Development of a Risk Analysis Model for Footways and Cycle Tracks

by S Bird, C R Sowerby and V M Atkinson

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DEVELOPMENT OF A RISK ANALYSIS MODEL FOR FOOTWAYS AND CYCLETRACKS

Version: 1

by S Bird, C R Sowerby and V M Atkinson (TRL Limited)

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CONTENTS

Executive summary

The objective of this report is to apply risk management techniques to the management and maintenance of footways and cycle tracks, essentially to address the physical risk of accidents to pedestrians and cyclists resulting from the construction and maintenance of footway and cycle track surfaces.

The background to the current safety management culture is considered, and a working definition of risk management is given as:

> *'The identification, analysis and economic control of those risks which can threaten the assets or business of an organisation.'*

In the context of footway and cycle track maintenance, risk would be measured as the number of injury accidents per km walked or cycled.

The elements of current risk assessment as applied in industry are applied in footway and cycle track management and several areas for examination are revealed.

Detailed advice on risk management is given in relation to policy and categorisation, and on strategic, tactical and operational issues. This is based on risk management reviews, investigation of accidents and reviewing third party claims. Lessons learned from other parts of the network are also included.

Recent records of third party claims were examined at three local authorities in the UK, in order to identify factors that influence the numbers of accidents. The numbers of claims in relation to defect height was examined and there is a peak of claims in the range 15 - 20mm; (the threshold for safety defects is generally 20mm). From this, and relationships derived elsewhere in the report, the probability of a person injuring themselves on a defect of given height is derived.

Other sources of data on the numbers and outcomes of falls on walking surfaces were examined. Based on data from the Royal Society for the Prevention of Accidents (ROSPA), the lower and upper bound estimates of the number of A&E admissions each year due to falls on public walking surface defects are around 20,000 and 190,000 respectively. About 5% of A&E cases resulted in admission to hospital. Data gathered at one A&E department in London suggested that only about one sixth of such accidents proceed to claims against the highway authority. However, this proportion could vary elsewhere.

Only limited suitable data have come to light on accident rates for cyclists. For the purposes of making preliminary estimations of risk, a rate of accidents due to surface condition on cycle tracks is estimated as 75 accidents per million kilometres cycled.

Medical literature on aspects of walking, tripping and obstacle clearance was reviewed. Many factors influence whether a person fails to notice a defect, then trips or slips on that defect, then falls, and then injure themselves:

- Environmental factors include weather, lighting, distractions, obstacles, slippery surfaces, spills, ridges, ramps and steps.
- Personal factors include type of footwear and its slip resistance, and objects being carried.
- Biomedical factors include changes due to ageing and disease and the use of medications, drugs or alcohol. Diseases such as osteoporosis increase the risk of fractures following a fall.

While the leg is swinging forward, the toe is generally the lowest part of the foot. A number of studies in the laboratory have shown that the clearance between the toe and the ground is between 15 and 20mm for younger adults, while it is less than 10mm for the elderly, although no data on toe clearance in outdoor conditions has been located. Most people who notice a trip defect will negotiate it by increasing toe clearance; falls tend to occur when defects are not noticed. There is an expectation that footways for general use will be regular and consistent. Isolated trips on such footways present a greater hazard than those on a footway known to be in poor surface condition, especially on busy footways where there may be distractions or where defects may be obscured by a

large number of pedestrians. Most healthy adults will recover from a trip and not fall, while the elderly are less able to recover and are more likely to sustain serious injuries than the young.

A cost of a fall on a footway of £5,606 (2005 prices) has been calculated following the methodology used for deriving the costs of road accidents for use in the appraisal of road schemes.

A risk assessment model for footways is developed to calculate the number of accidents on a highway authority's network. The model is based on deriving the probability that a person walking over a given defect will fall and be injured, and on the assumption that the numbers of defects on the network will be a dynamic balance between the rate at which they appear and the rate at which they are repaired. A software tool containing this model is under development.

The model may be used to explore the effects of changes in maintenance policy on numbers of accidents. For example, the number of accidents on a typical urban network would increase if maintenance and safety inspection intervals were increased. The model may also be used to provide data for use in a whole life cost model on the 'cost', in terms of accidents, of not carrying out maintenance work. In one case, the annual cost of accidents approaches £0.7/m^2 prior to resurfacing. If no maintenance or resurfacing is carried out, the annual costs of accidents may rise to over £3/m^2 in some cases after 30 years.

The model has been based on several simplifying assumptions and approximations, and further data is required in order to improve its accuracy.   As a check on the overall accuracy, the model was used to predict the total number of footway accidents in England and Wales. The result was around 25,000 accidents per year and compared with the range of 20,000 to 190,000 A&E admissions described above.

Thus, at present, the model will be a useful guide to assist highway authorities in setting maintenance policy by giving an indication of the consequences, in terms of an approximate number of accidents occurring, of following a particular policy.   It should not be regarded as an accurate prediction of the number of accidents at any one time or location. However as the use of computer databases for recording claims becomes more widespread it will be possible to refine the model. It will also be possible for an individual authority to adapt the model on the basis of its local information and conditions.

1 Introduction

The Kindred Associations (1998) reported on issues of highway liability and supported a pro-active approach to controlling third party claims based on risk assessment. The code of practice for highway maintenance management (Roads Liaison Group, 2005) emphasises the importance of understanding and assessing the risks and consequences involved in highway maintenance. The Framework for Highway Asset Management (CSS, 2004) gives guidance on how risk management could be applied to a UK road network. As part of previous footway research, Bird et al (2002) set out a systematic approach to footway maintenance, discussed the legal background, and suggested a coherent matrix of inspection frequency, investigatory level and response time.

The objective of this report is to build on the previous work and apply risk management techniques to the management and maintenance of footways and cycle tracks.

Risks associated with management of the highway network include accident, injury or health risks to users and employees, network loss, operational risks, environmental damage (e.g. spillage), financial risks, political risks, liability and legal compliance. This report essentially addresses the physical risk of accidents resulting from the construction and maintenance of footway and cycle track surfaces, although these accidents may also have financial and other consequences.

Also, this report considers only risks associated with a highway authority’s duty to maintain in accordance with the Highways Act 1980. Highways are excluded from the definition of a workplace in Health and Safety regulations; therefore highway authorities have not traditionally applied risk management procedures in highway maintenance policy. The other aspects of Health and Safety legislation that highway authorities must apply in its design and in its construction and maintenance operations are not specifically addressed.

2 Background and general considerations

2.1 Definitions

The current safety management culture derives from the Robens Committee report (1972), which sets out the framework for Health and Safety Legislation. In place of a prescriptive approach, with an ever-increasing number of rules and regulations, a self-regulating approach was put forward which encourages management and workforces to identify hazards, assess risks and implement preventative measures.

Therefore a working definition of risk management is considered to be:

> *'The identification, analysis and economic control of those risks which can threaten the assets or business of an organisation.'*

Once identified, risks must be prioritised to ensure they are dealt with efficiently.

In practice risk and hazard are defined in many ways, or even used interchangeably. Definitions taken from current standards are shown in Table 1.

Table 1 Definitions

Accident: Unplanned event giving rise to death, ill health, injury, damage or other loss.
Hazard: A source or a situation with a potential for harm in terms of human injury or ill health, damage to property, damage to the environment, or a combination of these.
Hazard identification: The process of recognising that a hazard exists and defining its characteristics.
Incident: Unplanned event which has the potential to lead to an accident.
Risk: The combination of the likelihood and consequence of a specified hazardous event.
Risk assessment: The overall process of estimating the magnitude of risk and deciding whether or not the risk is tolerable or acceptable. A risk is acceptable if it is so low that no thought need be given to its likelihood in the conduct of normal life, whereas a tolerable risk is not regarded as something to ignore, but rather as something to keep under review and reduce still further if possible.

In the context of footway and cycle track maintenance, an "accident" could be a person injured due to a fall caused by the "hazard", such as an uneven surface. Risk would be measured as the number of injury accidents per km walked or cycled.

There are various reasons why it is desirable for highway authorities to assess and manage the risk of hazards on footways and cycle tracks.

1. A highway authority has a duty to maintain footways and cycle tracks. Its objectives (Bird et al, 2002) would include reducing the numbers of accidents and injuries, as far as reasonably practical, taking into account the economic costs of such measures. Case law also provides a guide as to what is considered reasonably practical.
2. Highway authorities and their insurers are necessarily concerned about their exposure to risks and their liability for third party claims. A robust risk management strategy will lead to a reduction of third party claims and can reduce insurance premiums. Highway authorities appear to be receiving an increasing number of footway related third party claims, which may be the result of the active marketing of claims services. These are aspects that need to be addressed at the strategic level.
3. Highway authorities must also support the government's aim to encourage walking and cycling and to reduce traffic congestion. Maintaining public access (including, importantly, access for those with mobility impairments) to footways and cycle tracks

is important. People with mobility impairments may find more difficulty in negotiating hazards than other members of society.

4. The highway authority's duty of Best Value encourages a 'cross-cutting' approach and focus on desired outcomes rather than processes. Some performance indicators drive aspects of risk management, for example repair of defects within the required response time and percentage of third party claims repudiated.
5. The code of practice for highway maintenance (Roads Liaison Group, 2005) states that the management of highway maintenance, including the establishment of regimes for inspection, setting standards for condition, determining priorities and programmes, and procuring the service should all be undertaken against a clear and comprehensive understanding and assessment of the risks and consequences involved.

Many local authorities are contracting out their services and the question arises whether or how to retain or transfer risk. Risk management procedures assist with these decisions, e.g. whether to insure, retain, reduce or transfer risk.

It is important that those organisations with a responsibility for footways and cycle tracks become aware of, and recognise, the generic and specific statutory duties and discretionary powers that apply to the design, management and maintenance of highway structures. The difference in failure to fulfil a statutory duty, as opposed to failure to exercise a discretionary power is highly significant.

3 Application of risk management principles to footways and cycle tracks

3.1 Risk assessment

The code of practice for highway maintenance management (Roads Liaison Group, 2005) states that risk assessment need not be a highly technical process, but is fundamentally a structured and systematic expression and recording of collective good judgement based on the best available data.

A risk assessment needs defined scope and objective(s) and to be carried out by a competent person who is aware of the specific and generic hazards. It is necessary to consider the means of determining tolerability of risks. Options include professional judgement, cost benefit analysis and risk tolerability criteria. Finally risk assessment must be recorded.

The elements of current risk assessment, as applied in industry, are set out in Table 2, together with how these elements may be applied in footway and cycle track management. It is immediately apparent that many elements are already used in highway management, although some new areas are revealed, which are underlined.

Once hazards have been identified, hazard controls are considered. However, it is necessary to be aware that control measures can introduce other hazards. The ideal is to eliminate the hazard. Protection (e.g. use of personal protective equipment) is used only as a last resort. The principles of hazard control are set out in Table 3, together with how these elements may be applied in footway and cycle track management. The current regime of inspection and repair addresses the issue of safeguarding, but there remains scope for eliminating or reducing risk by design and proactive preventative maintenance. However with limited resources, highway authorities may be confined to conducting reactive maintenance.

Table 2 Application of risk assessment in footway and cycle track management (new areas revealed for consideration underlined)

Element of risk assessment	General application in industry[1]	Application in footway and cycle track management
1. Classify work activities.	Prepare a list of work activities covering premises, machinery, plant, people and procedures (as relevant), and gather information about them.	Quantify the asset, i.e. inventory of footways and cycle tracks, location, usage (category), users, condition.
2. Identify hazards.	Identify all significant hazards relating to each item of plant and machinery and/or work activity. Consider who might be harmed and how.	Identify all ways in which the footway and cycle track would be a hazard to users. Consider defects, i.e. trips, potholes, etc.
3. Determine risk.	Make a subjective estimate of risk associated with each hazard assuming that planned or existing controls are in place. Assessors should also consider the consequences of failures in controls and failures to use the controls.	Estimate the risk posed by each hazard - normally a function of its dimension, but other factors such as location will be important too. Current defect thresholds are based on experience and legal precedent, which in turn are based on 'reasonableness'. Procedures should take into account the possibility that there may be a failure in the controls (e.g. the next inspection may be missed, or remedial works not carried out) An aspect of this report is to provide a more rational basis for risk estimation. An assessment of risk should have a proactive element, namely taking into account the likelihood of particular defects occurring and modes and rates of deterioration, as well as the hazardous nature of defects.
4. Decide if risk is tolerable.	Judge whether planned or existing precautions (if any) are sufficient to keep the risk under control and to meet legal requirements.	This is partly covered by the previous item, although highway authorities must weight the tolerability of risk when setting their policy and allocating resources. Also, when assessing the hazard posed by a particular defect an inspector will take into account local factors (e.g. outside an old people's home). Tolerability of risks relates to the likely injuries caused by footway and cycle track defects. Defects are viewed differently than the risks posed by, say, a missing vehicle restraint.
5. Prepare risk control action plan.	Prepare a plan to deal with any issues found by the assessment to require attention.	A highway authority's maintenance policy, with its regime for inspection and repair, is a plan for dealing with risk associated with footway and cycle track defects. Some elements are discussed below in relation to hazard controls.
6. Review adequacy of action plan.	Re-assess risks on the basis of the revised controls and check that risks will be tolerable.	Monitoring will be important where repairs have been postponed, or they are below the thresholds, to detect if they deteriorate and become hazardous. It will be important to keep a highway authority's policy under review and revise it in relation to any changed circumstances; for example, a change in legislation or new knowledge about a risk. A changed local circumstance might be that buses start to run on a pedestrian area, causing defects to develop more quickly, or use of motorised sweeping.

1. The Hazards Forum (1996)

Table 3 Hazard controls

Element of hazard control – in order of priority	General application in industry[1]	Application in footway and cycle track management
1. Eliminate hazard by design	Inherently safe design and construction.	'Design out' hazards, e.g. avoid steep slopes or steps. Better quality construction will lengthen time before defects appear. This should be taken into account in the whole life cost and prioritisation process. Appropriate construction should be used where there is a risk of damage by vehicle overrun, utility excavation and tree roots (for the reason of risk reduction, as well as securing more durable construction). Good detailing to eliminate hazards, e.g. appropriate drainage and falls to avoid ponding of water. A proactive preventative maintenance regime will ensure surfaces are repaired before they become hazardous (this might be termed inherently safe maintenance).
2. Reduce hazard by design	Reduce risk by design.	Skid resistant surfaces, hand rails at steps.
3. Safeguarding	Take the necessary protection measures (e.g. safeguarding) in relation to risks that cannot be eliminated.	The inspection and repair regime should be such that defects are detected and repaired without exposing the public to unreasonable (intolerable) risk. Placing barriers or temporary repairs are expedients.
4. Information, training and personal protective equipment	Inform users of residual risks due to any shortcoming of the protection measures adopted, indicate whether any particular training is required and specify any need to provide personal protective equipment.	Placing warning notices is an expedient. It is probably unacceptable to consider more general training or personal protective equipment for the public, although highway authorities could encourage the use of cycle helmets, for example.

1. The Hazards Forum (1996)

3.2 Specific advice

Taking into account experience of risk reviews of highway authorities, risk management for footways and cycle tracks should be addressed at strategic, tactical and operational levels and specifically in categorisation, policy for inspection, intervention levels and repairs, records, complaints and comment procedures, allocation of resources and prioritisation, claims procedures and database and management systems.

This section sets out specific items of advice based on experience of risk management reviews, investigation of accidents and reviewing third party claims. Lessons learned from other parts of the network are also invaluable.

Advice	**Comments**
Policy	
Ensure policy is achievable	Policies, such as footway intervention levels, need to be realistic and consistently achievable.
Document policy	All polices and practices should have a documented rationale.
Set policy according to resources	An achievable policy will take account of the likely availability of resources (and other pressures on the service).
Consult users	The views of pedestrians and cyclists should be taken into account when formulating policies.
Obtain member approval	Obtain formal member (committee) approval of policies and practices.
Be aware of policies of neighbouring authorities	In legal proceedings brought against highway authorities, it is not unusual for the policies and practices of the authority to be compared (benchmarked) against those developed and implemented by their neighbours.
Have a documented policy on the selection and use of modular surfaces	The policy developed should provide guidance on where and why modular units and bituminous materials will be used (and importantly, not used).
Communicate objectives, policies, standards, responsibilities and record keeping standards within organisation	It is important that all persons, teams, sections etc. with an interest in the management, operation and maintenance of footways and cycle tracks are identified and communications encouraged with respect to the definition of roles, responsibilities etc. This is becoming even more significant given the many different groups operating within a highway authority, including those who are not direct employees, e.g. consultants and contractors. It is important that all staff have a good awareness of not just the specific role/s they fulfil, e.g. the undertaking of routine visual inspections to detect and address safety related defects, but also of the contribution their role makes to wider objectives, i.e. contributing to reducing accidents.
Categories	
Documented and logical categories	This is one of the essential building blocks of a sound highway management regime, enabling resources to be prioritised and targeted to where they are most needed.
Review categories	Categories must be regularly reviewed to ensure that they continue to reflect the current usage.
Obtain actual usage volumes	Categories based on measured usage have been found to be most useful in setting strategy (with respect to the level of service provided) and prioritising works on the ground.
Determine boundaries of network	Lack of a full understanding of the precise boundaries of the road network (e.g. with trunk roads) has caused problems in terms of ability to successfully defend claims.
Note where a facility is actively promoted	The promotion of facilities by other council departments or kindred organisations, e.g. Tourist offices, may enhance expectations for service. Ensure adequate provision for its on-going maintenance.

Advice	Comments
Strategic issues	
Other assets and prior knowledge	Footways and cycle tracks are only a part of a highway authority's assets, which in turn are a part of local authority or government assets. Interactions between risks are not always obvious, especially when they occur between unrelated departments within an organisation. Traditionally each department/discipline has dealt with their own specific risks, e.g. operations managers will concentrate on operational risks; human resources may address employee risks; and so on. However, to implement an integrated risk management strategy these managers must co-ordinate their risk management activities. This has an important implication in potential liability of a highway authority. Prior knowledge of one division of the local authority, e.g. environmental management, would be deemed to be available to the whole highway division. This requires what is termed 'joined-up thinking' and lessons learnt in one section should, where relevant, be communicated throughout the organisation.
Tactical issues	
Utilities	The influence of utility companies and other activities on the network should also be taken into account in risk management. For example, claims relating to utility construction should be forwarded to the company concerned.
Consider maintenance during design	Although matters of design are not specifically addressed here, in its early stages it is essential that maintenance engineers are consulted to prevent poor designs and for future maintenance. Safety audits often identify a number of important issues but auditing is often missed. Safety audits are only applied to new sites but it is important that existing routes are also assessed as part of the maintenance regime, assessing things such as street furniture, vegetation and sight lines for pedestrians and cyclists as well as motorists. Safe routes to school schemes are often introduced without consultation with maintenance staff. These routes are often forgotten during winter maintenance, with resources concentrating on carriageways and main shopping areas. A number of authorities have found to their cost that a new facility cannot actually be maintained with the organisation's existing equipment. This creates vulnerability and necessitates the need for innovative (and often expensive, non-standard) solutions. An audit of design plans and/or the facility itself soon after opening can highlight potential problems in this regard at the earliest opportunity. Designers must also be encouraged to design with maintenance in mind.
Consider how to prevent, discourage and react to, acts of vandalism (e.g. physical damage, offensive graffiti etc.)	Such acts can affect the safety, serviceability and sustainability of a facility and it is therefore necessary to consider a suitably effective response to such acts.

Advice	Comments
Operational issues	
Inspect on foot	A safety inspection should identify the hazards relevant to the user, therefore, except possibly in rural areas, an inspection from a vehicle is not likely to be effective. Some ridden inspections of cycle tracks should be considered.
Known hazards for pedestrians	The following features are known to have caused accidents: projections (‘trips’), potholes, uneven surfaces, loose surfaces, slippery surfaces, rocking slabs or ironwork, overgrown or overhanging vegetation, weed growth, defective ironwork, missing covers, exposed electrics, drainage defects leading to ponding.
Known hazards for cyclists	As above, although overhanging vegetation, low structure clearance and edge damage are particularly hazardous for cyclists.
Keep open mind about other hazards	An inspector should keep an open mind about other potential hazards. As described above, these are most likely to be noticed while on foot.
Consider needs of mobility impaired	Again, hazards are most likely to be noticed while on foot.
Do not ignore ‘built in’ defects	It is important that an inspector reports hazards arising from poor design, construction and installation. They may be someone else’s fault, but the highway authority may still be liable. Currently training and experience of inspectors tends to concentrate on debris, obstructions and damage. Examples include finger posts that restrict access for maintenance vehicles undertaking such activities as grass & hedge cutting, winter maintenance and ditch clearing and high kerbs adjacent to cycle tracks that restrict maintenance.
Non-rectified faults	Re-identification of the non-rectified faults in successive inspections is an important reminder for contractors that repairs should be performed, but prolonged inaction leads to vulnerability to third party liability.
Review categories at special events	Consider the implications of increased usage at cycle races, charity events, etc. and adjust category or undertake a special inspection.
Note natural desire lines	It is important that facilities are provided where there are obvious and foreseeable desire lines.
Are barriers needed and are they effective?	Are barriers needed to prevent use by unauthorised vehicles? Any barriers need to be robust and effective & their continuity, condition and effectiveness formally reviewed at regular intervals.
Is a shared footway and cycle track wide enough?	Perhaps the easiest and most effective way to address this is to observe usage of the facility during a routine visual inspection of the facility and report back any concerns.
Is the end of the cycle track or need to dismount signed?	Locations where it is unsafe to continue cycling should be identified.
Report redundant street furniture	Redundant street furniture (such as a tourism sign for a facility that is no longer ‘open’) reduces user safety and contributes to clutter.

4 Footway accidents

Information on the numbers and severities of footway accidents is necessary in order to make a quantified assessment of risk and identify factors that may cause or influence the numbers of accidents. The main sources of information are records of third party claims against highway authorities and hospital accident records, which are reviewed in this section.

4.1 Review of third party claims data

4.1.1 General

Records of third party claims, made against three local authorities in the UK, were examined:

- London Borough of Bromley (March 1998 to March 2002).
- Rhondda Cynon Taff County Borough (RCT) (February 2000 to March 2002).
- Hampshire County Council (March 1998 to June 2001).

A total of 1,307 claims on footways were identified, but no claims on cycle tracks were noted. Information about the footway networks and some details about the analysis of this data are contained in Appendix A. The numbers of claims made, rather than settled claims, were counted in this review, as it is broadly assumed that each claim represents an accident, whereas not all claims following an accident are settled, because the highway authority may have a justifiable defence. Furthermore it is considered that the focus of a highway authority's policy should be reducing the number of accidents, rather than simply avoiding third party claims.

Various relationships have been investigated with the objective of investigating the factors affecting the risk of a person having an accident on a footway or cycle track, e.g. the probability that one person will injure themselves when passing a defect.

4.1.2 Age

The age of the claimant was recorded on 487 data lines and is summarised in Figure 1.

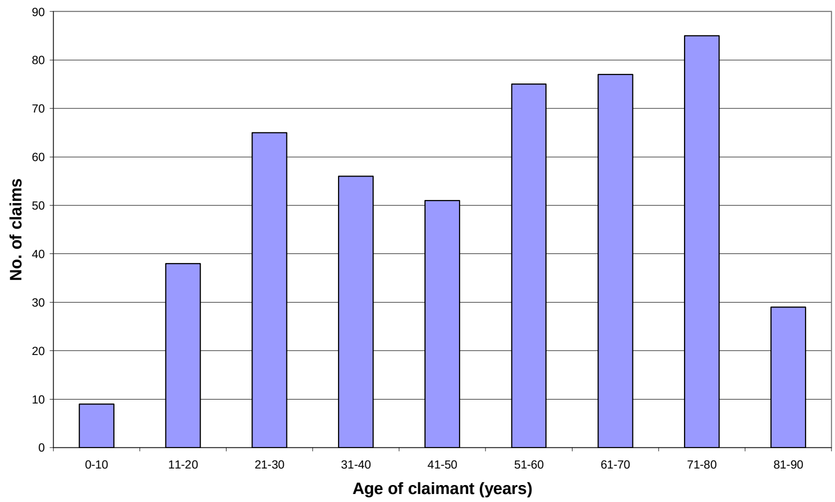

Figure 1 Number of claims according to age of claimant

Over half (55%) of the claims recorded on defects of 20mm or less were made by people over the age of 60. 40% of all claims were made by people over 60 years old. This may partly be due to the physical walking characteristics of the elderly.

At one authority there was a noticeable increase in the number of claims in a particular age range in one year, with the suspicion that these represented the efforts of claims services.

To further understand the significance of age on the probability of injury the data have been normalised with respect to national statistics of the average number of kilometres walked per person per year in each age group (DfT, 2002c), shown in Figure 2.

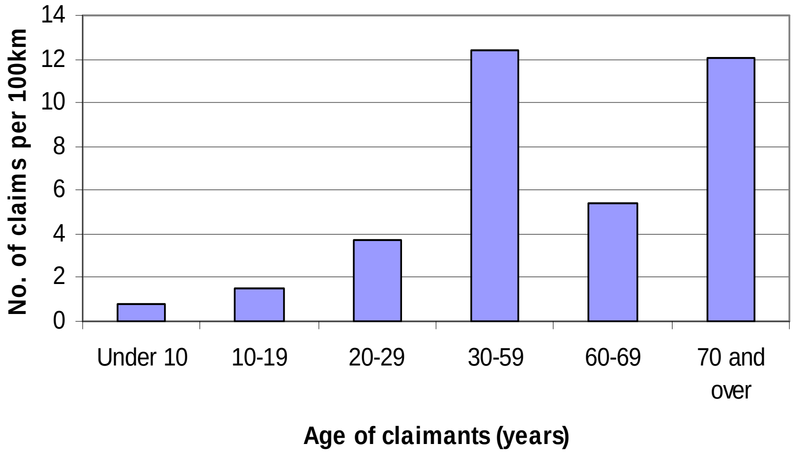

Figure 2 Number of claims by distance walked and age

4.1.3 Defect height

The height of the defect was recorded in 389 cases and Figure 3 shows the distribution of the number of claims within each range of defect height. These include a variety of types of defect (trip, unevenness, pothole, etc.) which have not been considered separately because there were relatively few claims for each type.

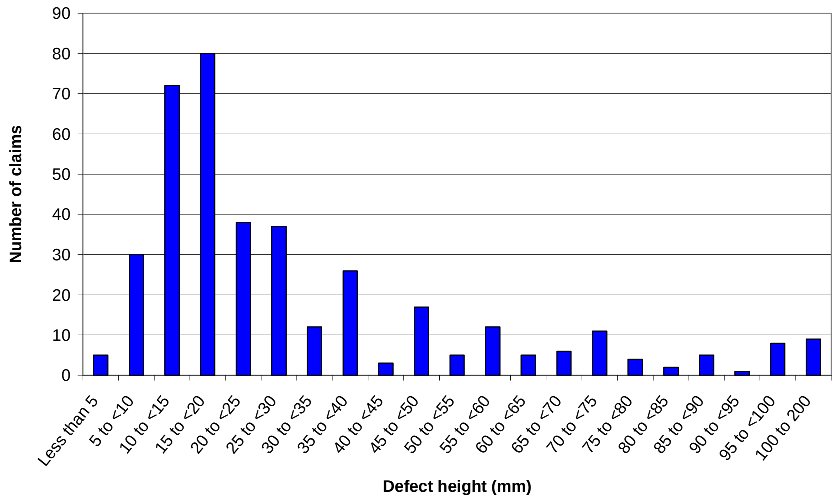

Figure 3 Number of claims by defect height

There is a peak of claims in the range 15 – 20mm; (the threshold for safety defects is generally 20mm). This is similar to the findings of a review of personal injury accidents in Sheffield from 1992 to 1997 which showed a peak in the range 10 to 19mm (Pearson, private communication), where the safety threshold was 20mm. This appears to suggest that intervention policy has been effective in limiting the number of defects over 20mm, however it is necessary to consider the number of defects within each height range and the number of people walking over each defect before drawing conclusions about the probability of injury in relation to defect height. Figure 3 also shows that accidents do result from defects less than 20mm.

4.1.4 Risk of accidents

The probability of a person injuring themselves on a given defect can be calculated from the number of people walking past the defect per accident attributed to that defect. This can be derived from the total person km walked, the number of defects per km, the number of claims and the relation between the number of claims and number of accidents.

Person km walked can be estimated from details of the three networks studied and typical pedestrian flow data. Network lengths for the authorities in which claims were studied, the period of study and details of maintenance regimes are shown in Table A1 in Appendix A.

Pedestrian flow data has been obtained from several authorities in the UK as described and summarised in Appendix B. The nominal flows shown in Table B20 were used in the analysis.

In order to estimate the number of defects developing per year per km, TRL analysed data from highway authorities and undertook local surveys. The details of this exercise are presented in Appendix C. The results are summarised in Figure 4 below.

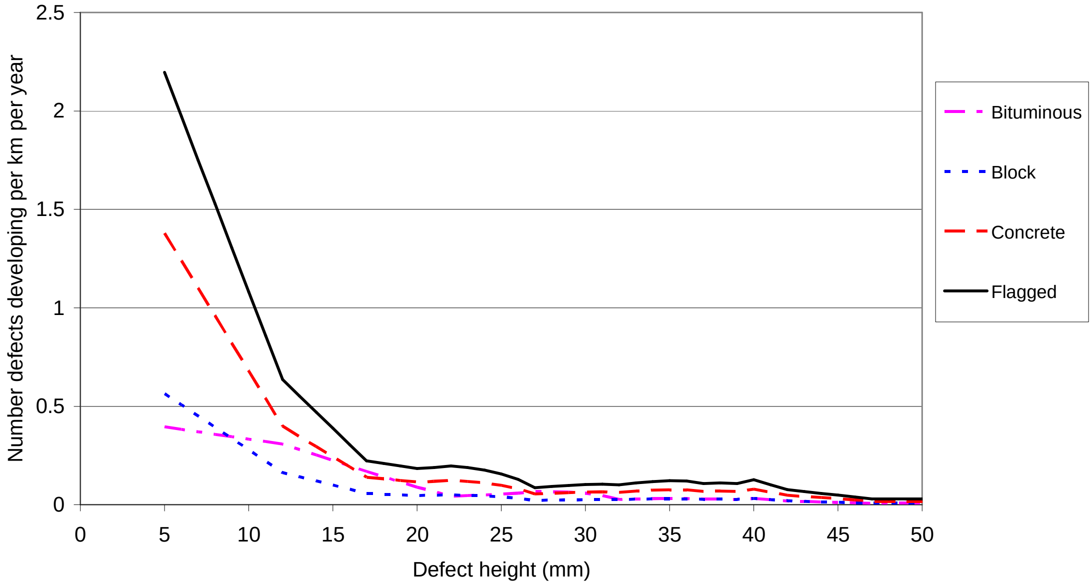

Figure 4 Number of defects developing per km

The probability of a person having an accident due to a defect is shown is shown in Figure 5, based on detailed calculations shown in Appendix E.

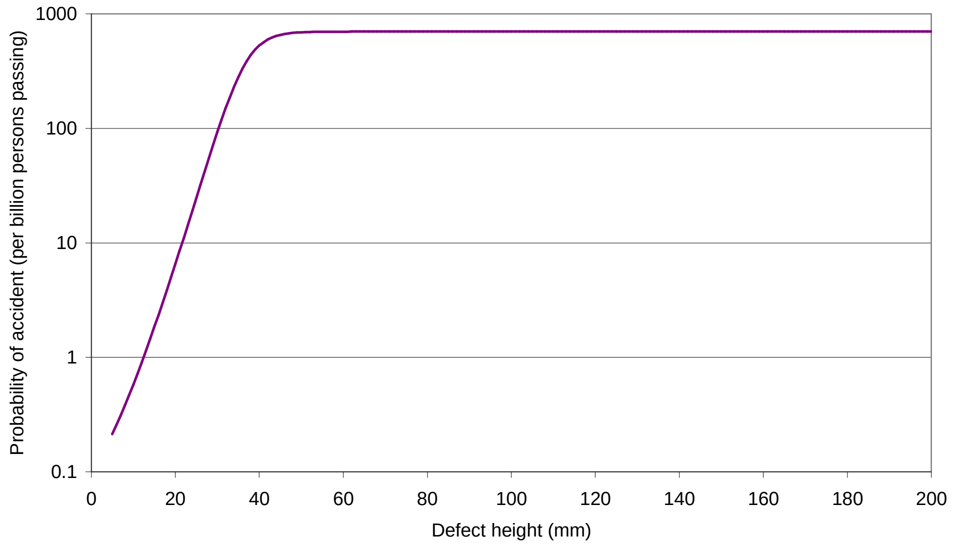

Figure 5 Probability of an accident

4.1.5 Construction type

Information on construction type at the location of the accident was recorded for 497 claims. Slabs account for almost half of these claims, however the relative length of and pedestrian flow over each construction type is not known, thus no conclusion can be drawn here as to the probability of injury according to construction type.

4.1.6 Injuries

The records of claims, in some cases, included descriptions of injuries sustained. Injuries were classified into three categories as shown in Table 5.

Table 4 Numbers of casualties in each category on records of claims from 3 highway authorities

Category of injury[1]	**Number of claims**	**Percentage of total**	**Description**
Serious	170	13%	Broken bones, knocked out teeth, surgery required
Slight (hospital treated)	142	11%	Cuts, broken toes and fingers, sprains and tendon and ligament damage
Slight (GP treated)	223	17%	Cuts, bruises, damage to clothing and glasses
No record of any injury	535	59%	

1. Choice of category was on the basis of type of injury, as normally only these were recorded - not place of treatment.

These data are discussed in relation to the costs of walking accidents in Section 7.4.

4.2 Data from hospitals

Many kinds of data on accidents resulting in hospital treatment are contained in the Home Accident Surveillance System (HASS) and Leisure Accident Surveillance System (LASS) databases, now maintained by ROSPA (2005). This is based on interviewing patients in A&E units at a sample of around 20 hospitals. A multiplication factor of 20.5 is then used for deriving a national estimate. The database shows that in 2002 there were 244,422 falls on public roads, streets, pavements, verges, footways, roads, paths etc. It was possible to eliminate those associated with certain external factors, such as use of alcohol, roller skates and ice, leaving a total of 193,151. Uneven surface is mentioned in the accident description for 948 entries, this equates to 20,434 in the national estimate. However, in many cases no description is given as to the cause of the fall, so no definite conclusions can be drawn as to the number of accidents that are the result of surface condition. Thus, around 190,000 might be the upper bound, and 20,000 the lower bound estimate of A&E admissions each year due to falls on public walking surface defects.

The outcomes following these falls are shown in Table 5. This shows that about 5% of A&E cases were admitted, which is similar to the proportion of home accidents (Hopkin and Simpson, 1996), suggesting that the pattern of severity of home accidents is similar to that of injuries following falls on streets. This is of significance, as discussed below, when deriving the average cost of fall accidents.

Table 5 Outcomes of falls from HASS/LASS database

Outcome	Proportion %
Admitted	5
Referred to outpatient	32
Referred to GP	11
Examined, no treatment given	6
Did not wait	2
Treated, no more treatment required	42
Other	2

Information gathered by the Department of Health on all hospital admissions (Hospital Episode Statistics, DoH, 2005a), reproduced in Table 6, shows that there were 68,916 admissions in 2003/04 for ‘falls on same level from slipping, tripping and stumbling’, which included a high proportion of elderly people. However these numbers include falls in all places, including the home, so it is not possible to draw conclusions regarding falls on public walking surfaces.

Table 6 HES for admissions 2003/04

Item[1]	Number
Finished Consultant Episodes	74,145
Admissions	68,916
Male	26,134
Emergency	64,695
Mean length of stay (days)	10.4
Median length of stay	4
Mean Age	63
Age 0-14	8,085
Age 15-59	16,517
Age 60-74	12,550
Age 75+	36,959
Bed days	680,101

1. Category W01 Fall on same level from slipping, tripping and stumbling

Hunt et al (1991) gathered data on patients attending one A&E department in London with injuries attributed to tripping on uneven pavements. Extrapolating to the national level they estimated that there were 60,000 cases in the UK. They compared this with 10,000 claims from compensation lodged in 1987, and suggested that only about one sixth of such accidents proceed to claims against the highway authority.

4.3 Discussion

It is apparent that neither third party claims nor hospital records provide an accurate representation of the numbers of footway accidents. However in the absence of suitable information the following assumptions are made in order to derive data for making a quantified assessment of risk:

- Each third party claim is the result of an accident. Although injuries are recorded in few cases, it is considered unlikely that someone will make a claim unless they were hurt in some way. Also, the extent of fraudulent claims could not be determined, but they are not assumed to represent a significant proportion of claims.
- The number of footway injury accidents is six times greater than the number of claims.

5 Cycle accident data

Some knowledge of the accident rates for cyclists is necessary in order to assess risk on cycle tracks. Information relating accidents to surface defects is required in particular. However only very limited suitable data have come to light, summarised in Table 7 and described below.

Table 7 Summary of data on cycling accidents

Source	Accident rate per 10^6 km cycled
UK police records (STATS19) 1996 to 2001	5.5 (all highways)
Cyclists, UK Estimated on the basis of information from Cyclist’s Touring Club (Watkins, 1984)	146 (roads) (6% due to road surface)
Survey of cyclists, USA Kaplan (1975)	178 major roads 167 minor roads 469 cycle paths (16% surface defects)
USA updated Morittz (1998)	41 major roads 59 on minor roads 32 signed bike routes 26 on-street bike lanes 88 multi-use trail 282 off road/unpaved 1026 Other (most often 'sidewalk')

Based on national statistics of police accident records (STATS19, DfT, 2002a) and traffic flow (DfT, 2002b), the rate of pedal cyclist casualties from 1996 to 2001 is estimated at around 5.5 per million km cycled. This figure compares with approximately 1.1 in Holland in 1994 (OECD, 1998), 2.2 in Helsinki and 1.2 casualties per million km cycled in Sweden (Pasanen). However, the figure for the UK is known to be misleading for a number of reasons. The police records do not necessarily discriminate between casualties occurring on the carriageway, cycle track and footway. They only include cycle tracks if adjacent to the carriageway, i.e. within the highway boundaries, and therefore exclude off-highway cycle tracks. Finally the number of casualties is likely to be under reported. TRL studies (Mills, 1989 and Page, 1996) comparing police records with those in hospital casualty departments, show reporting rates of 27% overall, but 10% on cycle tracks, 2% on footways, none on footpaths and 36% on roads.

The Cyclist’s Touring Club (Watkins, 1984) carried out a questionnaire survey of cycling and cycling accidents, but did not report an accident rate as those who had had accidents were more likely to respond. Nevertheless, based on information in the report, an accident rate of 146 accidents per million km cycled has been estimated. Road surface was stated to be the cause of 6% of the accidents.

Franklin (1998) summarised research on cycle path safety. Although not explicitly stated, the implication is that accidents due to surface defects represent only a small proportion of reported accidents. Reported causes of accidents include collisions, loss of control, vehicles crossing driveways, stationary vehicles, head on collisions and junctions, but no mention is made of surface defects. On the other hand, there may be a problem of minor injury accidents and damage to bicycles caused by surface defects that might result in a claim against the highway authority.

Accident rates in the USA reported by Kaplan (1975) are based on a survey of cyclists and are more likely to be representative of all USA cycle accidents than police reported figures would be. Morittz (1998) provided updated figures.

With regard to causes of accidents, Kaplan (1975) found that 43% were reported as a 'fall', about 90% of which were termed ‘serious’. Kaplan expressed surprise at the number of accidents that did not involve others (vehicles, cycles, pedestrians etc); 60% of falls are reported as being caused by rider error (e.g. loss of control) and 40% (i.e. 16% of total accidents) caused by surface defects or debris (a poorly-maintained road surface containing large pot holes or longitudinal cracks, rocks, gravel, or other debris). In the updated report Morittz reports 59% as falls, without further details.

Because of the lack of suitable data, risk on cycle tracks could not be pursued further. However based on the above information, for the purposes of making preliminary estimations of risk, a rate of accidents due to surface condition on cycle tracks is estimated as 75 accidents per million km cycled.

6 Physiology of walking

6.1 Introduction

A study of the physiology of walking should provide insight into the factors that influence walking accidents. A significant body of medical research has been undertaken on aspects of walking, tripping and obstacle clearance by healthy people of all ages (but focussing particularly on the elderly) as well as those suffering from pathological gaits. This section contains a brief review of this research relevant to the maintenance of public footways.

6.2 Walking

Walking is a complex process involving many bodily faculties, and falls result from a combination of environmental, personal and biomedical factors:

- Environmental factors include weather, lighting, distractions, obstacles, slippery surfaces, spills, ridges, ramps and steps.
- Personal factors include type of footwear and its slip resistance, and objects being carried.
- Biomedical factors include changes due to ageing and disease and the use of medications, drugs or alcohol.

Studies (such as Smeesters et al, 2001, and a series by Pavol et al, 1999) suggest that the majority of trips induced in healthy adults do not result in falls, while the increasing risk of falling in the elderly is due to a failure to recover from a trip because of slower reaction times and/or decreasing lower limb strength. The elderly also have an increased risk of injury; diseases such as osteoporosis increase the risk of fractures following a fall.

Types of fall at the same, or near-same, level are distinguished as tripping, slipping, stumbling, tumbling and crumpling. Of these types, only tripping and slipping are associated with the environmental factors of the walking surface (Hyde et al, 2002).

Gait analysis is the systematic study of the manner of walking. A gait cycle is the time between successive repeated actions when walking, such as the right foot making initial contact with the ground. Initial contact is made by the heel of the right foot. The right foot rotates until the toe makes contact with the ground and the left foot is raised, heel first. When the left toe is off the ground, the left foot is swung pass the right foot until the left heel makes contact with the ground. The right heel is then raised before the right foot is swung forward past the left foot and when the right heel makes contact with the ground, the gait cycle is completed (Whittle, 2002)[1].

The timing and placing of successive steps must be continually adjusted in order to maintain dynamic equilibrium of the body during walking (Nashner, 1980). This inherent instability of upright posture is exploited to assist in propelling the body forward by a forward orientation of the body relative to the feet. The two critical gait phases in walking on the level are when the rear part of one heel is in contact with the ground at the moment when the toe of the other foot is lifted off.

[1] The nomenclature for the gait cycle varies from one publication to another. The terms used herein are those taken from Whittle (2002), who states that these terms would be understood by most people in the field.

6.3 Tripping

A trip occurs when the surface being walked on has an abrupt increase in height that is large enough to snag the toe and cause a loss of balance (Winter, 1991). The successive positions of the left leg during a single gait cycle are shown in Figure 6, which shows that during the swing phase the foot is lifted then swings through, making an arc centred about the knee. In the swing phase the toe is generally the lowest part of the foot, and hence it is most often the toe that makes contact with any trip hazard.

Figure 6 Positions of left leg during a single gait cycle

On level ground, a number of studies have shown that the clearance between the toe and the ground is in the range 15 to 20mm for younger adults, while it is less than 10mm for the elderly. Based on a study by Murray (1967), which found toe clearance to range from 1mm to 38mm, with a mean of 14mm, it was estimated by Civil and Forensic (2002) that a rise of height of 6mm would represent a trip hazard for 90% of those tested. Thus they considered 6mm to be an acceptable threshold for consideration of a trip hazard. As discussed below, this figure appears to be based on the results of measurements in laboratory conditions and relates to indoor walking. No data on toe clearance in outdoor conditions has been located.

Pedestrians can successfully step over obstacles when these are seen and their attention is not diverted. For example, Chen et al (1991) found that age had no effect on the clearance when stepping over obstacles, with subjects achieving a mean clearance of 64mm for crossing a 25mm obstacle. Older adults adjust their gait to prevent falls, adopting a conservative strategy incorporating slower speed and shorter steps. In an experiment Patla and Vickers (1997) found that the participants looked at an obstacle for about 20% of the time when they were approaching it, however they did not look at it when stepping over. Chen et al (1996) showed that people are more likely to make contact with an obstacle when their attention is distracted; this is especially so for the elderly.

Thus, as indicated by Hyde et al (2002), the relevance of a trip hazard depends on the context in which it is presented. Brown (2001) suggests that in the natural environment trip hazards, such as tree roots, protruding stones etc., are anticipated by walkers and their walking style is adjusted appropriately. This would accord with the common-sense expectation that footways for general use will be regular and consistent, and that a trip presents a greater hazard in a built-up environment, especially on busy footways where there may be distractions or where a pedestrian's view of the walking surface may be hidden by other pedestrians.

Hyde et al (2002) suggest that the probability of tripping increases with the projection angle of the trip, as illustrated in Figure 7, however this does not appear to be supported by experimental findings. This could be of significance when considering footway construction material. For example, the projection angle of most defects in a modular surface will be 90°, whilst defects in bituminous surface are likely to be rounded and of lower projection angle.

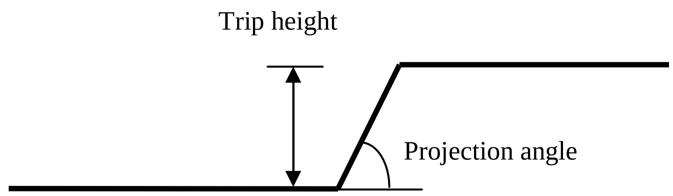

Figure 7 Trip height and projection angle

6.4 Slipping

During normal walking on non-slippery surfaces, the heel naturally slides up to 10mm for a short time after initial heel contact. The heel contact phase is considered to be more challenging for stability and more hazardous from a slipping viewpoint because forward momentum maintains body weight on the leading foot causing the foot to slide forward (Redfern et al, 2003). It is evident that healthy pedestrians can negotiate slippery surfaces when these are anticipated, but unexpected slipperiness will present a particular hazard.

Brungraber (1976) has stated that the most probable value for the minimum static coefficient of friction to prevent slips on level ground for most of the population ranges from 0.3 to 0.35, so the currently accepted US Standard requiring a value of 0.5 provides a safety margin of approximately 50 per cent. The coefficient of friction suggested for safe running is 1.1 (Hyde et al, 2002).

6.5 Gait in the elderly

A number of investigations have been undertaken on changes in gait with increasing age, especially by Murray et al (1969). The gait of healthy elderly people appears to be simply a ‘slowed down’ version of the gait of younger adults. However, a gradual decline in balance abilities and speed of gait occurs with age. One cause of tripping is that the timing of the anterior tibialis muscle (which lifts the ankle and toes during walking) becomes out of synchronisation, with the result that the toe may catch on an obstacle (Newton, 1997). Falls in elderly people are associated with a large number of fractured femurs and other serious morbidity (Kirtley, 1999).

The elderly tend to have more trouble walking in situations that require speed (e.g. crossing the street), agility (e.g. walking on uneven surfaces or in crowds), or in the dark (Newton, 1997). Thus the condition of the pavements is especially important in places that serve the elderly and people who are physically less able (e.g. sheltered housing).

Vision is vital to normal walking but visual acuity decreases with age. Newton (1997) stated that changes in contrast sensitivity occur, which relate to the ability to detect objects or obstacles in the pavement environment. One way to accommodate this change is to improve the lighting of the environment. A decline in depth perception results in a decreased ability to judge distances and relationships among objects in the visual field. Stairs, carpets with patterns, kerbs and other raised surfaces can be a problem for people with decreased depth perception.

6.6 Regulations and guidelines for walking surfaces

Various regulations and guidelines for walking surfaces in workplaces, buildings, for the disabled and for footways are summarised in Table 8.

Table 8 Summary of regulations and guidelines for walking surfaces

Source	Summary of requirement or guideline
Workplace Health, Safety and Welfare Regulations (HMSO, 1992), Regulation 12	*'…suitable for the purpose for which it is used… no hole or slope, or be uneven or slippery… free from obstructions…'* There are no specific requirements concerning the slip resistance and the size of any defects. It is generally considered that a static coefficient of friction of 0.5, as used in the American Standard, and a dynamic coefficient of 0.4 as used as a British Standard is acceptable. New guidelines are being prepared for a new British Standard on the slip resistance of floors and floor finishes.
ANSI A117.1 (1992) and ASTM F 1637 (1995) Relating to buildings and walking surfaces in the USA	Vertical changes in level: < 6mm allowed without edge treatment 6 – 13mm bevelled not steeper than 1 in 2 > 13mm - ramp or stairway
A Guide to Best Practice on Access to Pedestrian and Transport Infrastructure, DfT (2002f)	< 5% gradient (although shallower gradients may cause problems for some users) < 2.5% crossfall 2 – 5mm joints between flags and pavers, wider joints (6-10mm) filled with compacted mortar. < 3mm deviation under a 1 m straight edge Cobbled surfaces not appropriate 35 to 45 dry friction
BS 8300: 2001 Design of buildings and their approaches to meet the needs of disabled people	< 5mm deviation under a 3m straight edge < 5mm difference in level < 10mm joint width < 5mm joint depth
NRSWA Specification (DfT, 2002e)	< 6mm step at edge of reinstatement < 10mm vertical step over more than 100mm
AG26 (TRL, 2003)	A polished paver value (PPV) value of 45 is adequate for general use

6.7 Discussion and conclusions

No research has been found which directly investigates the probability of a person falling on a given defect, nor on any differences there might be between walking in the laboratory or inside a building and in the open, and such research is recommended. However, based on the above findings a simplified sequence of events involved in falling, together with factors that influence them, is shown in Table 9.

Table 9 Chain of events in falling

Sequence of events	Factors that influence event
Person fails to notice defect *Most people will negotiate a defect if it has been noticed*	Distractions, expectation of walking surface, density of pedestrians, eyesight, lighting, influence of alcohol or drugs, speed of walking.
1. Trip: foot catches on defect	Toe clearance, footwear.
2. Slip: foot slips	Coefficient of friction of surface and footwear, influence of water or any spillage.
Person falls *Most healthy adults will recover from a trip, and not fall*	Age (reactions and lower limb strength), influence of alcohol or drugs, speed of walking, objects carried.
Person is injured	Age (reactions and upper limb strength - to break fall), disease (osteoporosis), speed of walking.

Thus there are many factors that influence whether a person falls and is injured. Those involved in dealing with claims should note that there may be exacerbating factors not associated with the surface, e.g. use of alcohol, footwear and objects carried.

In relation to defect height, it is thus considered that the probability that a person falls would be influenced by toe clearance and increasing visibility of larger defects, as shown schematically in Figure 8.

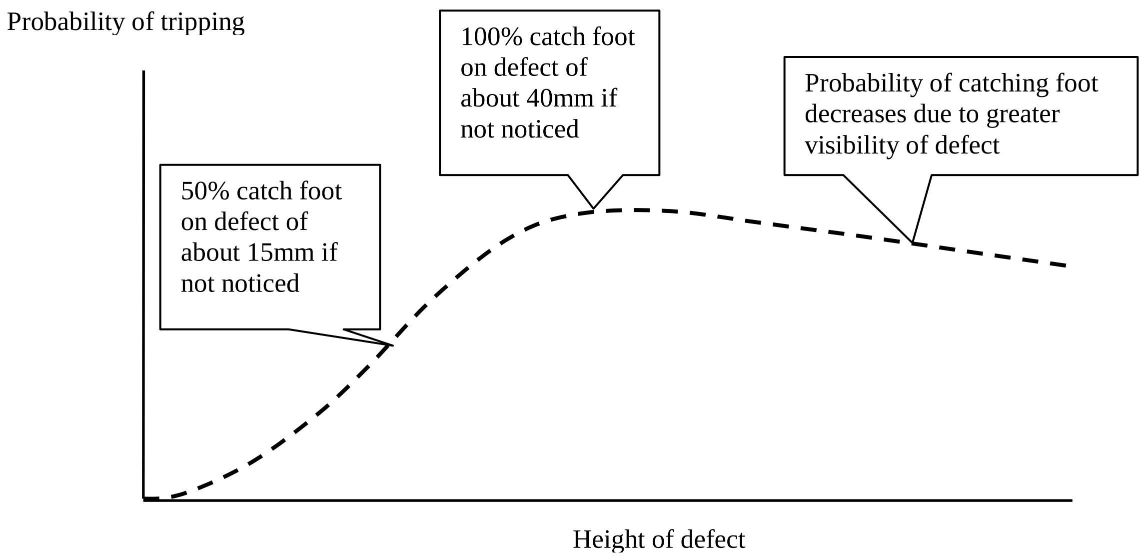

Figure 8 Proportion of persons catching toe on defect

The form of this relationship is based on Murray's findings (described above in Section 6.3) that 50% of people would catch their foot on a defect at around 15mm (which is not noticed), and 100% at around 40mm. However these are thought to relate to laboratory findings, thus in the open the relevant heights may differ. This form of relationship appears to be in accord with the findings of the analysis of claims, see Figure 5.

From the study of the physiology of walking (and the record of claims) it is clear that pedestrians can and do trip, fall and injure themselves on defects of height less than 20mm – the most commonly accepted safety investigation threshold.

7 The costs of walking accidents

7.1 Introduction

An aspect often overlooked with regard to trip hazards is the 'whole cost' to society of poorly maintained footways. As well as the cost of compensation payments, older people falling on pavements are likely to be a significant cost to the NHS, since the injuries they sustain are likely to be sufficiently serious to require hospital treatment. In addition, the National Council on Ageing (2001) reported that the Audit Commission's report 'United they stand: co-ordinating care for elderly patients with hip fractures, 1995' clearly established that older people experiencing falls frequently sustained a fracture of the neck of the femur which meant that they had to be admitted into care homes, with all the associated costs.

Methods of evaluating costs of accidents are reviewed in this section, then the cost of a footway accident is derived.

7.2 Costs of accidents –DfT method

For the use in the appraisal of road schemes, the cost of a casualty in a road traffic accident is estimated at £40,290 (Highway Economics Note No 1, DfT, 2002d). This represents the value of preventing an accident and includes the following cost elements:

- Lost Output. This is calculated as the present value of the expected loss of earnings plus any non wage payments (national insurance contributions, etc.) paid by the employer.
- Human costs. These represent the pain, grief and suffering to the casualty, relatives and friends, and, for fatal casualties, the intrinsic loss of enjoyment of life over and above the consumption of goods and services.
- Medical and ambulance. Hospital treatment and ambulance costs.

Definitions of severity used are:

- Fatal – death occurs within 30 days of the accident.
- Serious – casualties who die as a result of their injuries more than 30 days after the accident, all casualties who are admitted to hospital as an in-patient as a result of their injuries, and casualties who are not detained in hospital but have any of the following injuries: fractures, concussion, internal injuries, crushings, severe lacerations and severe general shock requiring medical treatment.
- Slight – casualties with injuries such as a sprain, bruise or cut which are not judge to be severe, or slight general shock.

TRL reports (e.g. Hopkins and Simpson, 1996) fully describe the bases of the cost. Using similar methods they also derive the casualty costs for home accidents shown in Table 10. Home accidents were found to be less severe than road accidents, so average weighted costs are much less – around 30% of those for road accidents.

Table 10 Estimated costs of a home accident casualty (2005 prices[1])

Injury Severity	Lost Output (£)	Human costs (£)	Medical and ambulance (£)	TOTAL (£)
Fatal	364,063	682,065	681	1,046,809
Serious	3,842	31,935	2,697	38,474
Slight (hospital treated)	1,068	3,551	627	5,247
Slight (GP treated)	0	160	0	160
Weighted average, all casualties	1,936	9,786	908	12,630

1. Adjusted from the 1994 prices derived by Hopkins and Simpson (1996)

Other costs, such as damage to vehicles and property, police time and insurance administration are also provided for evaluation of road traffic accidents, but it is thought these would not feature significantly in walking accidents.

The London Health Observatory (2002) estimated the costs of all types of injuries and accidents in London. They used DfT costs for road accidents, making some adjustments to the output and human costs. However they used completely London-based data for the medical and ambulance costs, resulting in a cost about 20% of that derived using the DfT method for this element. Only total costs are given so it is not possible to estimate the average cost of each accident caused by falls in London.

7.3 Cost of NHS services

Enquires to the Department of Health indicate that overall costs of treatments and other such indicators are not derived. Costs of all types of treatments and procedures in the NHS are listed in detail in the Healthcare Resource Group (HRG) reference costs (DH, 2004). It would be possible to build up costs due to a range of typical injuries following a fall, but this would take considerable effort and require detailed medical knowledge.

However the cost of hospital treatment for road traffic accident victims that may be recovered by the DH (2005b) provides a further indication of costs. The flat rate charge for treatment without admission is currently £483 and the daily rate charge for treatment with admission is £593. In deriving these figures the severity of road accident injuries and range of treatments necessary was taken into account, therefore these medical costs are likely to be more than for those associated with falling on footways.

No data has been found that gives an indication of further costs that might arise, particularly for the elderly, of long term care following an injury sustained by a fall.

7.4 Derivation of costs of footway accident

As described in Section 4.1.6, the records of claims from three highway authorities, in some cases, included descriptions of injuries sustained. It is not certain how to interpret the large proportion of claims where there is no record of injury, either: 1. there was no injury, or 2.

there was an injury, but it was not recorded in the local authority records. Except in the case of fraudulent claims it is considered unlikely that someone will make a claim unless they were hurt in some way. Therefore it will be assumed conservatively that in these cases injuries were very slight without resulting in cost. This will underestimate the scale of injuries, hence overall costs.

If the costs derived by Hopkins and Simpson (1996) for home accidents, shown in Table 11, are weighted by the proportion of severities (Table 5), the resulting weighted average costs of falling on a footway are shown in Table 11.

Table 11 Estimated costs of casualty following a footway fall

		Costs £ (2005)			
Injury Severity	**Proportion of claims**	**Lost Output**	**Human costs**	**Medical & ambulance**	**TOTAL**
Fatal	0%	364,063	682,065	681	1,046,809
Serious	13%	3,842	31,935	2,697	38,474
Slight (hospital treated)	11%	1,068	3,551	627	5,247
Slight (GP treated)	17%	0	160	0	160
Not recorded	59%	0	0	0	0
Weighted average, all casualties		617	4,569	420	5,606

The medical and ambulance cost of £420 appears reasonable in comparison with charges made for hospital treatment for road traffic accident victims. The total figure also includes elements for lost output and cost of pain, grief and suffering. Therefore the figure of around £6,000 represents a basis for economic evaluation of measures for preventing footway falls.

It can be argued that the costs of claims should not be added to these values, since they already allow for lost output and the human cost of pain, grief and suffering.

7.5 Cost of claims

Based on the results of a questionnaire survey of 158 responding UK highway authorities (Spong and Cooper, 1996), the average cost of claims for an injury on footways was about £1,370, and the average cost of claims per km of footway was about £200. In review of personal injury accidents in Sheffield from 1992 to 1997 the average cost of claims paid out was £2,361 (Pearson, private communication).

More recent estimates of the total costs of claims on footways range from £100m to £500m per year, although these would exclude information on claims settled in-house. The suspicion that there are fraudulent claims would need to be taken into account. The Association of Local Authority Risk Managers (ALARM) is leading a project to set up a national database on claims (www.alarm-uk.com) which could be a rich source of information. Also information could be obtained by approaching all highway authorities individually.

Based on this data a crude calculation indicates the following current cost of claim:

> The average number of falls resulting in A&E admissions is taken as 110,000 (the mean of the upper and lower bounds of 20,000 and 190,000, see Section 5).

The number of claims is assumed to be one sixth of this (Hunt et al, 1991, discussed in Section 5), i.e. 18,700.

Current total cost of claims is taken to be the mean of £100m to £500m, i.e. £300m

Average cost of claim: £300m/18700 = £16,042.

7.6 Discussion and conclusions

Since they are currently used in the appraisal of road schemes, it would appear reasonable to follow the method used by DfT (2002d) for deriving an estimate of the value of preventing an accident on footways. However the costs derived by Hopkins and Simpson (1996) for home accidents, shown in Table 11, are likely to be more representative of the treatments for injuries following falls, than those for road accidents.

The figure of £5,606 (2005 prices) for the costs of a fall on a footway would appear to be reasonable in comparison with the costs of a home accident (£12,603) and road traffic accident (£40,290, DfT, 2002d). The medical and ambulance portion (£420) appears reasonable in comparison with charges made for hospital treatment for road traffic accident victims (£483 for treatment without admission and £593 per day on admission). It also appears reasonable (and conservative) in comparison with a crude estimate of the current cost of a claim for a fall on the footway.

In providing an estimate of the costs of injuries and accidents in London, the London Health Observatory (2002) commented that different definitions of accidents exist across agencies and that data are incompletely recorded. Thus considerable study would be necessary to derive incontrovertible and statistically valid costs of accidents.

8 Footway risk model

8.1 Introduction

Although the various risks might not be quantified particularly well, if at all, highway engineers implicitly, if not explicitly, recognise the concept of taking risk into account. For example:

- Response time should relate to the intensity of use and degree of danger (Local Authority Associations, 1989).
- Yeomans (1995) suggested that setting safety intervention levels is an ideal candidate for a risk assessment approach. He discussed linking intervention level and response time with both traffic and likelihood of the defect causing an accident.
- Intuitively, the risk of an accident on a footway increases with defect dimension (e.g. trip height) and lengths of time pedestrians are exposed to the defect.

Defect thresholds are based on experience and legal precedent, which in turn are based on ‘reasonableness’. However it might be possible to develop a rational basis for these values, i.e. equate defect type and dimension (e.g. trip height) to risk of injury.

8.2 Risk model

A risk assessment model for footways is developed to calculate the number of accidents on a highway authority’s network. The measure of risk is the number of walking related injury accidents predicted on the network. A software tool containing this model has been developed.

The model is based on the assumptions that it is possible to derive the probability that a person walking over a given defect will have an accident, and that the numbers of defects on the network will be a dynamic balance between the rate at which they appear and the rate at which they are repaired.

The number of accidents on a section of the network per year ($N_{accident}$) is taken to be:

$$N_{accident} = \sum_{(\text{from } h = 5 \text{ to } 200\text{mm})} F \times L \times t \times N_{defect}(h) \times P_{accident}(h) \qquad (1)$$

Where:

F = pedestrian flow on the section of the footway network (pedestrians per day)

L = length of section of the footway network (km)

t = time of pedestrian exposure to defect (days)

$N_{defect}(h)$ = number of defects, of height h, developing on the network per km per year, see Appendix C, Figure C6.

$P_{accident}(h)$ = probability that one pedestrian will fall and injure themselves whilst walking past a defect of height h, see Figure 5, and Appendix E.

The sum of this product for each height (h) of defect is calculated over the range of defect height for which information is available, e.g. from 5 to 200mm. The total number of accidents on the network is the sum of that on different sections, e.g. all categories and construction types.

The predicted cost of accidents may be obtained by multiplying the number of accidents by the cost of walking accidents derived in Section 7 (£5,606 in 2005 prices).

Thus:

Cost (£) = 5,606 x $N_{accident}$

The input parameters of the model are:

- Pedestrian flow in each category. In the absence of any reliable local data on pedestrian flow it is suggested that the nominal flows given in Appendix B are used, which are based on a collation of national flow information.
- Length of network in each category and any other sub-division for which information is available, e.g. construction type.
- Inspection intervals, response time and safety and maintenance intervention thresholds.

The rate at which defects appear on the network and the length of time that defects remain (i.e. the time the pedestrians are exposed to defects) are directly influenced by an authority's maintenance policy. More preventative maintenance will reduce the numbers of defects that appear and the safety inspection frequency and response time will limit the period for which defects remain un-repaired.

Calculations are based on knowledge about the two factors: $N_{defect}(h)$ and $P_{accident}(h)$. In order to develop the model it was necessary to gain greater understanding of these factors and quantify them, which has been described in the earlier sections of this report.

The time that pedestrians are exposed to a defect will vary depending on whether the defect is considered to be a safety defect or maintenance defect:

<u>1. Detection and repair of safety defects (those greater than the safety threshold, typically 20mm and greater)</u>

It is assumed that an inspector will detect every defect exceeding the safety investigation threshold. Therefore (assuming defects develop at a uniform rate, as discussed in Appendix B4) a defect will be present, on average, for half of the interval between inspections before detection. Also it is assumed that the safety defect will be repaired at the end of the response time.

Therefore the average exposure time of a safety defect (e.g. 20mm and greater) is:

(0.5 x safety inspection interval) + response time.

<u>2. Repair of maintenance defects (those less than the safety threshold, but greater than the maintenance threshold, typically 13mm to <20mm)</u>

Ideally non-safety defects and above the maintenance threshold (e.g. 13mm) will be repaired during a programme of planned repair (e.g. patching) following a condition or maintenance inspection.

Therefore the average exposure time to non-safety defect (e.g. 13mm to <20mm) is:

0.5 x (maintenance inspection interval)

However it is understood that many authorities have only sufficient resources for repairing safety defects and programmed repairs are not carried out. Therefore non-safety defects will remain on the network until the footway is resurfaced, in which case the resurfacing interval should be substituted into the above equation. The model may be used to explore the benefits of reducing this interval or carrying out programmed maintenance.

3. Repair of non-maintenance defects during resurfacing

All defects will be removed during resurfacing or reconstruction of the footway. Some authorities have sufficient resources to carry out a programme of resurfacing; if this is not done the model may be used to explore the benefits of such a policy.

Therefore the average exposure time to non-safety defect (e.g. less than 13mm) is:

0.5 x (resurfacing interval)

8.3 Application of the model

8.3.1 Investigating changes in maintenance policy

Table 12 shows the results of applying the model to a typical urban network. It is understood that many authorities do not have sufficient resources for carrying out planned maintenance, thus inspection intervals, response time and safety intervention thresholds reflect those often achieved in practice. All data in Table 12 are assumed for demonstration of the model only.

The model can be used to examine the effects on network ‘risk’ of varying inspection intervals, response times and investigation levels. Table 13 shows the reduced numbers of accidents resulting from an improved maintenance regime.

Table 12 Typical urban network

Footway category	Pedestrian traffic	Surface type	Length in network	Interval between resurfacing	Maint. inspection interval	Maint. defect threshold	Safety inspection interval	Safety defect threshold	Safety defect response time	No. accidents (below maint. threshold)	No. accidents (maint. to safety threshold)	No. accidents (above safety defect	Number of accidents per year	
	No. per day		km	years	years	mm	days	mm	days	per year	per year	per year	Total	per 10^8 person km
1a	10,000	Bit.	5	20	5	13	28	20	1	0.23	0.15	0.44	0.82	4.512
	10,000	Block	5	20	5	13	28	20	1	0.21	0.06	0.44	0.71	3.915
	10,000	Conc.	5	20	5	13	28	20	1	0.52	0.15	1.08	1.75	9.570
	10,000	Flag	30	20	5	13	28	20	1	4.92	1.42	10.33	16.67	15.226
1	10,000	Bit.	5	40	10	13	60	20	7	0.47	0.29	1.09	1.85	10.156
	10,000	Block	5	40	10	13	60	20	7	0.42	0.12	1.09	1.64	8.962
	10,000	Conc.	5	40	10	13	60	20	7	1.03	0.30	2.67	4.00	21.908
	10,000	Flag	60	40	10	13	60	20	7	19.68	5.70	50.95	76.33	34.853
2	1,000	Bit.	200	40	20	13	90	20	28	1.88	2.33	8.62	12.83	17.575
	1,000	Block	5	40	20	13	90	20	28	0.04	0.02	0.22	0.28	15.452
	1,000	Conc.	5	40	20	13	90	20	28	0.10	0.06	0.53	0.69	37.772
	1,000	Flag	20	40	20	13	90	20	28	0.66	0.38	3.35	4.39	60.091
3	500	Bit.	500	60	20	13	180	20	180	3.52	2.92	39.83	46.28	50.713
	500	Block	5	60	20	13	180	20	180	0.03	0.01	0.40	0.44	48.461
	500	Conc.	5	60	20	13	180	20	180	0.08	0.03	0.97	1.08	118.460
	500	Flag	20	60	20	13	180	20	180	0.49	0.19	6.20	6.88	188.459
4	200	Bit.	500	60	20	13	360	20	180	1.41	1.17	21.24	23.82	65.263
	200	Block	5	60	20	13	360	20	180	0.01	0.00	0.21	0.23	63.013
	200	Conc.	5	60	20	13	360	20	180	0.03	0.01	0.52	0.56	154.032
	200	Flag	10	60	20	13	360	20	180	0.10	0.04	1.65	1.79	245.051
	Total length km		1400				Number of accidents on network			35.84	15.36	151.84	203.04	30.921
							Number of accidents per 100km			2.56	1.10	10.85	14.50	
	Cost of footway injury accident				£5,606		Cost of injury accidents			£200,915	£86,117	£851,207	£1,138,239	

Table 13 Adjustment of parameters (reduced inspection intervals)

Footway category	Pedestrian traffic	Surface type	Length in network	Interval between resurfacing	Maint. inspection interval	Maint. defect threshold	Safety inspection interval	Safety defect threshold	Safety defect response time	No. accidents (below maint. threshold)	No. accidents (maint. to safety threshold)	No. accidents (above safety defect	Number of accidents per year	
	No. per day		km	years	years	mm	days	mm	days	per year	per year	per year	Total	per 10^8 person km
1a	10,000	Bit.	5	20	5	10	28	20	1	0.11	0.18	0.44	0.73	3.989
	10,000	Block	5	20	3	10	28	20	1	0.13	0.05	0.44	0.62	3.387
	10,000	Conc.	5	20	3	10	28	20	1	0.31	0.12	1.08	1.51	8.279
	10,000	Flag	30	20	3	10	28	20	1	2.94	1.15	10.33	14.42	13.171
1	10,000	Bit.	5	20	1	10	28	20	7	0.11	0.04	0.62	0.76	4.180
	10,000	Block	5	20	1	10	28	20	7	0.13	0.02	0.62	0.76	4.177
	10,000	Conc.	5	20	1	10	28	20	7	0.31	0.04	1.51	1.86	10.210
	10,000	Flag	60	20	1	10	28	20	7	5.88	0.77	28.92	35.57	16.242
2	1,000	Bit.	200	20	1	10	90	20	28	0.43	0.14	8.62	9.19	12.587
	1,000	Block	5	20	1	10	90	20	28	0.01	0.00	0.22	0.23	12.585
	1,000	Conc.	5	20	1	10	90	20	28	0.03	0.00	0.53	0.56	30.762
	1,000	Flag	20	20	1	10	90	20	28	0.20	0.03	3.35	3.57	48.940
3	500	Bit.	500	20	3	10	180	20	180	0.54	0.53	39.83	40.90	44.827
	500	Block	5	20	3	10	180	20	180	0.01	0.00	0.40	0.41	44.618
	500	Conc.	5	20	3	10	180	20	180	0.02	0.01	0.97	1.00	109.067
	500	Flag	20	20	3	10	180	20	180	0.10	0.04	6.20	6.33	173.515
4	200	Bit.	500	20	5	10	180	20	180	0.22	0.36	15.93	16.50	45.217
	200	Block	5	20	5	10	180	20	180	0.00	0.00	0.16	0.16	44.798
	200	Conc.	5	20	5	10	180	20	180	0.01	0.00	0.39	0.40	109.507
	200	Flag	10	20	5	10	180	20	180	0.02	0.01	1.24	1.27	174.216
	Total length km		1400				Number of accidents on network			11.48	3.49	121.80	136.77	20.829
							Number of accidents per 100km			0.82	0.25	8.70	9.77	
	Cost of footway injury accident				£5,606		Cost of injury accidents			£64,382	£19,542	£682,810	£766,733	

8.3.2 *Equalising risk*

The final column in Table 13 and Table 14 shows the predicted accident rate, which is generally greater in the lower footway categories. Thus consideration may be given to improving the maintenance regime for these categories, with a view to ‘equalising’ the risk of an accident for an individual.

8.3.3 *Variation of key parameters*

The following graphs show the variation in the number of accidents in a typical network (Table 13) as parameters in the model are varied in turn.

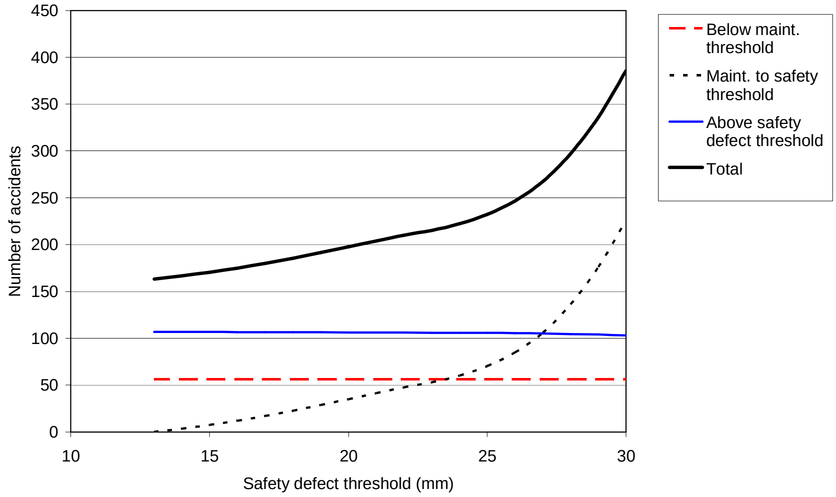

Figure 9 Variation in number of claims with safety defect threshold (IL)

This figure is best understood comparing the numbers of accidents when the safety defect threshold is reduced from 20mm to 13mm, as shown in Table 14.

Table 14 Variation in numbers of claims with safety defect threshold

	Number of claims per year Defect height			
Safety defect threshold	5 – <13mm	13 – <20mm	20mm and greater	Total
20mm	56.38	35.02	106.22	197.62
13mm	56.38	0.58	106.22	163.18

Reducing the threshold level results in an overall reduction in the number of accidents, due to a decrease in the number of accidents on defects between 13mm and 20mm; these would be subject to a safety repair regime if the safety defect threshold were reduced from 20mm to 13mm. However the much smaller number of accidents occurring on defects between 13mm and 20mm are now counted as accidents on defects above the threshold level, and so the total number of accidents above the safety defect threshold increases slightly as the threshold is reduced.

Figures 10 to 13 show how the number of accidents changes when various parameters are changed.

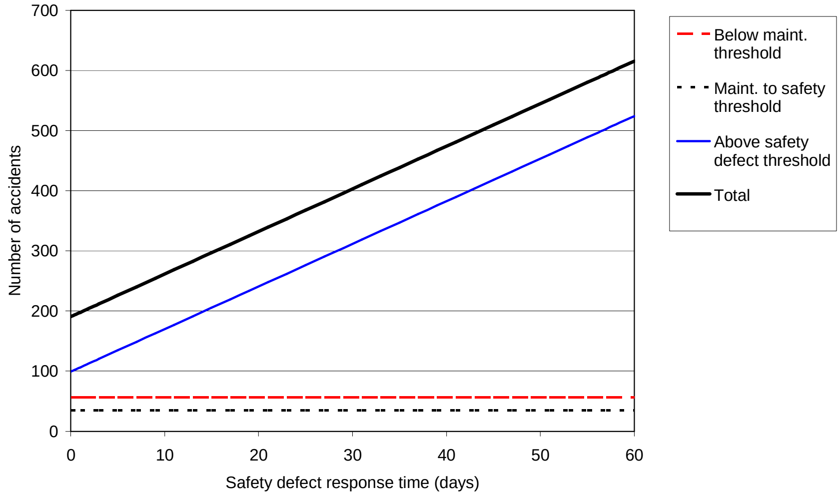

Figure 10 Variation in number of claims with response time

The number of accidents is shown to decrease with a decrease in response time. The number of accidents on defects below the safety threshold is not affected by the response time because these are not recorded, being repaired in the maintenance inspection cycle.

It is noted that there are some 190 accidents for a zero response time. This is because these arise in the period before a defect is detected (exposure time = 0.5 inspection interval + response time).

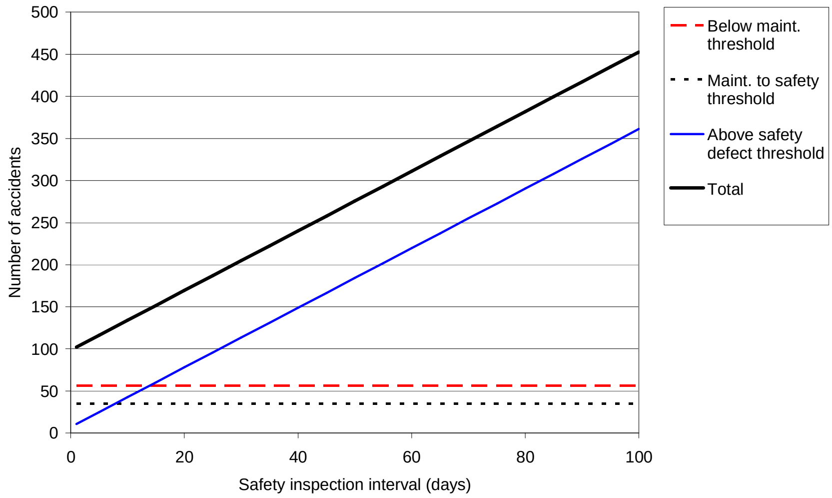

Figure 11 Variation in number of claims with safety inspection interval

Again the safety inspection interval has no effect on the number of accidents on defects below the safety threshold, as these defects are not recorded.

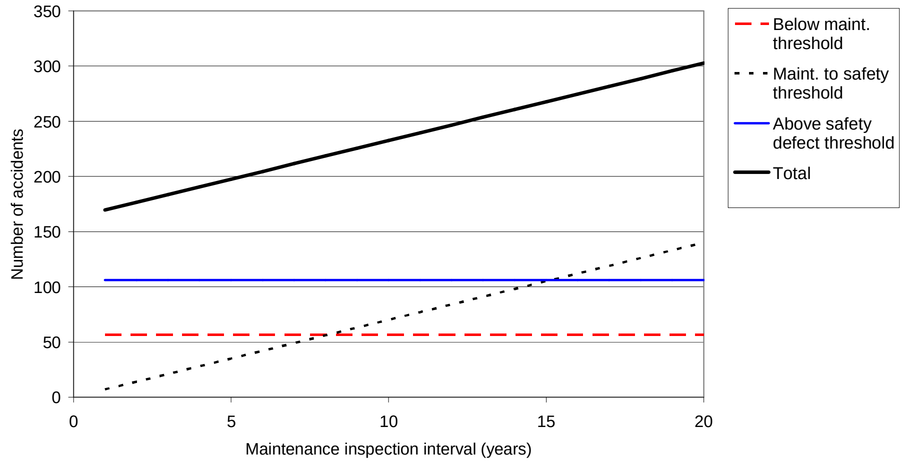

Figure 12 Variation in number of claims with maintenance inspection interval

In this case there will be a constant number of 106 accidents on defects above the safety investigation threshold, as it is not affected by the maintenance inspection interval. The graph shows that as the inspection interval is increased the number of accidents on defects below the safety investigation level is increased. However, most of these accidents do not normally result in successful third party claims.

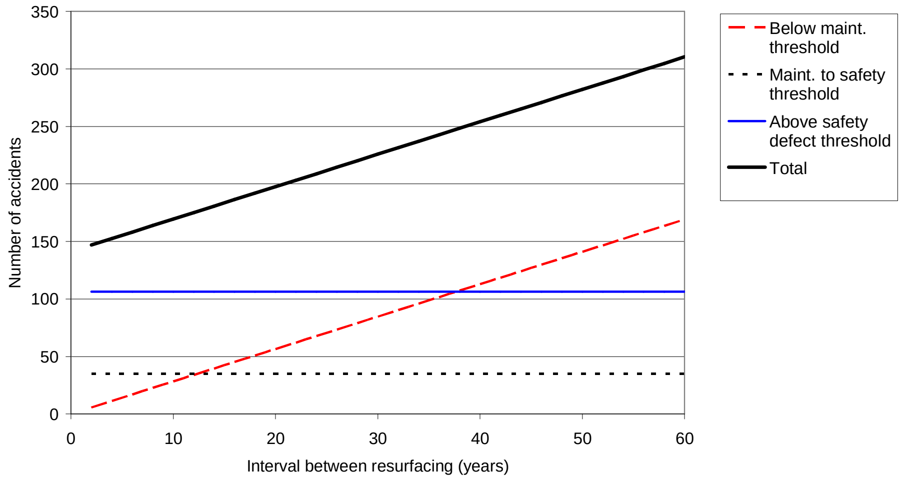

Figure 13 Variation in number of accidents with interval between resurfacing

8.3.4 Costs of accidents for Whole Life Cost model

The model may be used to provide data for use in a whole life cost (WLC) model on the 'cost', in terms of accidents, of not carrying out maintenance work. For example Figure 14 shows the annual cost of accidents for a Category 1a footway with bituminous surface, resurfaced every 20 years with maintenance inspections every 5 years. The maintenance defect threshold is 13mm, the safety inspection interval is 28 days, the safety defect threshold is 20mm, and the safety defect response time is 1 day

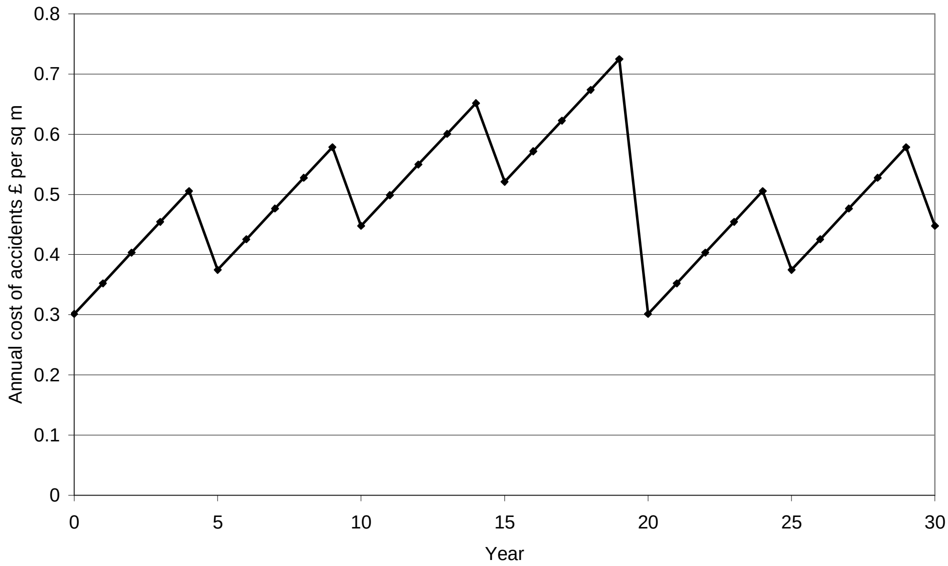

Figure 14 Annual cost of accidents

This shows a characteristic 'saw-tooth' shape, comprising the following components of costs of accidents:

- On defects above the safety threshold (20mm). These will normally be the same each year as safety defects occurring each year are usually rectified within the year. Safety inspection interval, safety defect threshold and response time should be set at the authority's current policy level, and current recommended values have been used here.
- On defects between the maintenance and safety defect thresholds (13mm to 20mm). This rises annually and is 'reset' after 5 years.
- On defects below the maintenance thresholds (13mm). This rises annually and is 'reset' after 20 years.

In this case, the annual cost of accidents approaches £0.7 per m^2 prior to resurfacing. If no maintenance or resurfacing is carried out, the annual costs of accidents may rise to over £3 per m^2 in some cases after 30 years.

As discussed in Appendix B4, defects have been assumed to occur at a uniform rate throughout the life of a footway, whereas this rate and the pattern of annual costs are likely to be less in the early life and increase towards the end of a footway's life.

8.4 Limitations of model

Risk is the combination of the likelihood and consequence of a specified hazardous event. It is apparent from the study of the physiology of walking (Section 6) that many factors influence whether a person notices a defect, falls on this defect and then injures themselves. However in order to develop a model it was necessary to make some simplifying assumptions to take into account factors for which data are available and to make judgements as to which are the most significant factors.

It is apparent that information on these factors is limited and comes from a variety of sources where data is not recorded in a consistent way. In particular, on present information it was not possible to distinguish between the hazardous nature of different types of defect (e.g. a step or pothole; vertical or bevelled edge, longitudinal or transverse). It is assumed that accidents are caused by trips because it is probably true that the 'trip' component of most defects such as potholes, kerbs, reinstatements, ruts, ironwork etc. is the cause of most accidents.

Neither was it possible to distinguish between the severities of injuries resulting from a fall. However it is considered that injuries sustained will more relate to the person falling (e.g. health and age) than the nature of the defect, and are thus largely outside of the control of the highway authority. Also, insufficient data were found for developing a similar model for cycle tracks.

In determining the probability of an accident $P_{accident}(h)$ it has been assumed that the risk of an accident is the same for all users. (This is not strictly true as elderly people and young children have a higher risk of injury than other groups. It is however apparent that fit and able pedestrians are capable of avoiding most defects).

Also, it has been assumed that footways are essentially narrow features, i.e. the width of the footway or location of the defect across the width of the footway is not taken into account.

An indication of the confidence in the results is contained in Section 8.5.

8.5 Confidence limits

The accuracy of the model and derived confidence limits for its results are discussed in this section. The parameters used, assumptions made and likely accuracy is summarised in Table 15 and discussed below.

Table 15 Parameters used in developing the model and principal assumptions

Parameter	Values assumed				Likely range	Comments and relevant section of report
Pedestrian flow assumed for the 3 authorities	**Category**	**Flow (pedestrians per day)**				Appendix B Table B20
	1a	10,000				
	1	10,000			816 – 31811	
	2	1,000			488 – 16800	
	3	500			556 – 7658	
	4	200			166 – 1405	
Length of footway in each category for the 3 authorities	**Category**	**Authority and length (km)**				* these numbers are based on figures from the authorities, the rest are assumed. Appendix A Table A1
		Bromley	Hants	RCT		
	1a	4	4*	4	±20%	
	1	60	60*	30	±20%	
	2	240	200*	150	±20%	
	3	800	508*	400	±20%	
	4	300	900	400	±20%	
	Total	1404*	1672	984*	±20%	
Time period of claims data		**Authority and period (days)**				These numbers are accurate. Appendix A Table A1
		Bromley	Hants	RCT		
		2162	1170	771	None	
Number of defects developing per km per year $N_{defects}(h)$	Number of defects per km (>13mm)	**Type of construction**	**Defect incidence (per km)**			Based on DVI data. Appendix C Table C1
		Bituminous	18		4 to 24	
		Block	9		5 to 17	
		Concrete	10		9 to 25	
		Flagged	35		9 to 40	
	Distribution of defects	Figure C2			±20%	Based on TRL survey
	Proportion of defects >30mm	0.2% for bituminous 0.7% for others determined by extrapolation				Appendix C
	Average time period over which defects developed	**Height range**	**Period (years)**			Appendix C
		greater than 20mm	0.25		0.1 to 0.5	
		less than 20mm	10		5 to 20	
	Defects assumed to develop at uniform rate					Appendix C
Probability of accident $P_{accident}(h)$	Figure E1				Limits shown on Figure E1, resulting in variation of predicted number of accidents by a factor of 7 less or greater.	Appendix E
Number of claims per accident	17%					Range cannot be estimated. Section 5
Predicted number of accidents	Overall confidence limits on predicted number of accidents				Factor of 7 less or greater	

As discussed in Appendix B, pedestrian flows have been measured at some locations in Bromley and Hampshire, which are in reasonable agreement with the nominal average from all locations, although there is no flow data from Rhondda Cynon Taff (RCT). Thus in the development of the model, the nominal flows are considered to be reasonably accurate. The range of values judged likely is shown in Table B20 and reproduced above.

Values for the total length of network have been provided for Bromley and RCT, while lengths of footway in Categories 1 to 3 have been supplied for Hampshire. Other values have been assumed using the proportions in each Category in Hampshire as a guide.

The time periods for which claims data have been assembled for each authority are known with accuracy.

The numbers of defects developing per km per year, $N_{defects}(h)$, is based on several parameters:

- The numbers of defects greater than 13mm was obtained from DVI data. It was necessary to make assumptions as to which DVI defects posed trip hazards and how to convert area and linear defects to numbers of trips. The resulting average of about 25 defects per km was shown to be in good agreement with NRMCS, which gives some confidence in the results, and the range of constituent data for each authority and in each category (see Table C1) is judged to indicate the likely range of this parameter.
- The distribution of defects, shown in Figure C1, is based on measurements of defect height over approximately 12km of footway. Results from different material types are compared in Figure 16 and on this basis a likely variation in the distribution of around 10% is considered likely.
- No defects of greater than 35mm height were noted, however it is apparent that higher defects do occur occasionally, see Figure 3. In order to populate the model with figures it was necessary to assume a proportion of higher defects. Further measurements would be required to verify the accuracy of this assumption.
- The average time over which defects developed was estimated taking into account comments on the extent of resurfacing carried out in the relevant authorities: generally little resurfacing or re-construction is carried out, thus the average age of footways would be in excess of 10 years.

A check on the accuracy of the predicted numbers of defects developing per km per year can be made by comparing this with the known number of defects repaired in Bromley. As indicated in Appendix A, 18,000 safety defects are repaired each year in Bromley. From the relationship shown in Figure 9 and the length of footway in Bromley it is predicted that about 5,000 defects of height greater than 20mm will occur each year, which is of similar order of magnitude to the number repaired.

The relationship between the numbers of claims and numbers of accidents is based on an extrapolation of numbers attending one A&E department in London and known claims in 1987, as described in Section 5. It would be necessary to make further comparisons between the numbers of claims and hospital A&E records to estimate the accuracy of this assumption.

Although there is considerable variation in the above parameters, their individual significance is reduced as they are amalgamated with claims data and then exposure is determined using a best-fit line (Figure E1). Based on the scatter of the exposure points the overall accuracy of the prediction of numbers of accidents is estimated to be a factor of seven less or greater.

As a check on the overall accuracy of the model, the total number of footway accidents in England and Wales has been calculated as and compared with accident statistics, based on the following input parameters:

- Length of footway network: 300,000 km (NRMCS, DfT, 2002g)
- Average pedestrian flow: 2,000 persons per day
- Average interval between resurfacing: 20 years
- Average safety inspection interval: 28 day
- Safety defect threshold: 20mm
- Response time: 7 days

The resulting prediction of around 25,000 accidents per year may be compared with the range of 20,000 to 190,000 A&E admissions described in Section 5

8.6 Limitations of the Model

It is apparent that the model has been based on many simplifying assumptions and approximations. Thus, at present, the model will be a useful guide to assist highway authorities in setting maintenance policy by giving an indication of the consequences, in terms of an approximate number of accidents occurring when this policy is followed. It should not be regarded as an accurate prediction of the number of accidents at any one time or location. However as the use of computer databases for recording claims becomes more widespread it will be possible to refine the model. It will also be possible for an individual authority to adapt the model on the basis of its local information and conditions.

8.7 Discussion

As it stands the model shows that the cost of accidents is reduced if the safety investigatory thresholds are lowered or the interval between inspections is reduced. However, it must be borne in mind that these actions would increase the costs of inspections and maintenance and thus the overall costs will not necessarily be reduced. The costs of inspections and safety repairs should be readily available to a highway authority and could be combined with the risk model to ascertain the cost benefits or otherwise of decreasing the inspection intervals.

The commonly used safety investigatory level defect threshold of 20mm is based on legal precedent, which takes account of what is reasonable for a highway authority to achieve. This is discussed by Bird et al (2002) and by the UK Highways Liability joint task group (2005). Although a highway authority may strive to achieve a better footway surface in some areas, recognising the needs of the elderly and the disabled, the costs may prohibit this. For example:

> In Sarah McArdle v Department of Regional Development [2005] NIQB 13 the plaintiff tripped on an edge of 12mm on a path. While it was accepted that the highway authority had to take into account the needs of elderly users, they also had to balance the risk against the cost and find the best compromise. To do otherwise would be unrealistic.

Also, what is achievable when carrying out safety repairs, needs to be taken into account. Safety repairs on footways are generally carried out using deferred set bituminous material, which is currently available with a minimum aggregate size of 6mm, appropriate for a 20mm layer thickness. The use of hot material is not practical for repairing safety defects, due to the small quantities required.

The safety investigatory level defect threshold of 20mm has proved to be achievable and defendable. Although it may be beneficial for authorities to strive for smoother footways in some areas the cost benefits of this need further consideration and there should be no change to current thresholds or recommended inspections regimes at present.

9 Recommendations for further work

Further information on the numbers of accidents on footways and cycle tracks will be required to make better estimates of the risks of accidents. The relationship between the numbers of claims and injuries and hospital or GP treatment should be examined.

It is apparent that neither third party claims nor hospital records provide an accurate representation of the numbers of footway accidents. However in the absence of other information the following assumptions are made in order to derive data for making a quantified assessment of risk:

> A study of walking on footways of various conditions would enable the results of research for medical purposes to be more readily applied in the maintenance of footways. The probability of a person falling on a given defect should be investigated.
>
> As the use of computer databases for recording claims is becoming more widespread they may be used to assemble data for refining the accuracy of the footways risk model. In order to develop the model nationally, or by an individual authority, the following data will be required to be recorded in such a database:
>
> For each claim:

- Date.
- Location.
- Footway category.
- Footway construction.
- Type, size and, if possible, cause of defect.
- Date of last safety inspection.
- Date last resurfaced or fully patched.

It is considered that the following information should also be collected so as to provide data on other aspects of claims.

- Age and sex of the claimant and the injuries sustained.

In order to gather more data on the development of defects it will be necessary to gather more data on the following, which may be accomplished using computer based asset management systems:

- The numbers of defects located (and repaired), their type and size in each category and type of construction of footway.

To refine the model, data on inspection and maintenance costs should be included, together with probable increases or decreases due to different threshold levels.

It is also recommended that the footway model be made available to local authorities in a user-friendly format.

10 Acknowledgements

The work described in this report was carried out in the Infrastructure and Environment Division of TRL Limited. The authors are grateful to Mr R Jordan who carried out the quality review and auditing of this report. The authors are also grateful to Mr B McMahon for work on the physiology of walking and Dr M Zohrabi and Mr B Ford for assembling records of pedestrian and cyclist flows.

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Appendix A. Information on networks studied

Table A1 Summary of networks and maintenance information

	Bromley	**Hampshire**	**Rhondda Cynon Taff**
Period of claims examined	March 1998 to March 2002	March 1998 to June 2001	February 2000 to March 2002
Length of footways	1404km	772km excluding Cat 4 (assumed 1672 people)	984km
Safety inspection interval or frequency	1 month for shopping 6 months for main road 12 months for urban and rural	a [1] – 1 general inspection per year b − 3 general inspections per year c – 6 general inspections per year d – 3 general and 9 safety inspections or 9 general inspections per year e – 6 general and 6 safety inspections per year or 3 general and 12 safety inspections per year f – 6 general and 12 safety inspections per year g − 9 general and 12 safety inspections per year	1 month for shopping 3 months for busy urban 12 months for other urban/busy rural and little used rural reactionary for interconnecting paths/steps
Safety defect threshold	Trips, potholes etc. 20mm. Gaps between flags, blocks etc. 20mm. A total of approximately 18,000 defects are noted and repaired each year.	Trips 20mm, but defects smaller than this are repaired if complaints received from the public or the footway is particularly busy.	Rocking flags 20mm. Potholes, or subsided or raised iron 20mm for shopping areas, 30mm for busy urban areas, 40mm for other urban/busy rural areas and 65mm for little used rural areas.
Response times	Emergency – commence within 2 hr and complete same day. Urgent – complete within 7 days. Planned minor works – complete within 5 weeks.	e – Immediate action. a – Action within 2 months. b – Monitor.	

1. In Hampshire inspection frequencies have a letter code. The footways are classified by their type and quantity of pedestrian flow.

Records of claims included most or all of the following items: date, location, category, the footway construction, and the location, type, size and, for some claims, the possible cause of the supposed defect, age and sex of the claimant and the injuries sustained.

However footway categories were not always recorded, or recorded in the same way. Therefore it was necessary to classify claims within a common classification, and to derive further items for use within the subsequent analysis, which are described below.

Footway categories and associated pedestrian flow and inspection frequencies were supplied in 461 of the data lines. The inspection frequencies have been recorded in two ways. Bromley and RCT data simply has the number of months between inspections, but that from Hampshire has a letter (a to g) corresponding to the number of inspections per year. The translation between footway category and classification inspection frequency or interval is shown in Table A2.

Table A2 Footway categories and safety inspection frequency

Category (IHT, 2001)	**Bromley, RCT**	**Hampshire**	
	Inspection interval **Months**	**Code**	**Inspection frequency** **per year**
1a	1	g	12
1	1	e & f	12
2	3	c & d	4
3	6	b	2
4	6 to 12	a	2 to 1

Pedestrian flow data obtained in Bromley and Hants is similar to the national average - see Appendix B. Appendix B shows the flow data obtained and the nominal flows suggested for the different categories of footway.

Appendix B. Pedestrian and cyclist flow data

This section presents a collection of pedestrian and cyclist flow data for selected towns and cities in the UK for use in the development of the risk analysis model. The data were obtained from TRL archive material and from local authority surveys - as available on their websites or supplied upon request.

The effect of transport policies and local authority transport plans (LTP) is monitored by surveys which are normally reported in traffic monitoring reports and transport statistics. All modes of transport are considered in LTPs including walking and cycling. However, little is known about pedestrian and cyclist flows on different footway and cycle route categories. It should be noted that data from some authorities was produced for specific purposes, such as justifying a new roundabout, crossing, etc.

For the purpose of this report, the available data were grouped into the footway and cycle track categories adopted by the "*Code of Practice for Highway Maintenance Management*" (Roads Liaison Group, 2005). The methodology adopted for categorising such data was to either visit the sites or to use on-line city maps to estimate their category from the location.

The data available for each town or city is summarised below. These towns and cities were not selected on any specific pattern, but the objective was to obtain as wide coverage as possible.

B.1 London Borough of Bromley

The information for London Borough of Bromley has been gathered through a TRL research project for the Orpington High Street, category 1 footways. It shows hourly pedestrian flows at three different locations in both north and south directions between 08:00 and 18:00 (which is only a 10 hour time period) in December of 1997 and 1998. The summary of results is shown in Table B1 to Table B3, with an average 10 hour flow calculated from the average of the two years.

Table B1. Average pedestrian flows in north Orpington High Street

North of High Street		**0800 - 0900**	**0900 - 1000**	**1000 - 1100**	**1100 - 1200**	**1200 - 1300**	**1300 - 1400**	**1400 - 1500**	**1500 - 1600**	**1600 - 1700**	**1700 - 1800**
19/12/1997	North	228	480	354	486	504	564	822	612	678	330
	South	420	564	414	438	366	534	984	246	168	114
18/12/1998	North	126	534	2322	810	918	930	828	1428	1122	558
	South	186	774	1320	600	654	1014	744	1338	1188	516
Total		960	2352	4410	2334	2442	3042	3378	3624	3156	1518
Average 10 hour flow = 13608											

Table B2. Average hourly pedestrian flows in central Orpington High Street

Central High Street		**0800 - 0900**	**0900 - 1000**	**1000 - 1100**	**1100 - 1200**	**1200 - 1300**	**1300 - 1400**	**1400 - 1500**	**1500 - 1600**	**1600 - 1700**	**1700 - 1800**
19/12/1997	North	408	1086	1236	1278	1254	1620	2340	786	1242	1008
	South	108	948	1974	2106	2094	1806	2112	654	756	1152
18/12/1998	North	258	774	1614	3666	3234	3270	2898	1656	1260	540
	South	342	1140	2364	2742	2334	2082	1788	1434	1278	720
Total		1116	3948	7188	9792	8916	8778	9138	4530	4536	3420
Average 10 hour flow = 30681											

Table B3. Average pedestrian flows in south Orpington High Street

South of High Street		0800 - 0900	0900 - 1000	1000 - 1100	1100 - 1200	1200 - 1300	1300 - 1400	1400 - 1500	1500 - 1600	1600 - 1700	1700 - 1800
19/12/1997	North	168	1110	1470	1578	1506	1242	1074	774	762	960
	South	36	420	1176	1218	1314	1194	1206	876	684	1074
18/12/1998	North	246	1218	1554	1626	1254	1884	1512	1152	1044	1188
	South	114	330	1782	2640	1200	1746	972	624	426	228
Total		564	3078	5982	7062	5274	6066	4764	3426	2916	3450
Average 10 hour flow = 21291											

Data from other measurements of pedestrian and cyclist flows in Bromley, taken between 0700 and 1900 in both directions are shown in Table B4 to Table B9 below.

Table B4 Pedestrian counts for Category 1 footway in Bromley (counts taken from 0700 to 1900 in both directions)

Count	Road	Area	Location	Age <16	Adult	Total	Rural/ Urban	Cat
14	High Street	Chislehurst	Between Ashfield Lane and Loop Road	54	762	816	U	1

Table B5 Pedestrian counts for Category 2 (P2) footways in Bromley (counts taken hourly from 0700 to 1900, in both directions)

Count	Road	Area	Location	Age <16	Adult	Total	Rural/ Urban	Cat
1	Croydon Road	Elmers End	Just North of the Glade	98	501	589	U	2
3	High Street	Penge	Between Kenilworth Road and Kingsdale Road	306	1528	1834	U	2
4	Southend Rd	Beckenham	Between Stumps Hill Lane and Braeside	80	158	238	U	2
5	Bromley Road	Shortlands	Between Shortlands Road and Park Hill Road	227	1006	1233	U	2
7	Burnt Ash Lane	Plaistow	Between Milk Street and Roslin Way	509	1450	1959	U	2
8	Beckenham Rd	West Wickham	Between St Davids Close and Blakes Green	201	146	347	U	2
20	Albermarle Rd	Beckenham	Between St Georges Road and Westgate Road	119	967	1086	U	2
29	High Street	St Mary Cray	Between Blacksmiths Lane and Millbrook Road	50	181	231	U	2
35	Masons Hill	Bromley	Between Wendover Road and Homesdale Road	89	958	1047	U	2
40	Anerley Hill	Crystal Palace	Just North of Palace Road	198	909	1107	U	2
			AVERAGE	**209**	**867**	**1075**		

Table B6 Pedestrian counts for Category 3 fooyways in Bromley (counts taken from 0700 to 1900 in both directions)

Count	Road	Area	Location	Age <16	Adult	Total	Rural/ Urban	Cat
2	Elmers End Road	Elmers End	Between Beck Lane and Dorset Road	61	538	599	U	3
6	Bromley Hill	Plaistow	Between Avondale Road and Kings Avenue	24	286	310	U	3
12	Bromley Common	Bromley Common	Between Magpie Hall Lane and Oakley Road	25	70	95	U	3
13	Widmore Road	Bromley	Between St Blaise Avenue and Palace Grove	151	1319	1470	U	3
16	Crofton Road	Crofton	Between Allington Road The Ridge	85	407	492	U	3
18	Court Road	Goddington	Just East Of Charterhouse Road	16	70	86	U	3
19	Sevenoaks Way	St Paul's Cray	Just South of Cornwall Drive	226	129	355	U	3
27	Southborough Lane	Southborough	Between the ends of Oxhawth Crescent	141	306	447	U	3
28	Crofton Lane	Petts Wood	Between Broadcroft Road and Derwent Drive	473	854	1327	U	3
31	Kentish Way	Bromley	Between Stockwell Close and Widmore Road	135	818	953	U	3
33	Glebe Way	West Wickham	Between Addington Road Silver Lane	27	201	228	U	3
34	Homesdale Road	Widmore	Just after Railway Bridge past Waldo Road	126	343	469	U	3
38	Perry Hall Road	Orpington	Just West of Cambray Road	113	286	399	U	3
39	Croydon Road	Anerley	Just West of Cambridge Road	74	482	556	U	3
			AVERAGE	**120**	**436**	**556**		

Table B7 Pedestrian counts for Category 4 footways in Bromley (counts taken from 0700 to 1900 in both directions)

Count	Road	Area	Location	**Age <16**	**Adult**	**Total**	**Rural / Urban**	**Cat**
9	Addington Road	Coney Hall	Lay-by West of Corkscrew Hill	0	20	20	U	4
10	Croydon Road	Coney Hall	From East of Coney Hill Road	30	142	172	U	4
11	Main Road	Biggin Hill	Between Village Green Avenue and Aperfield Road	24	134	158	U/R	4
15	Farnborough Way	Farnborough	Lay-by West of Cherrycot Hill	6	87	93	U	4
17	Sevenoaks Road	Orpington	Between Charterhouse Road and Goddington Lane	80	456	536	U	4
15	Farnborough Way	Farnborough	Lay-by West of Cherrycot Hill	6	87	93	U	4
17	Sevenoaks Road	Orpington	Between Charterhouse Road and Goddington Lane	80	456	536	U	4
21	Hayes Lane	Beckenham	Between Kingswood Avenue and Tootswood Road	10	89	99	U	4
22	Hayes Lane	Bromley	Between Hayes Road and Letchworth Drive	86	278	364	U	4
23	Sundridge Avenue	Elmstead Wood	Between Elmstead Lane and Romney Drive	27	147	174	U	4
25	Sheep Barn Lane	Leaves Green	East of Layjams Road	0	0	0	R	4
26a	Old Hill	Green Street Green	Just West of Roundabout	19	50	69	U/R	4
26b	Cudham Lane North	Green Street Green	Just West of Roundabout	20	64	84	R	4
30	Chelsfield Lane	Ramsden	Between Cockmannings Lane and	25	81	106	U/R	4
36	Perry Street	Chislehurst	Just West of West Entrance of Old Perry Street	36	82	118	U	4
37	Sevenoaks Road	Pratts Bottom	Just West of Roundabout	2	31	33	R	4
			TOTAL MEAN AVERAGE	**28**	**138**	**166**		

Table B8 Cycle counts for Category 2 cycle tracks in Bromley (counts taken hourly from 0700 to 1900 in both directions)

Count	Road	Area	Location	Age <16	Adult	Total	Rural/ Urban	Cat
6	Bromley Hill	Plaistow	Between Avondale Road and Kings Avenue	0	114	114	U	2
7	Burnt Ash Lane	Plaistow	Between Milk Street and Roslin Way	6	74	80	U	2
9	Addington Road	Coney Hall	Lay-by West of Corkscrew Hill	11	13	24	U	2
12	Bromley Common	Bromley Common	Between Magpie Hall Lane and Oakley Road	0	41	41	U	2
15	Farnborough Way	Farnborough	Lay-by West of Cherrycot Hill	12	26	38	U	2
31	Kentish Way	Bromley	Between Stockwell Close and Widmore Road	0	110	110	U	2
33	Glebe Way	West Wickham	Between Addington Road Silver Lane	7	65	72	U	2
35	Masons Hill	Bromley	Between Wendover Road and Homesdale Road	4	231	235	U	2
37	Sevenoaks Road	Pratts Bottom	Just West of Roundabout	3	46	49	R	2
			TOTAL MEAN AVERAGE	**5**	**80**	**85**		

Table B9 Cycle counts for Category 3 cycle tracks in Bromley (counts taken hourly from 0700 to 1900, in both directions)

Count	Road	Area	Location	Age <16	Adult	Total	Rural / Urban	Cat
1	Croydon Road	Elmers End	Just North of the Glade	3	66	69	U	3a/b
2	Elmers End Road	Elmers End	Between Beck Lane and Dorset Road	8	148	156	U	3b
3	High Street	Penge	Between Kenilworth Road and Kingsdale Road	8	104	112	U	3b
4	Southend Road	Beckenham	Between Stumps Hill Lane and Braeside	3	69	72	U	3a
5	Bromley Road	Shortlands	Between Shortlands Road and Park Hill Road	3	56	59	U	3b
8	Beckenham Road	West Wickham	Between St Davids Close and Blakes Green	4	29	33	U	3b
10	Croydon Road	Coney Hall	From East of Coney Hill Road	3	34	37	U	3b
11	Main Road	Biggin Hill	Between Village Green Avenue and Aperfield Road	0	28	28	U/R	3b
13	Widmore Road	Bromley	Between St Blaise Avenue and Palace Grove	6	88	94	U	3b
14	High Street	Chislehurst	Between Ashfield Lane and Loop Road	2	63	65	U	3b
16	Crofton Road	Crofton	Between Allington Road The Ridge	15	40	55	U	3a
17	Sevenoaks Road	Orpington	Between Charterhouse Road and Goddington Lane	9	68	77	U	3b
18	Court Road	Goddington	Just East Of Charterhouse Road	2	20	22	U	3a
19	Sevenoaks Way	St Paul's Cray	Just South of Cornwall Drive	26	21	47	U	3a
34	Homesdale Road	Widmore	Just after Railway Bridge past Waldo Road	10	84	94	U	3b
36	Perry Street	Chislehurst	Just West of West Entrance of Old Perry Street	6	53	59	U	3b
38	Perry Hall Road	Orpington	Just West of Cambray Road	10	34	44	U	3b
39	Croydon Road	Anerley	Just West of Cambridge Road	8	80	88	U	3b
40	Anerley Hill	Crystal Palace	Just North of Palace Road	2	98	100	U	3b
TOTAL MEAN AVERAGE				**7**	**62**	**69**		

B.2 Central London

A study, carried out by Desyllas et al (2003) for UCL, on the pedestrian demand modelling of large cities, showed that the distribution of hourly average pedestrian flows in Central London ranged from as low as 200 (P4 Category) to as high as 12,200 (i.e. a peak-hourly flow in P1a Category), with a gross average of 4,300 across the monitored sites. However these figures are not used in the final summary as there is no information on the number and range of sites.

Another study, carried out by Intelligent Space (2000), showed that pedestrian traffic within a P1 category (including Soho and Covent Garden) on a Friday and Saturday amounted to a peak hourly flow (assumed to be an hourly average of the peak periods of 0700 to 1000 and 1600 to 1900) of 1,766 pedestrians, increasing at the weekends to 2,183 pedestrians.

B.3 Northampton County Council

The following is an extract from the 2002 Edition of Transport Statistics for Northamptonshire (Northampton, 2002). The data was collected in 2001 and is based on manual counts of pedestrians and both manual and automatic counts of cyclists in each of the county's six major towns - Northampton, Wellingborough, Rushden, Kettering, Corby and Daventry. The counts were carried out over a 12-hour period from 0700 – 1900, at a number of junctions in each town. Inbound flows approaching the town centres were recorded. The average flows have been calculated assuming that the same number of people walk outbound over the course of the day.

The locations of the monitoring sites were given in the report but no definitions in terms of footway or cycleway category were specified. Site visits to the six towns were made and assessments of each location were carried out. The recorded flows are shown in Table B10. The monitoring sites were away from the town centres thus pedestrian flows on footways P1a and P1 categories were not represented. Also there is no data for cycle route category C3 (on predominantly recreational routes).

Table B10 Mean 12 hour flows (two-way flow estimated from one-way counts)

Town	Pedestrians					Cyclists		
	P1a	**P1**	**P2**	**P3**	**P4**	**C1**	**C2**	**C3**
Northampton	-	-	-	398	454	159	164	22
Daventry	-	-	1099	520	-	71	76	-
Wellingborough	-	-	-	975	222	-	143	-
Kettering	-	-	1031	486	-	179	117	-
Rushden	-	-	2444	542	-	163	-	-
Corby	-	-	1090	523	-	184	79	-
Average 12 hour flows	**-**	**-**	**2832**	**1148**	**676**	**302**	**232**	**44**

B.4 Essex County Council

The following has been extracted from the Essex Traffic Monitoring report (Essex, 2001). Monitoring was undertaken in Essex every three years by one 12 hour count per site. This report provided no information on the types of footway categories covered, but the low pedestrian flow values indicate that they are in the P2 to P4 categories. The cycle route monitoring site locations were all described as on either dedicated cycle routes (assumed as C2 category) or on-road cycle routes (C1 category).

Manual pedestrian and cyclist counts were carried out in ten towns. Automatic cycle monitoring was carried out in five towns to give average 12 hour flows.

The mean 12-hourly, two way flows of pedestrians and cyclists are given in Table B11.

Table B11 Mean 12 hour flows in Essex

Town	Manual count			Automatic count	
	P2 – P4 (assumed)	C1	C2	P2 – P4 (assumed)	C2
Brentwood	2026	112	-	-	-
Clacton and Frinton	531	151	54	-	-
Epping and Ongar	1061	35	-	-	-
Wickford	923	89	144	-	-
Loughton, Chigwell and Waltham Abbey	899	76	-	-	-
Harwich	1004	265	81	-	-
Basildon	-	-	136	-	-
Southend	3768	340	327	-	-
Maldon	469	129	38	-	-
Braintree	1632	149	67	-	-
Colchester	1535	232	-	542	107
Chelmsford	1108	272	-	1633	387
Witham	1902	131	-	379	75
Canvey				68	62
Harlow				462	169
Average 12 hour flows	**1405**	**165**	**121**	**656**	**158**

B.5 The City of Edinburgh Council

Data were obtained on two-way pedestrian and cyclist flow counts from 43 pedestrian footway locations and 37 cycle routes monitored between 0730 and 0915 hours. All counts were conducted manually; Table B12 shows the mean flows in the morning.

Table B12 Edinburgh's pedestrian and cyclist flows

Town	Pedestrians					Cyclists		
	P1a	P1	P2	P3	P4	C1	C2	C3
Mean flow during the early morning rush hour (0730 – 0915)	170	252	142	162	-	24	-	38

B.6 Cardiff City Council

This is an extract from the results of a three-year pedestrian flow study carried out by Cardiff Research Centre in Cardiff city centre between 1999 and 2001 (Cardiff, 1999, 2000 and 2001). There were a total of 11 sites, with either 3 or 4 counting points at each site. The flow was measured on footways on both sides of the road. The results of some of the most relevant sites are shown in Table B13. As these counts were carried out in the city centre, it has been assumed that both the East Queen and the Mid-Queen sites fitted the P1a category, with Queens Arcade fitting the P1 category.

Table B13 Peak hourly flows at three selected sites in Cardiff City Centre (assumed to be both footways in two directions)

Year	Day	2000	2001	2002	Average over 3 years
Site 1 (Mid Queen) P1a	Fri	6522	5343	6855	6240
	Sat	8760	7781	8189	8243
	Sun	3408	4563	4770	4247
Site 2 (East Queen) P1a	Fri	2803	3246	2559	2869
	Sat	8754	3995	-	6375
	Sun	1571	1691	-	1631
P1a AVERAGE		**5303**	**4437**	**5593**	**5050**
Site 3 (Queens Arcade) P1	Fri	2493	2928	2427	2616
	Sat	4440	4405	4043	4296
	Sun	1514	1553	1904	1657
P1 AVERAGE		**2816**	**2962**	**2791**	**2856**

B.7 Cambridge City Council

The following is an extract from Cambridge (1999) regarding a request from Trinity and St. John's Colleges for improved pedestrian crossing facilities along Queens Road, Cambridge, which resulted in a pedestrian flow count in 1996. Based on the location of this road on the map and its proximity to colleges, it has been classified as a P2 category. The 12 hour (7am – 7pm) weekday flow amounted to 16,800 pedestrians.

A further report (Cambridge, 2002) showed a peak hourly pedestrian flow of 470 in Silver Street (P2 category) and a peak hourly cyclist flow of 170 (assumed to be C1/C2 categories as no information was available on the route layout).

B.8 Hampshire County Council

Pedestrian counts in the city centre were undertaken by Winchester City Centre Management Group (Winchester, 2000), showing that the highest pedestrian flows recorded in the High Street between 9am and 5pm amounted to 11,355 people in the upper part of the High Street and 15,524 at the lower end as being representative of a typical weekday pedestrian flow (both directions). Additional counts were undertaken on the radial routes, as shown in Table B14. These, by definition, could be categorised within the P2 category as they feed into the primary walking routes (P1 category).

Table B14 Pedestrian counts (both directions) on Winchester's radial routes

Road detail	12 hour count (two way, 7am to 7pm)
Alresford Road	326
Chesil Street	722
St Cross Road	248
Stockbridge Road	539
Worthy Road	813
Bar End Road	279
Average 12 hour flow	**488**

A 2002 pedestrian and cyclist survey in central rural Hampshire (Alton, Petersfield and Alresford) (Hampshire, 2003a) and another one in Basingstoke (Hampshire, 2003b) provided the 12 hour data, given in Table B15.

Table B15 Pedestrian and Cycle Flows in some of Hampshire's town centres (Assumed to be two-way)

Cycle track category	Average 12 hour flow			
	P1	P2	C1	C2
Petersfield High Street	-	5168	157	157
Alton High Street	-	7658	191	191
Alresford West Street	-	5433	101	101
Basingstoke (The walk)	31811	-	159	159
AVERAGE	**31811**	**6086**	**152**	**152**

B.9 Wiltshire

Wiltshire County Council monitored both pedestrian and cycle flows over a four-year period in various towns (Wiltshire, 2001). The results represented two-way flows for all the surveyed sites for the morning peak (07.30-09.30), afternoon peak (16.00-18.00) and 12 hour (07.00-19.00) situation. The daily flow data are summarised in Table B16. No information was provided regarding cycle route categories.

Table B16 12 hour pedestrian and cyclist flows across Wiltshire

Town	Pedestrians			Cyclists		Year
	P1	P2	P3	Range	Average	
Calne	-	409 -1894	163	78-302	137	1999
Chippenham	-	Up to 3078	35-437	25-315	140	1998
Devizes	-	282 - 1269		71-246	161	1998
Melksham	-	264-1969	-	35-590	279	1997
	-	375-1757	-	14-439	153	2000
Salisbury	693	Up to 11381	From 53	33-344	162	1997
	-	Up to 9561	From 97	34-436	213	2000

B.10 Northern Ireland

A survey carried out in Belfast Town Centre (Belfast, 2001) showed a peak hourly flow of 10,000 pedestrians in Royal Avenue (P1 category) between 3pm and 4pm in June 2001.

B.11 Summary of data

The daily pedestrian and cyclist flow values assembled above from various towns and cities in the UK have been summarised in Table B17 to Table B19. Because of the various methods of flow measurement, it is not always possible to compare all areas with one another, but a substantial amount of comparative data is available for the three main types of flow. This is represented in the three tables that accommodate the different periods of measurement for flows including average hourly flows (Table B17), average peak flows (Table B18) and average 12 hourly flows (Table B19). In Table B18 and Table B19 the range of data from the previous sections has been used as an approximate basis for the minimum and maximum values across the pedestrian footway and cycleway categories.

Table B17 Average hourly flows for all towns

All towns and cities considered	**Pedestrians**					**Cyclists**		
	1a	1	2	3	4	C1	C2	C3
Central London (hourly average flow)	12200	-	-	-	200	-	-	-
Central London (peak hourly flow)	-	1766 - 2183	-	-	-	-	-	-
Summary	12200	1766 - 2183	-	-	200	-	-	-

Table B18 Average peak flows for all towns

All towns and cities considered		**Pedestrians**					**Cyclists**		
		1a	1	2	3	4	C1	C2	C3
Cardiff (peak hourly flows – assumed on both sides of carriageway from 3 selected sites)	Year 2000	5303	2816	-	-	-	-	-	-
	Year 2001	4437	2962	-	-	-	-	-	-
	Year 2002	5593	2791	-	-	-	-	-	-
Cambridge – Silver Street (peak hourly)		-	-	470	-	-	170		-
Edinburgh – mean flow during the early morning rush hour (0730 – 0915)		170	252	142	162	-	24	-	38
Maximum		5593	2962	470	-	-	170	170	-
Minimum		170	252	142	162	-	24	-	38

Table B19 Average 12 hour flows for all towns

<table>
<tr><th colspan="2" rowspan="2">All towns and cities considered</th><th colspan="5">Pedestrians</th><th colspan="3">Cyclists</th></tr>
<tr><th>P1a</th><th>P1</th><th>P2</th><th>P3</th><th>P4</th><th>C1</th><th>C2</th><th>C3</th></tr>
<tr><td colspan="2">Bromley – Orpington High Street (Average for 10 hour period from 2 day samples)</td><td>-</td><td>13608 - 30618</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td colspan="2">Bromley – Other streets</td><td>-</td><td>816</td><td>1075</td><td>556</td><td>166</td><td>-</td><td>85</td><td>69</td></tr>
<tr><td colspan="2">Northants Area (2 way estimate from 1 way counts)</td><td>-</td><td>-</td><td>2832</td><td>1148</td><td>676</td><td>302</td><td>232</td><td>44</td></tr>
<tr><td colspan="2">Essex</td><td>-</td><td>-</td><td>656 - 1405 (assumed)</td><td>165</td><td>121 – 158</td><td colspan="3">-</td></tr>
<tr><td colspan="2">Cambridge</td><td>-</td><td>-</td><td>16800</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td colspan="2">Winchester</td><td>-</td><td>-</td><td>488</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="4">Hampshire</td><td>Petersfield High Street</td><td>-</td><td>-</td><td>-</td><td>5168</td><td>-</td><td>157</td><td>157</td><td>-</td></tr>
<tr><td>Alton High Street</td><td>-</td><td>-</td><td>-</td><td>7658</td><td>-</td><td>191</td><td>191</td><td>-</td></tr>
<tr><td>Alresford West Street</td><td>-</td><td>-</td><td>-</td><td>5433</td><td>-</td><td>101</td><td>101</td><td>-</td></tr>
<tr><td>Basingstoke (The walk)</td><td>-</td><td>31811</td><td>-</td><td>-</td><td>-</td><td>159</td><td>159</td><td>-</td></tr>
<tr><td colspan="2">Maximum</td><td>-</td><td>31811</td><td>16800</td><td>7658</td><td>1405</td><td>302</td><td>232</td><td>69</td></tr>
<tr><td colspan="2">Minimum</td><td>-</td><td>816</td><td>488</td><td>556</td><td>166</td><td>101</td><td>101</td><td>44</td></tr>
</table>

The nominal flows shown in Table B20, derived from the above, were used in the subsequent analysis.

Table B20 Nominal pedestrian flow

Category (Roads Liaison Group, 2005)	**Nominal flow** (pedestrians per day)
1a	>10,000
1	10,000
2	1,000
3	500
4	200

B.12 References

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Appendix C. Analysis of defect data

This appendix describes the incidence of defects (that present a trip hazard) on the footway network for use in the footway risk model.

Safety and maintenance surveys are regularly conducted on local authority footways, which identify defects including trip hazards. Data from a selection of local authorities have been used in this study together with survey work conducted by TRL.

C.1 Numbers of defects per km

Detailed Visual Survey (DVI) data were provided by three highway authorities:

- Blackpool Council.
- Hampshire County Council.
- Liverpool City Council.

DVI surveys recorded a number of defect types some of which do not present trip hazards, such as “Minor Fretting”. Analysis was restricted to the following defect types thought to pose a potential trip hazard:

- Spot defects such as trips > 13mm, areas of ponding or depressions and potholes (recorded as count)
- Length of longitudinal trip > 13mm (recorded as length in meters)
- Moderate subsidence producing a difference in level of 10-30mm (recorded as area in m^2)
- Severe subsidence producing a level change > 30mm (recorded as area in m^2)
- Cracked and depressed or missing blocks/flags with vertical projections > 13mm (recorded as area in m^2)

Data tables for each local authority and a combined total table are provided in Appendix D.

Whilst numbers of spot detects was reported in the DVI data, only the total lengths or total areas (of longitudinal and area defects) within each 20m section was reported. Thus the numbers of individual lengths or areas of these defects is not known. Also the numbers of individual hazards within each of those lengths or areas is not known. Therefore it is necessary to make some approximations in order to estimate the total numbers of defects that may represent trip hazards.

Examination of the DVI data in Appendix D (Table D1) shows that the percentage length and area of defectiveness (sub-tables F and J of Table D1) is relatively low (at most around 2%), and the number of 20m sections containing defects is relatively small (generally less than 10%). The average length or area of defectiveness within a 20m section affected is about 3.5m and $3m^2$ respectively, and the average number of spot defects within a 20m section affected is about 1.3 (sub-tables E, I and M of Table D1).

Therefore for simplicity it has been assumed that each length or area of defectiveness within a 20m section affected represents one trip hazard. Thus the total number of defects has been calculated as the sum of the number of 20m sections affected by linear or area defects and the number of spot defects (sub-tables C, G and M of Table D1).

This method does not take account of the associated length or area of defects. Thus 10 square metres of defect has the same weighting as 1 square metre. However, on average 3.5m or $3m^2$ of defect represents one trip hazard. This is an accord with observations made during the TRL survey that area defects, at least, do not present many trip hazards. Thus the assumptions made appear reasonable for the purposes of estimating the total numbers of defects, and are in reasonable agreement with the results of the NRMCS (DfT, 2002c), discussed below.

Table C1 shows the defect incidence per km for footways surfaced in different materials. The defect incidence is also shown graphically in Figure C1.

Table C1 Defect Incidence (defects per km)[1]

Construction Type	By authority			By footway category					
	Blackpool	Hampshire	Liverpool	1a	1	2	3	4	Weighted average
Bituminous	4.49	24.00	11.77	14.84	21.02	21.26	7.33	10.09	17.87
Block Paved	8.60	7.16	17.04	5.22	9.10	12.59	10.98	12.21	8.78
Concrete	12.74	25.94	25.10	8.91	28.80	87.82	16.98	12.88	22.30
Flagged	29.35	19.43	38.28	9.35	35.37	40.65	36.73	32.56	35.32
Weighted average	16.57	22.79	31.53	10.67	24.32	27.18	26.96	26.02	25.49

1. Calculated as the number of 20m sections affected by linear or area defects and number of spot defects (sub-table O in Table D1) divided by the total lengths of footway (sub-table B)

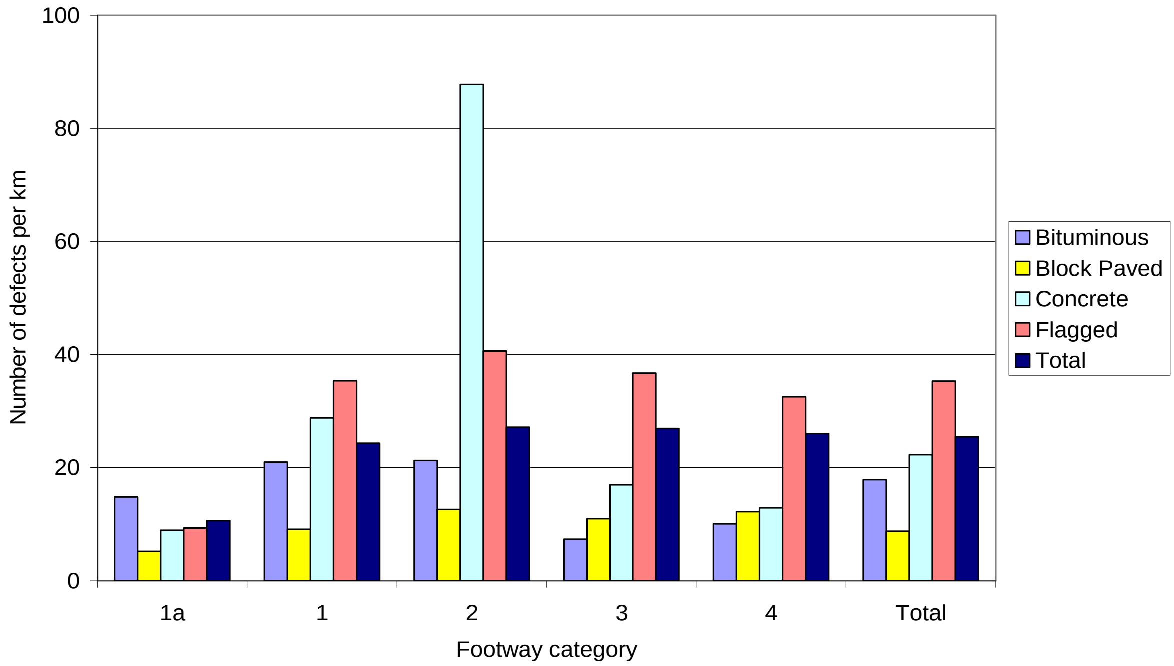

Figure C1 Footway defect incidence for different surface types (defects per km)

The average of about 25 defects per km is in good agreement with NRMCS (DfT, 2002c) that showed there were around 2 trips per 100m (i.e. 20 per km). However the NRMCS result of about 2.5% of the area of footways that are defective exceeds the percentage length and area of defectiveness found in the DVI surveys (sub-tables F and J in Table D1, at most around 2%).

A very high incidence of defects in concrete on hierarchy 2 footways was shown. However, there are very few concrete footways (concrete footways comprise only 2% of the total length). Analysis of the data showed that none of the defective areas appeared as concrete in the DVI inventory, which records the majority of the surface type of a footway. It is therefore likely that the concrete defects recorded occurred on concrete crossovers or reinstatements.

C.2 Height distribution of defects

TRL conducted a small survey to ascertain the frequency distribution of trip defects of different heights on areas of footways. Several sites in Berkshire were surveyed - in Reading, Wokingham and Crowthorne town centres. These included two sites in poor condition (those indicated by the authority as due for resurfacing). Defects were recorded in 5mm ranges, with defects exactly on the boundary between ranges being recorded in the higher range – i.e. a defect of exactly 10mm would be recorded as 10-15mm. Only defects greater than 5mm were measured. The results of this investigation are presented in Table C2 and Figure C2.

Table C2 Numbers of trip defects measured at sites in Berkshire

Heightmm	Bituminous		Bituminous (Poor Condition)		Blocks		Concrete		Flags		Flags (Poor condition)	
	No.	d/km	No.	d/km	No.	d/km	No.	d/km	No.	d/km	No.	d/km
5 to <10	24	2.4	83	60.6	9	41.8	4	64.3	26	34.6	16	38.3
10 to <15	27	2.7	62	45.3	5	23.2		0.0	7	9.3	8	19.1
15 to <20	13	1.3	36	26.3	3	13.9		0.0	2	2.7	2	4.8
20 to <25	1	0.1	9	6.6	1	4.6		0.0	2	2.7	2	4.8
25 to <30	2	0.2	5	3.6		0.0	1	16.1	0	0.0		0.0
30 to <35		0.0	1	0.7		0.0		0.0		0.0		0.0
Total	67		196		18		5		37		28	
Area sq m	2,531		2,46 6		388		112		346		752	

d/km = defects per km, assuming average footway width of 1.8m

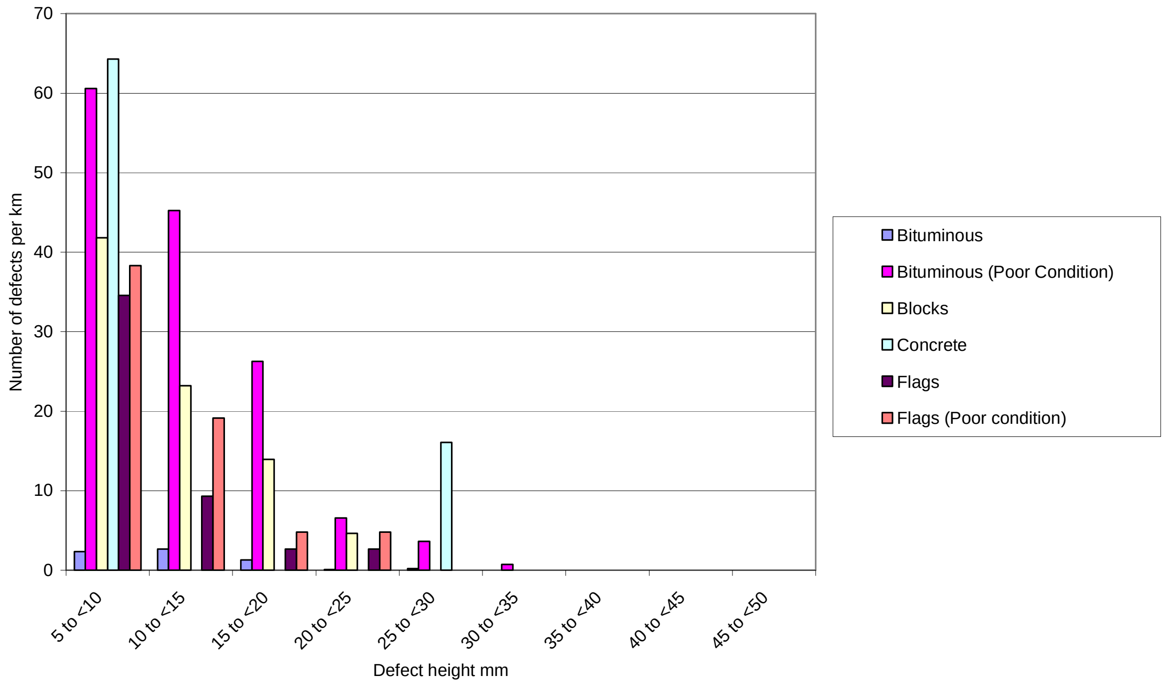

Figure C2 Approximate numbers of defects per km

The number of defects per km on bituminous surfaces in good condition is significantly less than on other types of surfacings which appeared to be in good condition, although the areas investigated were relatively small, especially those of concrete and blocks. Thus firm conclusions regarding defect incidence on different types of construction should not be drawn from this small sample. It should also be noted that these data were collected purely to obtain the distribution of trips in the various height categories – only transverse trips were measured.

The percentage of defects in each height range is shown in Figure C3.

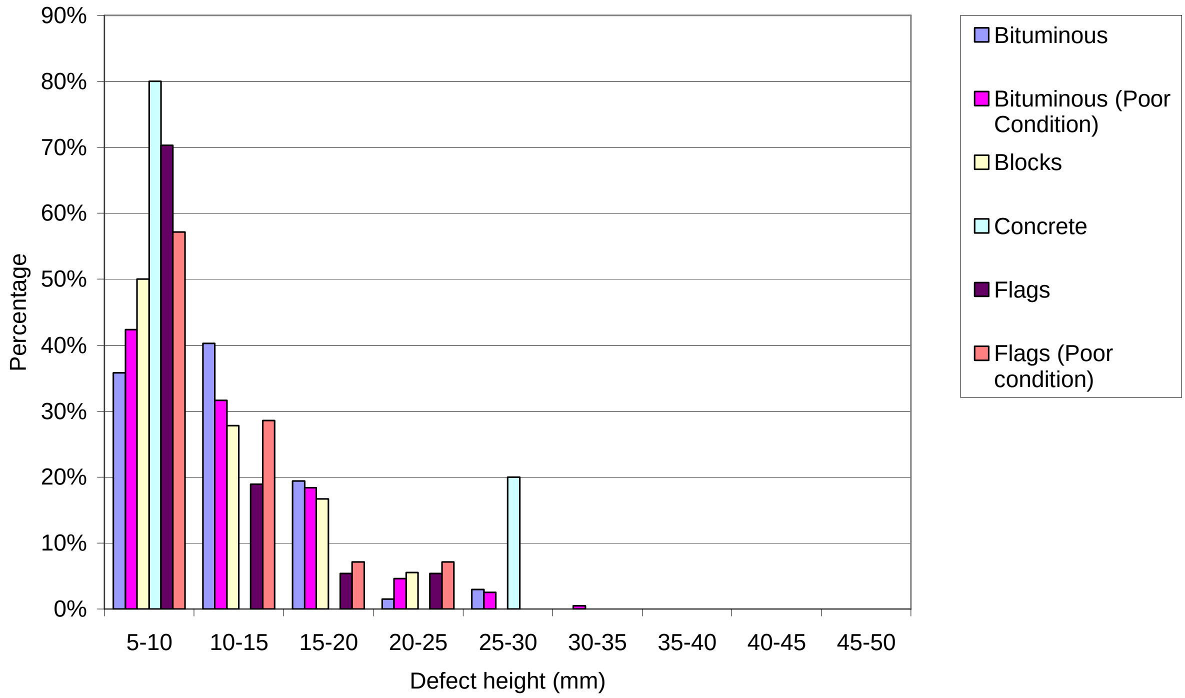

Figure C3 Percentage of defects in each height range

This shows that there are a significant proportion of defects between 5-10mm and 10-15mm. However DVI surveys do not record any defects less than 10mm, and, for trips, only defects greater than 13mm are recorded. As the claims data shows that there is a possibility of pedestrians tripping on defects between 5mm and 13mm these data will be used to derive the incidence of defects greater than 5mm.

There does not appear to be a marked difference between the proportions of defects in each height category for footways in good and in poor condition. However the proportion of defects on bituminous footways in the lower height category (5 to <10mm) was found to be generally less than that of other construction types.

Therefore two different distributions; “bituminous” and “other”, shown in Figure C4, which are the average distribution of defects on these surfacings, are used in the analysis.

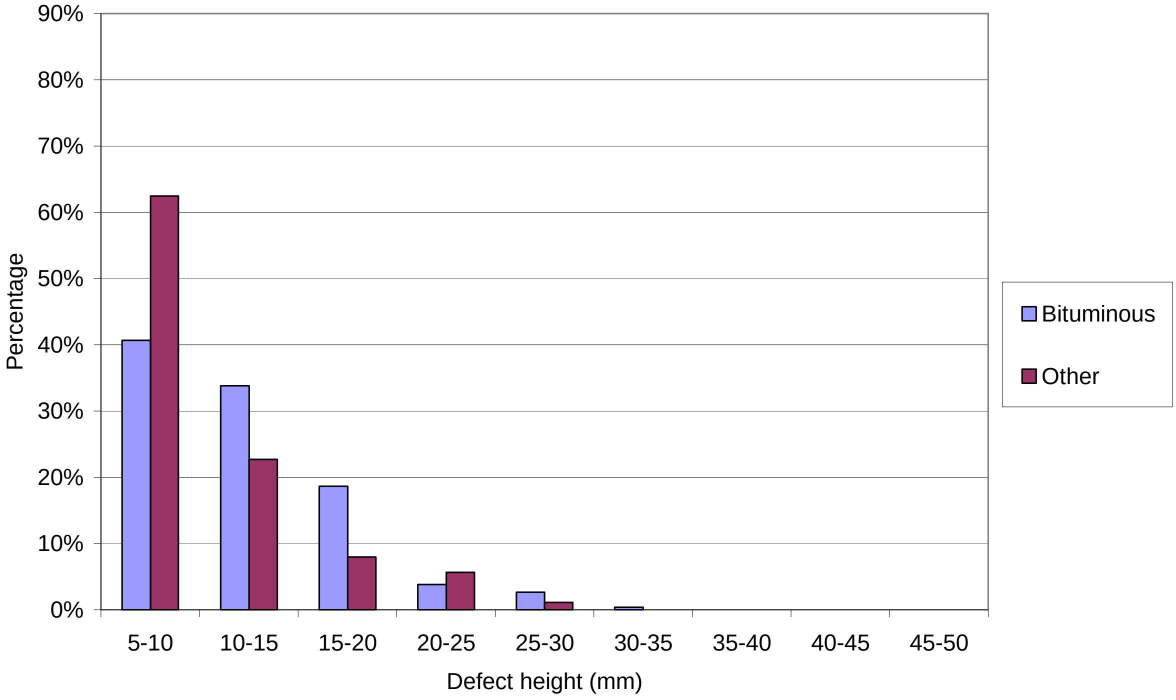

Figure C4 Assumed distributions of defect height

The incidence of defects of each height per km for each construction type is derived as follows:

- The total number of defects existing at any one time (generally over 13mm and according to type of construction) is obtained from the DVI data (Table D1).
- The height distribution from the TRL survey (Figure C4) is used to calculate the numbers of defects of each height (from 5mm to 200mm in 1mm steps).
- Although no defects of height greater than 35mm were recorded in the surveys, it is apparent that defects of greater height do occur occasionally. Therefore the 'TRL' height distribution was extrapolated using an exponential function over heights from 35mm to 200mm.

The resulting distributions are shown in Figure C5.

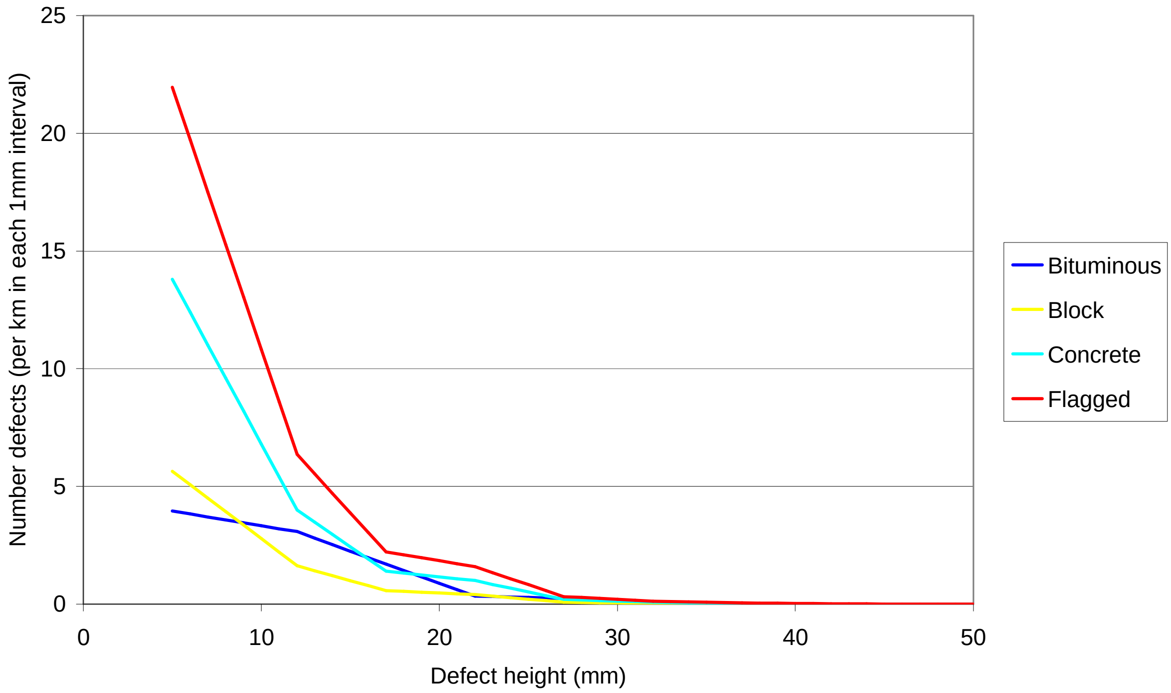

Figure C5 Derived numbers of defects per km

C.3 Discussion on rate of development of defects

The data reported above, represents a 'snap shot' of the number of defects on the network at a given time. This will be the result of a dynamic balance between the manner in which defects occur on the network and their repair by the highway authority. In order to take account of the influence of maintenance policy it is necessary to estimate the rate at which defects occur.

There is currently no footway deterioration model. As discussed by Bird et al (2002), unlike carriageways where deterioration is caused by wheel loading, footway deterioration is not generally caused by the number of pedestrians using the footway but by ageing (e.g. hardening of bitumen), tree roots, utility works or vehicle overrun. Thus the number of defects occurring might be expected to be greater towards the end of the footway's life, coupled with 'random' damage throughout. However for simplicity it is assumed that defects occur at a uniform rate through the life of the footway.

It is also assumed that defects appear 'over-night'. This is probably not the case with most defects as deterioration is likely to be gradual. However, it would seem to be a reasonable assumption as eventually, in practice, most defects will reach and exceed the investigation threshold 'overnight'.

In the absence of any reliable local data and for the purposes of demonstrating the model it is necessary to derive a rate at which the defects developed each year. More refined estimates of the rate at which defects developed could be obtained from the differences in DVI data from year to year and an authority's records of the numbers of repairs of safety defects carried out.

Enquiries to the sources of the DVI data indicated that maintenance is largely limited to addressing safety defects with some resurfacing of footways. Therefore it is assumed that the defects measured have developed over the following average periods:

- 0.25 years - for defects greater than the safety defect threshold (generally 20mm), being half the average safety inspection interval.

- 10 years - for defects less than the safety defect threshold, being half the average interval between resurfacing.

C.4 Rate of development of defects

The rate of development of defects is calculated as follows:

- The numbers of defects developing per year is calculated by dividing the number of defects per km by the time over which the defects developed, i.e. 0.25 years for defects greater than the safety defect threshold and 10 years for defects less than the safety defect threshold.
- The resulting distribution has a step at 20mm, so it is adjusted to give a smooth profile.

The calculated distributions of rate of development of defects used in the model are shown in Figure C6.

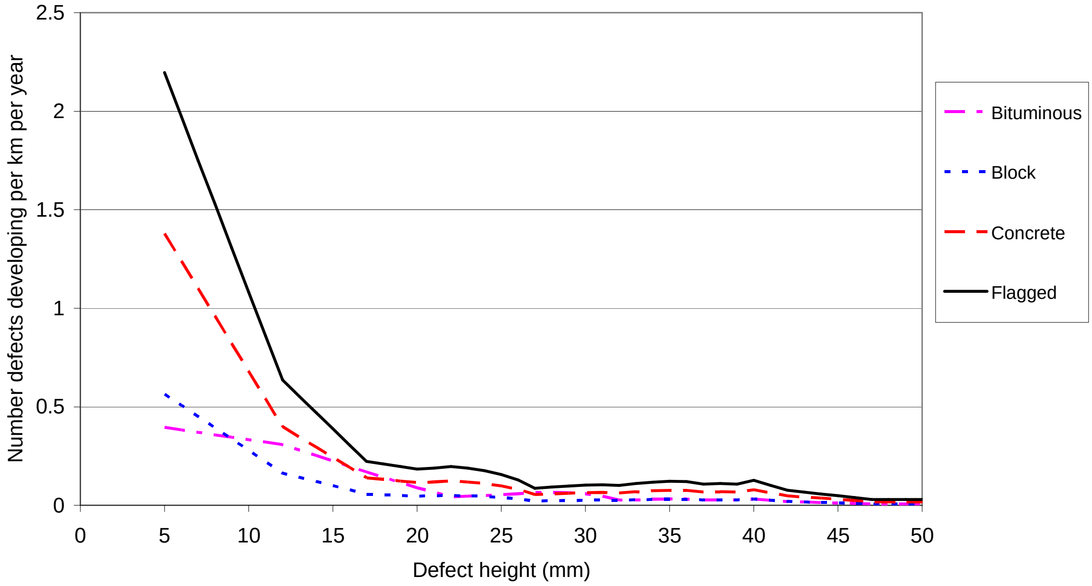

Figure C6 Rate of development of defects used in model ($N_{defect}(h)$)

Appendix D. Detailed Visual Survey (DVI) Data Analysis – Summary Tables

The following pages show summary tables of the DVI data analysis from the following Local Authorities:

- Blackpool Council
- Hampshire County Council
- Liverpool City Council

The tables use the following codes:

Code	Description	Feature Type
FBTR	Longitudinal Trip	Footway Bituminous
FKTR	Longitudinal Trip	Footway Block Paved
FCTR	Longitudinal Trip	Footway Concrete
FFTR	Longitudinal Trip	Footway Flagged
FBMS	Moderate Local Settlement/Subsidence	Footway Bituminous
FBSS	Severe Local Settlement/Subsidence	Footway Bituminous
FKCB	Cracked and Depressed Blocks	Footway Block Paved
FKMB	Depressed or Missing Blocks	Footway Block Paved
FCDD	Severe Local Settlement/Subsidence	Footway Concrete
FCMS	Moderate Local Settlement/Subsidence	Footway Concrete
FFCF	Cracked and Depressed Flags	Footway Flagged
FFDF	Depressed Flags (not Cracked)	Footway Flagged
FBSP	Spot Defects	Footway Bituminous
FKSP	Spot Defects	Footway Block Paved
FCSP	Spot Defects	Footway Concrete
FDSP	Spot Defects	Footway Flagged

Table D1 Combined analysis of Blackpool, Hampshire and Liverpool local authority DVI data

Inventory	Area (sq m) (A)						Length (m) (B)					
Category	1a	1	2	3	4	Total	1a	1	2	3	4	Total
Bituminous	85520.25	805413.6	805125.54	360487.4	266272.7	2322819	41846	403426	406706	159155	108215	1119348
Block Paved	83279.1	60910.75	21618.55	31841.08	8779.125	206428.6	25659	20118	9529	14388	4831	74525
Concrete	5219.8	10472.2	8479.925	31970.23	22822.55	78964.7	2245	4410	3769	20962	14210	45596
Flagged	75019.1	411997.3	454666.53	812532.1	625705.2	2379920	23219	146789	172177	364701	302226	1009112
Total	249038.3	1288794	1289890.5	1236831	923579.6	4988133	92969	574743	592181	559206	429482	2248581

	Defects	Category	1a	1	2	3	4	Total	1a	1	2	3	4	Total	1a	1	2	3	4	Total	1a	1	2	3	4	Total
			Number of 20m sections with longitudinal defect (C)						Total length of longitudinal defects (m) (D)						Average length of longitudinal defects within each 20m section (C/D) E						% defectiveness (length of defects/length of footway) (F)					
L	Bituminous	FBTR	0	63	112	249	191	615	0	188	314	969	660	2131	0.00	2.98	2.80	3.89	3.46	3.47	0.00	0.05	0.08	0.61	0.61	0.19
o	Block Paved	FKTR	6	20	8	16	9	59	33	98	21	30	27	209	5.50	4.90	2.63	1.88	3.00	3.54	0.13	0.49	0.22	0.21	0.56	0.28
n	Concrete	FCTR	0	17	22	62	58	159	0	31	71	133	111	346	0.00	1.82	3.23	2.15	1.91	2.18	0.00	0.70	1.88	0.63	0.78	0.76
g	Flagged	FFTR	28	521	1083	1887	1086	4605	277	1702	7500	8357	4981	22817	9.89	3.27	6.93	4.43	4.59	4.95	1.19	1.16	4.36	2.29	1.65	2.26
																			Average	3.53						
			Number of 20m sections with area defect (G)						Total area of area defects (sq m) (H)						Average area of area defects within each 20m section (G/H) (I)						% defectiveness (area of defects/area of footway) (J)					
A	Bituminous	FBMS	4	189	596	356	448	1593	15.9	878.6	2257.85	931.45	746.95	4830.75	3.98	4.65	3.79	2.62	1.67	3.03	0.02	0.11	0.28	0.26	0.28	0.21
r	Bituminous	FBSS	0	150	155	101	107	513	0	400.2	558.4	836.35	348.5	2143.45	0.00	2.67	3.60	8.28	3.26	4.18	0.00	0.05	0.07	0.23	0.13	0.09
e	Block Paved	FKCB	8	19	7	23	6	63	38	36.9	16.5	32.25	2.1	125.75	4.75	1.94	2.36	1.40	0.35	2.00	0.05	0.06	0.08	0.10	0.02	0.06
a	Block Paved	FKMB	17	19	33	79	23	171	44.1	25.7	127.25	264.9	36.8	498.75	2.59	1.35	3.86	3.35	1.60	2.92	0.05	0.04	0.59	0.83	0.42	0.24
	Concrete	FCDD	1	7	22	74	18	122	1	11.1	53.65	210.75	20.25	296.75	1.00	1.59	2.44	2.85	1.13	2.43	0.02	0.11	0.63	0.66	0.09	0.38
	Concrete	FCMS	0	16	59	164	65	304	0	31.8	142.67	398.95	83.45	656.87	0.00	1.99	2.42	2.43	1.28	2.16	0.00	0.30	1.68	1.25	0.37	0.83
	Flagged	FFCF	128	1708	2772	5413	4648	14669	916.17	7977.7	14638.12	19625.07	15573.53	58730.59	7.16	4.67	5.28	3.63	3.35	4.00	1.22	1.94	3.22	2.42	2.49	2.47
	Flagged	FFDF	55	1661	2103	3652	2791	10262	284.1	5374.47	8827.22	9125	7091.32	30702.11	5.17	3.24	4.20	2.50	2.54	2.99	0.38	1.30	1.94	1.12	1.13	1.29
																			Average	2.96						
			Number of 20m sections with spot defect (K)						Number of spot defects (L)						Average number of spot defects within each 20m section (K/L) (M)						Number of spot defects per km (N)					
S	Bituminous	FBSP	457	5263	4660	358	321	11059	617	8076	7784	461	346.1	17284.1	1.35	1.53	1.67	1.29	1.08	1.56	14.74	20.02	19.14	2.90	3.20	15.44
p	Block Paved	FKSP	77	102	55	31	21	286	103	125	72	40	21	361	1.34	1.23	1.31	1.29	1.00	1.26	4.01	6.21	7.56	2.78	4.35	4.84
o	Concrete	FCSP	16	64	188	50	37	355	19	87	228	56	42	432	1.19	1.36	1.21	1.12	1.14	1.22	8.46	19.73	60.49	2.67	2.96	9.47
t	Flagged	FDSP	191	1357	774	1614	1065	5001	6	1302	1041	2443	1315	6107	0.03	0.96	1.34	1.51	1.23	1.22	0.26	8.87	6.05	6.70	4.35	6.05
																			Average	1.32						

Number defects	Number of spot defects + number 20m sections with longitudinal and area defects (C+G+F) (O)					
Category	1a	1	2	3	4	Total
Bituminous	621	8478	8647	1167	1092.1	20005.1
Block Paved	134	183	120	158	59	654
Concrete	20	127	331	356	183	1017
Flagged	217	5192	6999	13395	9840	35643
Total	992	13980	16097	15076	11174.1	57319.1

	Defects per km (O/B)					
Category	1a	1	2	3	4	Total
Bituminous	14.84	21.02	21.26	7.33	10.09	17.87
Block Paved	5.22	9.10	12.59	10.98	12.21	8.78
Concrete	8.91	28.80	87.82	16.98	12.88	22.30
Flagged	9.35	35.37	40.65	36.73	32.56	35.32
Total	10.67	24.32	27.18	26.96	26.02	25.49

Table D2 Analysis of Blackpool Council DVI Data

		Category	1a	1	2	3	4	Total	1a	1	2	3	4	Total	1a	1	2	3	4	Total
		Defects	Number of 20m sections with longitudinal defect						Total length of longitudinal defects (m)						% defectiveness (length of defects/length of footway)					
L	Bituminous	FBTR	0	19	28	42	8	97	0	42	114	185	50	391	0	0.109287	0.1591	0.214552	0.756544	0.192141
o	Block Paved	FKTR	3	4	3	13	2	25	8	10	3	21	3	45	0.180343	0.25355	0.135993	0.159007	0.305499	0.181635
n	Concrete	FCTR	0	4	0	7	2	13	0	15	0	7	3	25	0	34.09091	0	0.082567	0.347222	0.235916
g	Flagged	FFTR	28	41	93	492	43	697	277	193	629	1970	157	3226	6.415007	1.318216	1.561879	1.436897	1.073578	1.529229
			Number of 20m sections with area defect						Total area of area defects (sq m)						% defectiveness (area of defects/area of footway)					
A	Bituminous	FBMS	0	43	162	91	16	312	0	57.95	219.2	281.65	41.3	600.1	0	0.054783	0.117496	0.14564	0.291663	0.119354
r	Bituminous	FBSS	0	37	55	44	11	147	0	70.2	113	173.75	26	382.95	0	0.066363	0.06057	0.089845	0.183613	0.076165
e	Block Paved	FKCB	0	5	3	7	1	16	0	5.2	2.1	3.65	0.2	11.15	0	0.038522	0.0394	0.012487	0.010089	0.017931
a	Block Paved	FKMB	11	5	7	69	7	99	18.9	2.9	46.5	227.2	24.2	319.7	0.15567	0.021484	0.872437	0.777296	1.220804	0.51414
	Concrete	FCDD	1	2	0	49	1	53	1	6.5	0	145.35	4	156.85	0.028237	3.468517	0	1.778678	0.381534	1.208202
	Concrete	FCMS	0	1	0	12	2	15	0	2.5	0	14.8	1.1	18.4	0	1.334045	0	0.181111	0.104922	0.141734
	Flagged	FFCF	113	228	543	1964	245	3093	797.17	1125.8	2103.4	6665.15	804.4	11495.92	4.322837	2.517048	1.978543	2.276914	2.780793	2.340695
	Flagged	FFDF	55	51	397	1394	189	2086	284.1	265	2062.66	3450.13	478.7	6540.59	1.540597	0.592483	1.940221	1.178615	1.654855	1.331735
			Number of 20m sections with spot defect						Number of spot defects						Number of spot defects per km					
S	Bituminous	FBSP	0	76	135	102	13	326	0	82	154	110	12.1	358.1	0	2.133694	2.149247	1.275717	1.830837	1.75974
p	Block Paved	FKSP	3	18	15	28	4	68	3	19	15	32	4	73	0.676285	4.817444	6.799637	2.422958	4.07332	2.946519
o	Concrete	FCSP	7	4	22	13	2	48	8	4	23	17	2	54	6.73968	90.90909	958.3333	2.00519	2.314815	5.095782
t	Flagged	FDSP	6	45	69	154	26	300	6	52	73	159	26	316	1.389532	3.55167	1.812674	1.159729	1.777899	1.497943

Inventory	Area						Len					
hier--->	1a	1	2	3	4	Total	1a	1	2	3	4	Total
Bituminous	2901.95	105782	186559.7	193387.7	14160.2	502791.5	577	38431	71653	86226	6609	203496
Block Pave	12141.1	13498.65	5329.9	29229.55	1982.3	62181.5	4436	3944	2206	13207	982	24775
Concrete	3541.5	187.4	33	8171.8	1048.4	12982.1	1187	44	24	8478	864	10597
Flagged	18440.9	44727	106310.6	292727.4	28927	491132.9	4318	14641	40272	137101	14624	210956
Total	37025.45	164195	298233.2	523516.4	46117.9	1069088	10518	57060	114155	245012	23079	449824

Frequency is number of defects per km

Table D3 Analysis of Hampshire County Council DVI Data

		Category	1a	1	2	3	4	Total	1a	1	2	3	4	Total	1a	1	2	3	4	Total
		Defects	Number of 20m sections with longitudinal defect						Total length of longitudinal defects (m)						% defectiveness (length of defects/length of footway)					
L	Bituminous	FBTR	0	4	1	0	0			5	0	17	6	0	0	23	0	0.005116	0.001978	0
o	Block Paved	FKTR	3	8	2					13	25	58	12			95	0.117797	0.411143	0.205128	
n	Concrete	FCTR	0	0	0					0	0	0	0			0	0	0	0	
g	Flagged	FFTR	0	12	38					50	0	87	438			525	0	0.281836	5.005714	
			Number of 20m sections with area defect						Total area of area defects (sq m)						% defectiveness (area of defects/area of footway)					
A	Bituminous	FBMS	4	60	209	1	0			274	15.9	311.8	1100.9	3	0	1431.6	0.019245	0.050675	0.205774	0.071188
r	Bituminous	FBSS	0	49	72	0	0			121	0	133.9	303.5	0	0	437.4	0	0.021762	0.056729	0
e	Block Paved	FKCB	8	8	1					17	38	8	9			55	0.053417	0.019936	0.075735	
a	Block Paved	FKMB	6	4	18					28	25.2	14.2	52.6			92	0.035424	0.035386	0.442627	
	Concrete	FCDD	0	0	0					0	0	0	0			0	0	0	0	
	Concrete	FCMS	0	0	0					0	0	0	0			0	0	0	0	
	Flagged	FFCF	15	112	47					174	119	809.1	355			1283.1	0.210328	0.923897	1.864848	
	Flagged	FFDF	0	7	18					25	0	49.7	119.3			169	0	0.056752	0.626694	
			Number of 20m sections with spot defect						Number of spot defects						Number of spot defects per km					
S	Bituminous	FBSP	457	4978	4394	62	0			9891	617	7726	7459	107	0	15909	14.95069	23.2528	24.58519	46.95042
p	Block Paved	FKSP	74	74	32					180	100	96	41			237	4.711869	6.805132	7.008547	
o	Concrete	FCSP	9	52	18					79	11	75	26			112	10.39698	33.31853	25.76809	
t	Flagged	FDSP	185	667	206					1058	0	431	457			888	0	13.96223	52.22857	

Inventory	Area								Len						
hier--->	1a	1	2	3	4			Total	1a	1	2	3	4	Total	
Bituminous	82618.3	615291.8	535003.7	4214.2	231.2			1237359	41269	332261	303394	2279	220	679423	
Block Pave	71138	40129.1	11883.6					123150.7	21223	14107	5850			41180	
Concrete	1678.3	4219.3	1692.8					7590.4	1058	2251	1009			4318	
Flagged	56578.2	87574.7	19036.4					163189.3	18901	30869	8750			58520	
Total	212012.8	747214.9	567616.5	4214.2	231.2			1531290	82451	379488	319003	2279	220	783441	

Frequency is number of defects per

Table D4 Analysis of Liverpool City Council DVI Data

		Category	1a	1	2	3	4	Total	1a	1	2	3	4	Total	1a	1	2	3	4	Total
		Defects	Number of 20m sections with longitudinal defect						Total length of longitudinal defects (m)						fectiveness (length of defects/length of foo					
L	Bituminous	FBTR		40	83	207	183	513		129	194	784	610	1717		0.394	0.613	1.11	0.6017	0.726
o	Block Paved	FKTR		8	3	3	7	21		30	6	9	24	69		1.451	0.407	0.762	0.6235	0.805
n	Concrete	FCTR		13	22	55	56	146		16	71	126	108	321		0.757	2.595	1.009	0.8092	1.046
g	Flagged	FFTR		468	952	1395	1043	3858		1422	6433	6387	4824	19066		1.404	5.223	2.806	1.6773	2.578
			Number of 20m sections with area defect						Total area of area defects (sq m)						efectiveness (area of defects/area of footw					
A	Bituminous	FBMS		86	225	264	432	1007		508.85	937.75	646.8	705.65	2799.05		0.603	1.122	0.397	0.2802	0.48
r	Bituminous	FBSS		64	28	57	96	245		196.1	141.9	662.6	322.5	1323.1		0.233	0.17	0.407	0.128	0.227
e	Block Paved	FKCB		6	3	16	5	30		23.7	5.4	28.6	1.9	59.6		0.325	0.123	1.095	0.028	0.283
a	Block Paved	FKMB		10	8	10	16	44		8.6	28.15	37.7	12.6	87.05		0.118	0.639	1.444	0.1854	0.413
	Concrete	FCDD		5	22	25	17	69		4.6	53.65	65.4	16.25	139.9		0.076	0.794	0.275	0.0746	0.24
	Concrete	FCMS		15	59	152	63	289		29.3	142.67	384.15	82.35	638.47		0.483	2.112	1.614	0.3782	1.093
	Flagged	FFCF		1368	2182	3449	4403	11402		6042.8	12179.72	12959.92	14769.13	45951.6		2.16	3.698	2.493	2.4748	2.663
	Flagged	FFDF		1603	1688	2258	2602	8151		5059.77	6645.26	5674.87	6612.62	23992.5		1.809	2.018	1.092	1.1081	1.39
			Number of 20m sections with spot defect						Number of spot defects						Number of spot defects per km					
S	Bituminous	FBSP		209	131	194	308	842		268	171	244	334	1017		8.187	5.401	3.454	3.2943	4.302
p	Block Paved	FKSP		10	8	3	17	38		10	16	8	17	51		4.838	10.86	6.774	4.4167	5.951
o	Concrete	FCSP		8	148	37	35	228		8	179	39	40	266		3.783	65.42	3.124	2.9972	8.67
t	Flagged	FDSP		645	499	1460	1039	3643		819	511	2284	1289	4903		8.087	4.149	10.04	4.4819	6.629

Inventory	Area						Len					
hier--->	1a	1	2	3	4	Total	1a	1	2	3	4	Total
Bituminous		84339.8	83562.15	162885.5	251881.3	582668.75		32734	31659	70650	101386	236429
Block Paved		7283	4405.05	2611.525	6796.825	21096.4		2067	1473	1181	3849	8570
Concrete		6065.5	6754.125	23798.425	21774.15	58392.2		2115	2736	12484	13346	30681
Flagged		279695.55	329319.575	519804.68	596778.225	1725598.03		101279	123155	227600	287602	739636
Total		377383.85	424040.9	709100.13	877230.5	2387755.38		138195	159023	311915	406183	1015316

Frequency is number of defects per km

Appendix E Calculation of probability of claim

The number of people walking past a defect per claim is here defined as exposure. Exposure can be calculated from the total pedestrian km walked, the number of defects per km and the number of accidents resulting in a claim.

For the claims data from the three authorities, exposure has been calculated for each defect height as:

$$\text{Exposure} = \frac{\text{Total pedestrian km walked x number of defects per km}}{\text{Number of claims in study period}}$$

Where:

- The total pedestrian km walked has been derived from:
  - i The nominal pedestrian flows shown in Appendix B, Table B20. Note: as described in Appendix A, pedestrian flow data obtained in Bromley and Hampshire is similar to the national average.
  - ii The length of footway in each network as shown in Appendix A (Table A1).
  - iii The relevant period of time is the period over which claims data was analysed, i.e. the periods indicated in Appendix A (Table A1).
- The numbers of defects per km of each height are those derived in Appendix C (Figure C5).
- The numbers of claims for each height are those obtained from the analysis of claims (Section 4.1.3, Figure 3).

The results are plotted as the diamonds in Figure E1, together with the best fit function (of the form $y=a^{bx}+c$) and upper and lower bound confidence limits.

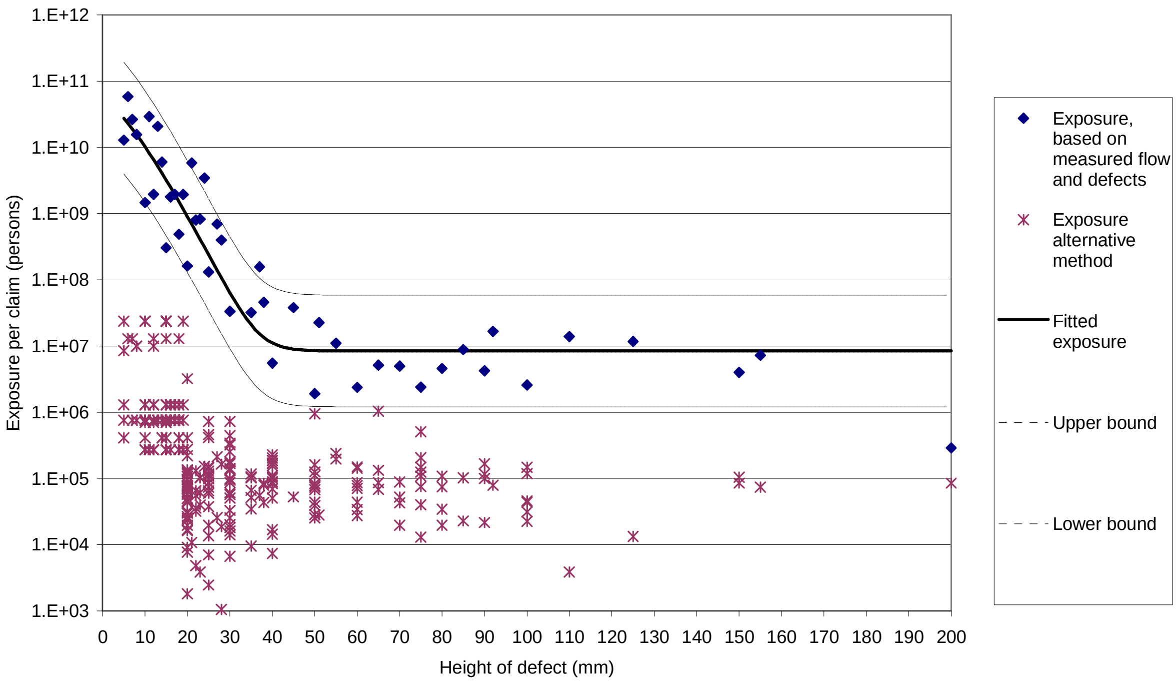

Figure E1 Exposure

Exposure is considered to be the inverse of the probability of a pedestrian making a claim, e.g. if on average there is one claim per one million pedestrians walking past a defect then the exposure is one million and the probability of an accident is one-in-a-million. The probability of injury (the inverse of the trend line, shown above, multiplied by the factor of six injury accidents per claim, see section 4.2) is shown in Figure E2.

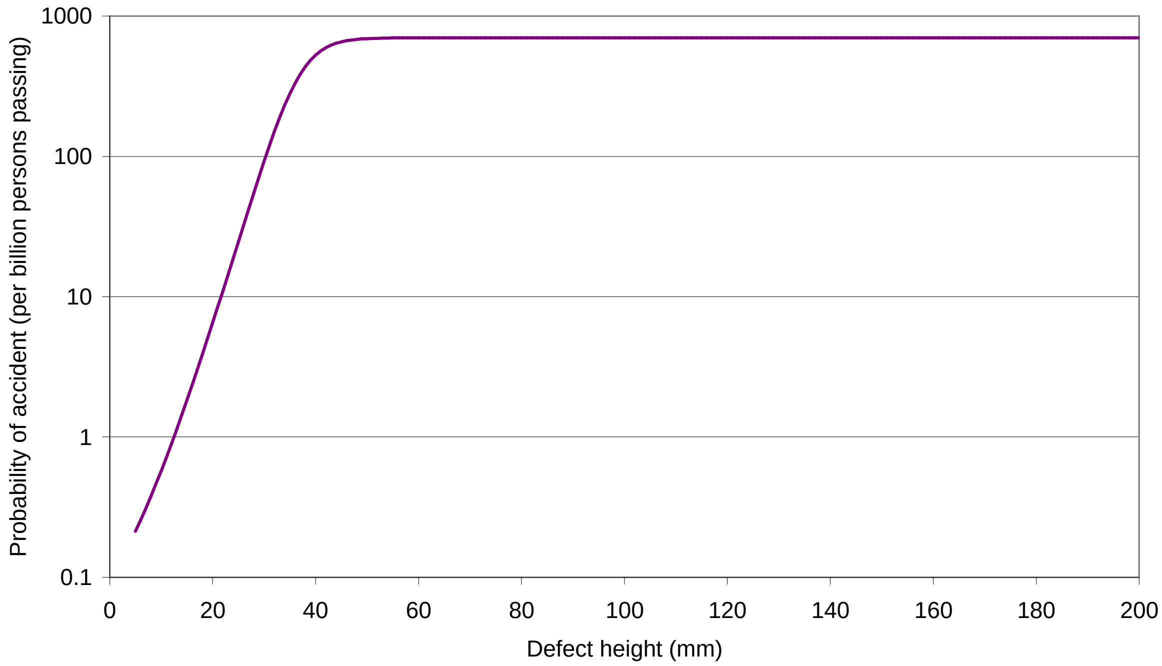

Figure E2 Probability of accident ($P_{accident}(h)$)

Therefore, as shown in Figure E2, the probability of a person falling on a defect and making a claim ($P_{accident}$), used in subsequent analysis, ranges from about 10^{-10} for small defects to 10^{-6} for larger defects.

An alternative approach has also been considered which does not depend on knowing the number of defects, so providing some further confidence in these findings. For each claim the number of pedestrians likely to have passed the defect since it appeared has been calculated as:

No. of pedestrians = period of exposure x flow.

The period of exposure varies depending on the height of defect:

- For defects of height greater than the safety defect threshold the period of exposure is half the safety inspection interval (on the assumption that no defect was present at the last inspection, otherwise it would have been repaired, and that defects occur randomly with time).
- For defects less than the safety defect the period of exposure is the study period (on the assumption that few of these defects would be repaired during routine maintenance).

Results have been plotted as crosses in Figure E1 above. This approach ignores exposure of defects that have not resulted in a claim, so represents a lower bound value. Because of the assumptions made, there is a marked step at 20mm (the safety defect threshold); nevertheless the general form of the relationship is in accord with the above findings.