to demonstrate the transferability of techniques for predicting pedestrian numbers. We recommend that in the first instance the predictive models developed in the Coventry Transportation Study be used to predict numbers which will separately be being counted as part of the appraisal of a scheme. Where the prediction is unsuccessful, it may be appropriate to test some of the other model forms described in subsection 3.3, or alternatively to recalibrate the CTS models. There are, however, four situations in which the CTS models are almost certain to be inadequate. The first is in the range of land uses covered. In particular Transportation Termini and Recreation Facilities are not considered in the model, and additional data will be needed to estimate their pedestrian generating effects. The second is in the need to estimate numbers of suppressed, rerouted and diverted trips. This is, of course, extremely difficult, but may be possible if sufficiently reliable models can be developed to predict the numbers who might otherwise be expected in a location. This in turn suggests the third area of need, for more accurate identification of catchment areas from which pedestrians are drawn to a location. If it were possible to identify those catchment areas, it would be possible to estimate, on the basis of land use, the total number of pedestrians likely to be affected, the routes that they might be expected to take and the locations that they would frequent. Finally, there is the question of disaggregation by pedestrian type which will be needed if predictive models are to stand alone for all purposes.

7.4 Sampling Procedures

Subsection 6.5 also raises the question of appropriate sampling periods, an of the level of accuracy required in the estimate. The latter can best be determined from experience with evaluation (see 7.1), but we suspect that there is already substantial count data available which, with a limited number of further surveys, could enable appropriate count periods and expansion factors (similar to those for traffic in TAM (DTp, 1981)) to be determined.

7.5 Perception and Definition of Amenity

There is evidence that the techniques employed to identify the factors in the environment that are important to pedestrians may well influence the result. In addition the settings in which these studies have taken place are surprisingly limited. There is a need to compare, in a controlled study, the effectiveness of differing survey techniques in identifying the relative importance of the factors listed in subsection 6.6. Such a study could also help to identify appropriate proxy parameters for factors such as danger and appearance which are not measurable in their own right, and to determine the relationship between the individual factors and overall satisfaction with an area.

7.6 Dose-response relationship for annoyance

Subsection 6.7 highlights the problems associated with attempting to determine appropriate thresholds for individual factors. Of these, the most tractable problems are associated with identifying nuisance thresholds. We recommend that the preferred techniques identified ~~in~~ 7.5 above be used to determine the relationship between traffic levels, factor levels and expressed annoyance. In particular, such work is needed for the factors of danger, air pollution, visual aspects for which least is known. The surveys should aim to identify thresholds for different types of pedestrian, as a basis for reassessing the groupings suggested in 6.4, and should cover the range of traffic conditions from lightly trafficked streets to the highest flows suggested as thresholds in 6.7.

7.7 Dose-response Relationships for Behavioural Changes

We have no clear understanding of how pedestrian behaviour, with the possible exception of road crossing, is related to the factors identified. In particular trip suppression, rerouteing and redistribution hve been ignored in virtually all studies to date, since they concentrate on pedestrians identified at the site. The development of such relationships will present a substantial research challenge, but is almost certainly of considerable importance in the most heavily trafficked urban areas.

7.8 Accidents

Of the other responses identified in 6.7, health effects and time losses are both reasonably well understood, but there is surprisingly little information on the likelihood of pedestrian accidents in different locations and conditions. A combination of detailed accident data analysis, counts and conflict studies may help to throw further light on this important attribute of pedestrians' environment.

7.9 Local authority methods

One further area where research is needed was identified in subsection 2.3, which reviewed readily available material on local authority evaluation methods. It seems likely that other local authorities will have developed unpublished methods for determining pedestrian numbers and estimating effects on them. It is recommended that a short review exercise be mounted to identify these and to update the recommendations from this report accordingly.

7.10 Research Priorities

Among the research proposals outlined above, some are more urgent, and some more tractable than others. Some can sensibly be combined. On this basis, we recommend the following order of priority:-

i) Comparative testing of alternative attitudinal surveys, and their use to identify priority environmental factors, and the relationship between those factors and overall satisfaction with an area (7.5);

ii) Dose-response relationships for annoyance as a basis for reappraising the thresholds suggested in 6.7 (7.6);

iii) As part of (ii), count surveys to identify proportions of pedestrians by type (7.2);

iv) As part of (iii) and more generally as opportunities arise, tests of the CTS predictive models for pedestrian numbers (7.3);

v) As part of (iii) and using already available data, development on sampling procedures and expansion factors for short period counts (7.4);

vi) Review of unpublished local authority evaluation techniques and update the recommendations in 6 accordingly (7.9);

vii) Development of improved techniques for predicting accident rates (7.8);

viii) As opportunities arise in scheme evaluation, testing the sensitivity of the outcome to the recommendations in section 6 (7.1);

ix) Further development of the CTS and related predictive models (7.3);

x) Development of techniques for determining dose-response relationships for behavioural change (7.7).

8. REFERENCES

The following references have been revealed from four major sources:

(1) IRRD Abstracts Catalogue and the Social Science Citation Index (SSCI).

(2) A search through appropriate journals in the fields of:

- Traffic Engineering and Control
- Accident Analysis and Prevention
- Transportation Planning and Technology
- Ergonomics
- Psychology and Behaviour
- Environment

(3) A listing of references cited in articles identified under (1) and (2) above.

(4) A review of appropriate literature within the TEST study (1976).

In terms of the subject areas under review a total of 330 references were deemed applicable, with the majority being post 1972. Of the revealed articles those which are referred to in the text (as primary or secondary references) appear here prefixed by *.

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