
VOLUME 11 SECTION 3 PART 8
PEDESTRIANS, CYCLISTS,
EQUESTRIANS AND COMMUNITY
EFFECTS

CONTENTS

1. Introduction
2. Journey Length, Local Travel Patterns
3. Predicting Changes in Journey Lengths
4. Changes in Amenity
5. Community Severance
6. New Severance
7. Relief from Existing Severance
8. Possible Mitigation Measures
9. Stages in Assessment: Pedestrians, Other Travellers, Communities
10. Further Reading

ANNEX I - Counting Pedestrians

1. INTRODUCTION

1.1 This part of the Advice Note gives guidance on assessing a scheme's impact on the journeys which people make in its locality. It considers journeys made by people as pedestrians (including ramblers), cyclists and equestrians. For ease of reference, the term 'pedestrians and others' is used below to describe this group. However, impacts on local vehicle traffic should also be assessed where relevant using the same principles.

1.2 Where existing travel patterns within the locality would be broadly unaffected, the assessment will concentrate on any changes in journey length or amenity experienced by pedestrians and others (CHAPTERS 3 and 4).

1.3 Considerations of road safety contribute to the overall assessment of amenity. The design of facilities for Pedestrians, Cyclists and Equestrians are addressed in DMRB 2, 6 and 8. In some cases, a scheme may cause community severance - significant changes in journey lengths or travel patterns within a community. This may occur, for example, if a new road acts as a barrier which deters people from using certain facilities. If a new road diverts traffic and makes an existing road easier for people to cross, community severance may be reduced (CHAPTERS 5, 6 and 7).

2. JOURNEY LENGTH, LOCAL TRAVEL PATTERNS

2.1 As a first step in assessing how a scheme might affect the duration or distance of pedestrians' and others' journeys, existing local travel patterns should be established. The method described below may need to be adjusted depending on the complexity of existing travel patterns, the likely impact of the scheme and the assessment stage reached. The methodology should therefore be read in conjunction with CHAPTER 9, which gives advice on the level of assessment generally needed at each key stage.

Method for establishing existing local travel patterns of journeys on foot

2.2 Two alternative methods are described:

- (A) for cases where travel patterns are likely to be reasonably straightforward.
- (B) for cases where travel patterns are considered to be complex.

A. The steps to take are:-

Identify key community facilities and draw their catchment areas on a map. The following key facilities and their catchment areas should be covered by the assessment, where relevant:-

- (a) Doctors' surgeries;
- (b) Hospitals;
- (c) Aged persons homes;
- (d) Schools;
- (e) Shops;
- (f) Post Offices;
- (g) Churches;
- (h) Parks, play areas, sport centres etc.

2.3 In some cases it may be necessary to assess other important facilities (for example, libraries, railway/tube stations, bus services, riding schools). In determining the importance of these additional facilities, the following factors should be taken into account:-

- level of use;
- use by vulnerable groups, such as the aged, disabled people or children;
- availability of alternative facilities;
- importance in its own right (for example, a hospital may be visited infrequently, but the need to do so could be vital).

2.4 In estimating the number of users within a catchment area, it should be assumed that people will use the nearest available facility unless there is evidence to the contrary. Where applicable, this assumption can be tested by asking for information from owners and managers about the number and home location of their customers or users.

2.5 Origin/destination surveys should be considered in cases where pedestrians' and others' travel patterns are complex and a scheme could have a major impact.

B. In these cases the steps to take are:-

Take counts of user flow (ie, number of travellers, with their direction specified) to determine more precisely the number of people likely to be affected. Vulnerable groups - for example, the elderly, disabled people and children - should be separately identified where they constitute a disproportionate number of the users of a route or community facility. Care should be taken in choosing the days on which counts are made to ensure that samples are representative (for example, recreational routes should be assessed at weekends and routes to work during the week). Typical roads and streets which are likely to be heavily used by pedestrians and others which may need to be included in any count are those which are part of a bus route, or along which are found places of work, or schools or other community facilities. Counts should also be made for footpaths, bridleways and cycle routes where it is known (or believed) that they are frequently used. Advice on methods of counting pedestrians is at

ANNEX 1, and similar methods are applicable to cyclists and equestrians as well. If it is known that new developments in the locality are due to take place, then an estimate should be made of likely increases in flows of pedestrians and others.

3. PREDICTING CHANGES IN JOURNEY LENGTHS

3.1 The following method can be used for predicting changes in journey lengths and patterns. 'Journey length' here is used to cover both the distance travelled and the time taken. It extends the method used for determining existing travel patterns of pedestrians and others.

3.2 In the absence of local data, the following assumptions should be made about average journey speeds: 5 km/hr for people on foot, 10 km/hr for equestrians and 20 km/hr for cyclists. For delays at road crossings, approximate correlations between mean pedestrian delays, traffic flows and the main types of crossing facility, are shown in Figure 1. This Figure can be used to assess changes in journey time caused either directly by a scheme, or indirectly by changes in traffic flows on existing roads. Cyclist delays at crossings will be the same as those experienced by motor vehicle traffic, except in the case of specific crossings associated with cycle tracks, etc.. By adding the figures for time spent moving and waiting for particular journeys, the total additional time for pedestrians' and others' journeys can be calculated.

3.3 Vulnerable groups - for example, the aged, disabled and children - should be separately identified where they constitute a disproportionate number of the users of a route or community facility. Where this is the case a reduced average journey speed of 3km/hr for people on foot should be used. This is because elderly people and disabled people are more easily dissuaded from making a journey due to longer travelling times than are other adults, yet they are likely to be more dependent on community contacts to maintain their quality of life. Children are also particularly vulnerable, as their parents may feel the need to prevent them using or crossing certain roads.

3.4 Although the physical severance due to roads is permanent, the perceived disbenefit from the new road diminishes with time as people move in or out of the area affected. Thus the disbenefits are most evident during construction and in the first few years of operation. In taking account of changes in pedestrians' and others' journey lengths due to traffic flow, therefore, opening year traffic figures should be used. In exceptional cases - for example, where the road will have a sharp increase in traffic a few years after opening but a very light flow initially - a different year should be selected (for example, the

year with the greatest forecast increase in traffic).

3.5 When making predictions of changes in journey lengths the following steps should be taken:-

- (i) draw on a map the important routes used by pedestrians and others and the catchment areas for each key facility;
- (ii) draw a possible alternative route on the map, along with existing roads which are forecast to experience increases or reductions in traffic levels of more than 30%;
- (iii) include on the map likely mitigation measures (principally points where pedestrians can cross the possible route);

For increased traffic flow

- (iv) calculate increases in journey length for pedestrians and others using important routes. Also calculate typical journey length changes for people living in community facility catchment areas severed by the possible route, or by an existing road with traffic flows 30% or more higher;
- (v) for each severed part of a catchment area, locate the nearest alternative facility. Estimate the change in journey length which people would experience in the following two scenarios: if they continued to use their present facility and if they changed their trip pattern to use the nearest alternative;

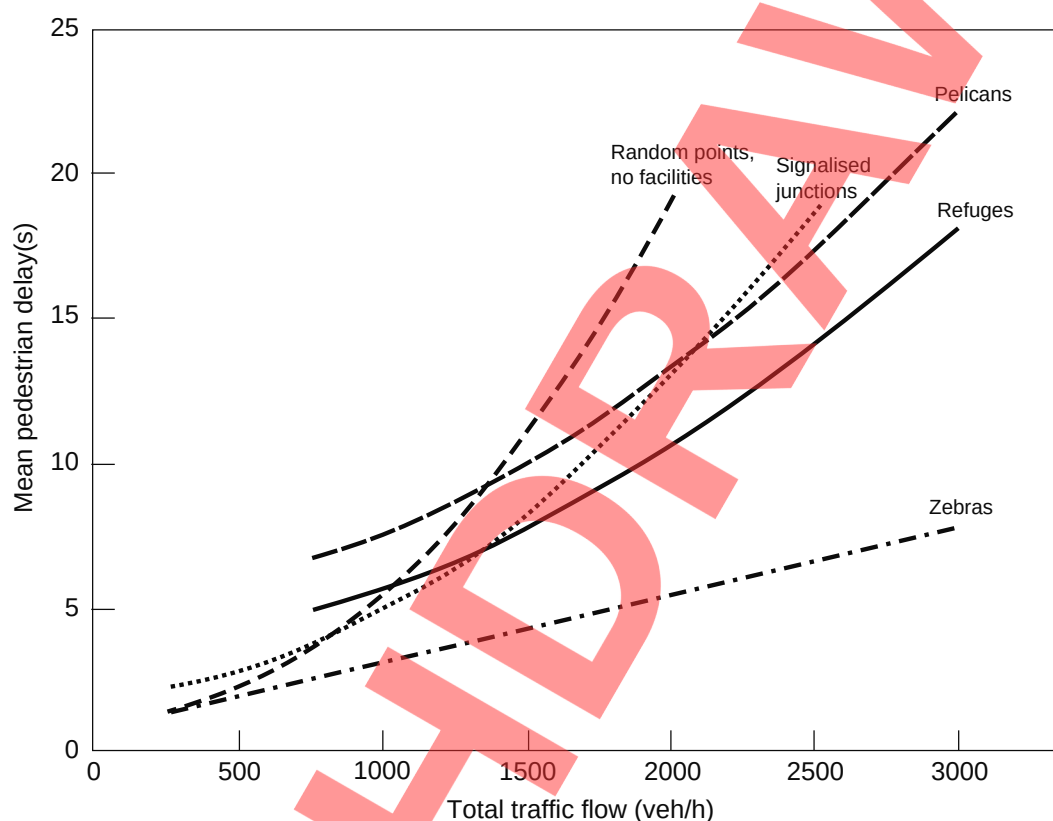
For reduced traffic flow

- (vi) calculate reductions in journey length for pedestrians and others using important routes which would be relieved of more than 30% of their traffic. Also calculate typical journey length changes for parts of a community facility catchment area which would be relieved of more than 30% of their traffic;
- (vii) for each part of a catchment area which would benefit from a route being relieved of more than 30% of its traffic, locate the nearest alternative facility.

Estimate the change in journey length which people would experience in the following two scenarios, firstly if they continued to use their present facility and secondly if they changed their trip pattern to use the nearest alternative;

(viii) repeat steps (iv) to (vii) for all routes used by pedestrians and others and for all parts of catchment areas which would be affected by a scheme.

3.6 Using this method a schedule should be produced showing changes in typical journey lengths and likely changes in travel patterns, with an estimate of the number of people affected in each case (where relevant, identifying those in vulnerable groups). This information can also be used as the starting point for assessing changes in amenity for pedestrians and others, and community severance.



Mean pedestrian delays associated with different road crossing situations

Source: TRRL SR 356

Figure 1

4. CHANGES IN AMENITY

4.1 The value of a route should not be considered solely in terms of the quantity and frequency of use. Amenity is defined as the relative pleasantness of a journey. It is therefore concerned with changes in the degree and duration of people's exposure to traffic - fear/safety, noise, dirt and air quality - and the impact of the road itself - primarily any visual intrusion associated with the scheme and its structures. Whilst the volume and composition of traffic are very important determinants of amenity, other factors should also be taken into account. For pedestrians, these factors include footpath width and distance from traffic, any barriers between pedestrians and vehicle traffic, and the quality of any street furniture and planting. For ramblers, changes in the quality of the landscape or townscape will also be relevant. For cyclists, they include positive factors, such as the clear signing of alternative routes for cyclists, and subways or cycle crossings, and negative factors, such as junctions where cyclists and vehicles are not separated. For equestrians, landscape quality will generally be an important factor, as may some of those affecting cyclists, depending on the existing and proposed provision for riders. Safety for equestrians crossing a proposed route is a particularly important consideration, given that horses can react unpredictably and may stop suddenly in such situations.

4.2 Therefore, in assessing amenity for the routes used by pedestrians and others, a descriptive approach should be employed which gives an overall indication of the change in amenity and the number of journeys affected, and also cites the reasoning behind the judgement. The description of amenity impacts should include a reference to forecast traffic flows. For the reasons stated in paragraph 3.4 opening year traffic figures should always be used. In exceptional cases - for example, where the road will have a sharp increase in traffic a few years after opening but a very light flow initially - a different year should be selected (for example, the year with the greatest forecast increase in traffic).

The following examples illustrate the way in which changes in amenity should be described:-

Whitecroft Lydney High Street:

Published Scheme: Improvement in amenity for around 800 pedestrian and 40 cyclist journeys per day. AADT (1996, high growth) forecast to fall by 90%, to 2,000 (HGV flows by 95%, to 50).

Do Minimum: On existing A54 in village centre, there is a 1-2m footpath on one side of the road, adjacent to the carriageway and fronting houses and shops. The resulting amenity is very poor, and would deteriorate further without the scheme.'

Cavendish Road:

Published Scheme: Some reduction in amenity for around 500 pedestrian and 10 cyclist journeys per day. AADT (1995, high growth) forecast to increase by 60%, to 5,000 (HGVs by 50%, to 350), as some traffic diverts to this road to join the A28 at Redhill roundabout. Although pavements are typically 2m wide, they are adjacent to the carriageway. An alternative route is available for the cyclists using this road as a through route.

Do Minimum: No change to existing good amenity.'

Bridleway A7:

Published Scheme: Reduction in amenity for around 50 equestrian journeys and 100 journeys by ramblers each week. AADT (1996, high growth) 17,000 for proposed route where crosses bridleway. Proposed diversion is within 10m of carriageway; views would be significantly impaired by new road and equestrian crossing.

Do Minimum: Existing good amenity unchanged.'

5. COMMUNITY SEVERANCE

5.1 Changes in journey times and amenity for pedestrians and others may be such that they affect, adversely or beneficially, the degree to which a locality is subject to 'community severance'. In such cases, the assessment should be extended in scope to consider such effects.

5.2 Community severance is defined here as the separation of residents from facilities and services they use within their community caused by new or improved roads or by changes in traffic flows. The correlation between the degree of severance and the physical barrier of the road and its traffic is not straightforward. However, previous studies have established that severance is seen as an important consequence of the presence of new trunk roads.

5.3 In addition to changes in community severance caused by changes in pedestrians' and others' ability to travel in the locality of a scheme, severance may sometimes be caused by the demolition of a community facility or the loss of land used by members of the public. It is important that the assessment takes account of such impacts.

5.4 Community severance effects are not evenly spread amongst the people in the area around the road. As noted in CHAPTER 2, aged people, the disabled and children are particularly vulnerable to disruption of their travel patterns. The assessment of journey times and travel patterns will already have identified vulnerable groups and the assessment of changes in community severance should pay particular attention to routes and facilities used by them.

6. NEW SEVERANCE

6.1 New severance should be described using a three point scale, viz, Slight, Moderate or Severe severance. These descriptions should be coupled with an estimate of the numbers of people affected, their location and the community facilities from which they are severed.

When using the guidelines for describing community severance given below, the following factors should be taken into account:-

- (a) assessments should be conducted for the opening year. In exceptional cases - for example, where the road will have a sharp increase in traffic a few years after opening but a very light flow initially - a different year should be selected (for example, the year with the greatest forecast increase in traffic);
- (b) the guidelines are applicable both to the direct effects of a scheme, and to effects caused by increases in traffic levels on existing roads. In all cases, it is important to take account of other important factors, such as:-
 - the number of people whose journey will be affected;
 - the presence of particularly vulnerable groups, such as children, the aged or the disabled;
 - the fact that crossing at-grade will take longer during peak hours;
 - the type of road involved;
 - the provision of mitigation (see CHAPTER 8).
- (c) the guidelines apply specifically to pedestrians; cyclists and equestrians are less susceptible to severance because they can travel more quickly than people on foot, although they may still be deterred from making journeys which require them to negotiate additional roads and especially junctions.

Slight: In general the current journey pattern is likely to be maintained, but there will probably be some

hindrance to movement for example:

- pedestrian at-grade crossing of a new road carrying below 8,000 vehicles per day (AADT); or
- a new bridge will need to be climbed or a subway traversed; or
- journeys will be increased by up to 250 m.

Moderate: Some residents, particularly children and elderly people, are likely to be dissuaded from making trips. Other trips will be made longer or less attractive, for example:

- two or more of the hindrances set out under 'Slight' applying to single trips; or
- pedestrian at-grade crossing of a new road carrying between 8,000-16,000 vehicles per day (AADT) in the opening year.
- journeys will be increased by 250-500 m; or

Severe: People are likely to be deterred from making trips to an extent sufficient to induce a re-organisation of their habits. This would lead to a change in the location of centres of activity or in some cases to a permanent loss to a particular community. Alternatively, considerable hindrance will be caused to people trying to make their existing journeys. Such effects can be brought about by, for example:

- pedestrian at-grade crossing of a new road carrying over 16,000 vehicles per day (AADT) in the opening year.
- an increase in length of journeys of over 500 m; or
- three or more of the hindrances set out under 'slight' or two or more set out under 'moderate'.

7. RELIEF FROM EXISTING SEVERANCE

7.1 Relief from existing severance can be described using the terms Slight, Moderate or Substantial. A guide to the extent of the relief can be gained by considering the reduction in traffic on the existing highway network in the opening or selected year. This needs to be seen in the context of the size of the community affected, the presence of vulnerable groups and the existing road standards. For example, a modest reduction in heavy goods vehicles through a small village with a tortuous main street and narrow pavements can be a substantial relief to the community. However a similar reduction on the edge of a conurbation, where there is little or no desire to cross the road, may be of little consequence. The guidelines therefore suggest different levels of traffic flow changes for the same extent of relief in rural and peripheral areas. Both a minimum traffic flow and a minimum reduction in traffic must be expected before any relief can be claimed as there is little evidence to show that low traffic flows on existing roads produce community severance.

7.2 Where traffic reductions would be sufficient to produce substantial relief of severance, it may be possible for the local authority to pedestrianise an area. If this seems likely to occur the local authority should be consulted and their views included in the environmental assessment.

7.3 Estimates of the numbers of people who may benefit from the relief of severance should be made, with special reference to those in vulnerable groups, and an indication given of the geographical location of the relief.

7.4 The following guidelines should be borne in mind when choosing the descriptions to be given to any appreciable relief of existing severance. Given that relief of severance is not significant where traffic flows are already relatively low, the guidelines do not apply to roads with an existing AADT flow of less than 8,000 vehicles. Where particularly vulnerable groups are relieved from severance, the description may need to be amended to reflect this change.

Table 1. Categorising Relief from Severance by Reductions in Existing Traffic Levels

	Level of Relief from Severance		
	Slight	Moderate	Substantial
Built up Area	c.30%	30-60%	60%+
Rural Area	60-75% ₁	75-90% ₂	90%+ ₃

₁ Where the existing road is passing through a village or on the perimeter of a built up area use c.30%.

₂ Where the existing road substantially bisects a village or small town this figure may be halved.

₃ Where the existing road substantially bisects a village or small town this figure may be reduced to 60%.

8. POSSIBLE MITIGATION MEASURES

8.1 The assessment of pedestrian, cyclist, equestrian and community effects reported at each key stage should be based on the scheme with mitigation as agreed with the Overseeing Department's Project Manager.

8.2 Examples of possible mitigation techniques are described below:-

- facilities for pedestrians, such as at - grade crossings, underpasses, central reservations and footbridges;
- crossing facilities, such as footbridges, pedestrian underpasses, central reservations and crossing sites for equestrians;
- facilities for equestrians, such as crossing sites;
- barriers separating pedestrians from traffic, those may improve amenity but add to journey length and severance;
- facilities for cyclists, such as cycle lanes, or clear signing of alternative routes for cyclists.

8.3 DMRB 6.3 TA 57/87, 'Roadside Features', gives advice on aspects of route design which affect pedestrians, cyclists and equestrians.

8.4 In taking such mitigation into account in scheme assessment, the degree to which vulnerable groups will benefit should be considered. For example, a pedestrian footbridge may substantially reduce journey times and prevent considerable community severance, but some aged people may be unable to use it.

8.5 Reducing the impact of a road on pedestrians and other travellers is just one of the factors to be considered in route choice and design, and conflicts can exist. For example, a footbridge may increase visual intrusion. In addition, any mitigation measure must perform to an acceptable level in traffic, road safety and economic terms.

9. STAGES IN THE ASSESSMENT OF IMPACTS ON PEDESTRIANS, OTHER TRAVELLERS AND COMMUNITIES

9.1 The following levels of detail will generally be appropriate at the key stages. However, where a scheme has no impact on pedestrians or other non-motor vehicle travellers - for example, a widening scheme on an existing motorway - or where the impact is insignificant, no assessment is required once this fact has been established.

9.2 In very exceptional cases, where time savings or delays to pedestrians and others are substantial or appreciably different between options, they should be evaluated using the appropriate current economic values of time and included with the other monetary benefits.

Stage 1

9.3 The objective at Stage 1 is to undertake sufficient assessment to provide an appreciation of the likely effects on pedestrians, cyclists and equestrians and for people's ability to move around their local community, and to identify the relevant constraints associated with particular broadly defined routes, or corridors, as developed by the Design Organisation and agreed with the Overseeing Department's Project Manager.

9.4 The steps to take are:-

- (i) identify existing and proposed routes, rights of way and important community facilities used by pedestrians and others which may be affected by a possible route corridor. Particular attention should be paid to routes used by pedestrians and others for visiting important community facilities;
- (ii) assess in broad terms whether pedestrians' and others' journeys would be lengthened or reduced by a possible route, whether the amenity value of such journeys would increase or diminish, and whether some people would be deterred from making journeys which they currently make. Also assess whether their exposure to risk is likely to be made worse. At this stage it is not necessary to calculate increased journey times.

9.5 The result of the assessment at this Stage to be described in the Stage 1 report should consist of a statement illustrated by a map showing possible route corridors and routes and important community facilities used by pedestrians and others.

Stage 2

9.6 The objective at this Stage is to undertake sufficient assessment to identify the routes used by pedestrians and others, the community facilities and the effects upon these two categories to be taken into account by the Design Organisation in developing and refining route options, in agreement with the Overseeing Department's Project Manager.

9.7 The steps to take at this stage are described below. When carrying out investigations into usage and journey patterns, it is important to bear in mind that consideration of possible route options at this stage should not lead to unnecessary anxiety amongst local people, and even the blighting of properties. Members of the public should therefore not be asked for information on usage of community facilities, nor should origin/destination surveys be undertaken.

- (i) assess existing usage of community facilities and routes used by pedestrians and others; the changes to journey times associated with possible route options; and whether their safety and amenity is likely to be prejudiced. Counts of pedestrians and others should be undertaken where this is necessary to achieve the objective of this stage in the assessment. Vulnerable groups should be taken into account either by including them as separate categories in pedestrian counts, or by estimating likely usage of different routes from the proximity of community facilities, such as primary schools or old people's homes;
- (ii) assess any changes in the safety and amenity value of routes used by pedestrians and others which might be affected by a possible route options;
- (iii) where journey lengths would be increased, or where journey amenity would

be reduced, assess likely changes in community severance;

(iv) where cyclists will be significantly affected, obtain the views of the local highway authority officer responsible for cycling provision on the implications of different routes. The views of the Overseeing Department's Regional Cycling Officer should then be obtained through the Overseeing Department's Project Manager.

9.8 The results of the assessment at Stage 2, to be described in the Stage 2 report should consist of:-

(a) a map showing community facilities and their estimated catchment areas, the main routes used by pedestrians and others, the existing road network and the possible route options (with any mitigation measures which have been assumed clearly indicated). In some cases, it may be necessary to present the information on separate maps for each possible route option, or to annotate the maps;

(b) a report on the routes, including estimates of the number of pedestrians and others experiencing changed journey times, the extent of any change after allowing for agreed mitigation, the impact on pedestrians' and others' safety and amenity of the possible route options, and any changes in community severance. Particular attention should be paid to impacts on vulnerable groups.

counts are made (see ANNEX 1), or by obtaining estimates of the number of users or residents of vulnerable facilities (for example, a primary school, community centre or old people's home);

(ii) verify the earlier assessment of changes in journey length and amenity and community severance, allowing for any subsequent modifications (for example, to traffic forecasts, or the route alignment or mitigation on which the earlier assessment was based);

(iii) where cyclists will be significantly affected, obtain the views of the Cycle Touring Club (CTC), and local cycling groups and the local highway authority officer responsible for cycling provision on the implications of the preferred route. The views of the Overseeing Department's Regional Cycling Officer should then be obtained through the Overseeing Department's Project Manager;

9.10 The result of the assessment at Stage 3, to be described in the Environmental Statement should comprise a report assessing the number and location of pedestrians and others and their community facilities affected by the preferred route, taking proposed agreed mitigation into account. The report should also describe any benefits to pedestrians and others from the reductions in traffic along the existing route network. A map should be included which shows the community facilities, their catchment areas and routes used by pedestrians and others which are affected by the scheme.

Stage 3

Much of the assessment of the preferred route will already have been conducted prior to Stage 2. At this stage, therefore, the steps to take are:-

(i) refine the information on facilities and their catchment areas by asking for information from owners and managers of community facilities about the number and home area of their customers or users. In cases where pedestrians' and others' travel patterns are complex and a scheme could have a major impact, origin/destination surveys should be considered. Where relevant, it is important to estimate separately the numbers of people in vulnerable groups who will be particularly affected. This will usually be done either by including these groups as separate categories if pedestrian

10. FURTHER READING

10.1 The Appraisal of Community Severance
Hutton B, Clark J, Barnett N, Hathway T and Harrison T
TRL CR135 (1991)

10.2 The Measurement and Prediction of Pedestrian
Numbers May Hopkinson and Turvey (1991) TRL CR
149

10.3 Community Effects of Traffic Congestion : A
review of the London Assessment Study Data Travers
Morgan TRL CR 314

COUNTING PEDESTRIANS

1. Counts of pedestrian flows should be arranged so that the results are as representative as possible of typical flows. They should generally take place over two days, preferably spread out over a number of months, to avoid variations caused by the weather or local factors. Spring or autumn are likely to be the most appropriate times of year. In residential areas, counts taken on a weekday during school term time are likely to be most typical. In shopping areas, counts conducted on a Wednesday (if not early closing day) and a Saturday may be most representative. In holiday or recreational areas, counts during the summer months will probably be required. All pedestrian journeys between 8am and 6pm should be counted and their direction indicated (in exceptional circumstances, longer hours may be needed to reflect local factors).
2. Where necessary, pedestrian counts should identify separately the numbers of people in vulnerable groups who will be particularly affected (such as young children, the elderly and the disabled).
3. There are two main types of street survey which can be used to measure pedestrian flow:-
 - (a) Spot Counts. These should be undertaken by an observer who makes a manual count of pedestrians walking past in one direction (or both directions for quiet routes). This method should be used in simple situations and may also be necessary if pedestrians need to be classified into groups (for example, under 12s, adults, and people over 65).
 - (b) Video Monitoring. This method requires a video camera to scan and record pedestrian movements. The maximum range for counting pedestrians clearly using this technique is about 100m. In most cases, a video camera mounted at a first floor vantage point with a good view of both sides of the street will suffice. Indoor vantage points are generally more secure, but may involve difficulties of access for changing video cassettes. Providing that sufficiently robust equipment and secure locations can be obtained, an outside filming location may be preferable. In more complex situations - for example, at a busy intersection of three or more routes - a camera which is mounted on a van and can rotate through 360 degrees may be used. If the design organisation wishes to conduct video monitoring, permission should be sought from the overseeing Department's project manager. Where it is intended to use a rotating camera, specialist advice should be sought on the equipment required.
4. Existing predictive models of the number of pedestrians walking along and crossing a street are poor predictors and should not be used.
5. Further details of pedestrian count techniques can be found in TRL Contractor Report 149 (May, Hopkinson and Turvey, 1991).