UK ROADS LIAISON GROUP

FOOTWAY AND CYCLETRACK MANAGEMENT GROUP

ASSET MANAGEMENT GUIDANCE FOR FOOTWAYS AND CYCLE ROUTES: AN APPROACH TO RISK BASED MAINTENANCE MANAGEMENT

VOLUME 2

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This document has been prepared under the overall purview of the UK Roads Board’s Footway and Cycletrack Management Group’s (FCMG) project steering group comprising:

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1 INTRODUCTION

In 2016, the Department for Transport ("DfT") funded a programme of research on behalf of the UK Roads Liaison Group ("UKRLG") and its subgroups. This included a specific research project for the Footway and Cycletrack Management Group ("FCMG") which was procured and managed by Transport for London ("TfL") on behalf of FCMG and the DfT. The research project comprised three tasks:

1. Footway and Cycletrack Construction and Materials Review;
2. Footway and Cycletrack Risk Modelling; and
3. Cycleway Condition Assessment and Service Levels.

The commencement of the research project coincided with publication of *Well Managed Highway Infrastructure: A Code of Practice* (UKRLG, 2016) and the decision was taken that the outputs from the project should support and be aligned with the new code of practice (see Figure 1) and should aim to provide additional specific advice to support the management of walking and cycling infrastructure.

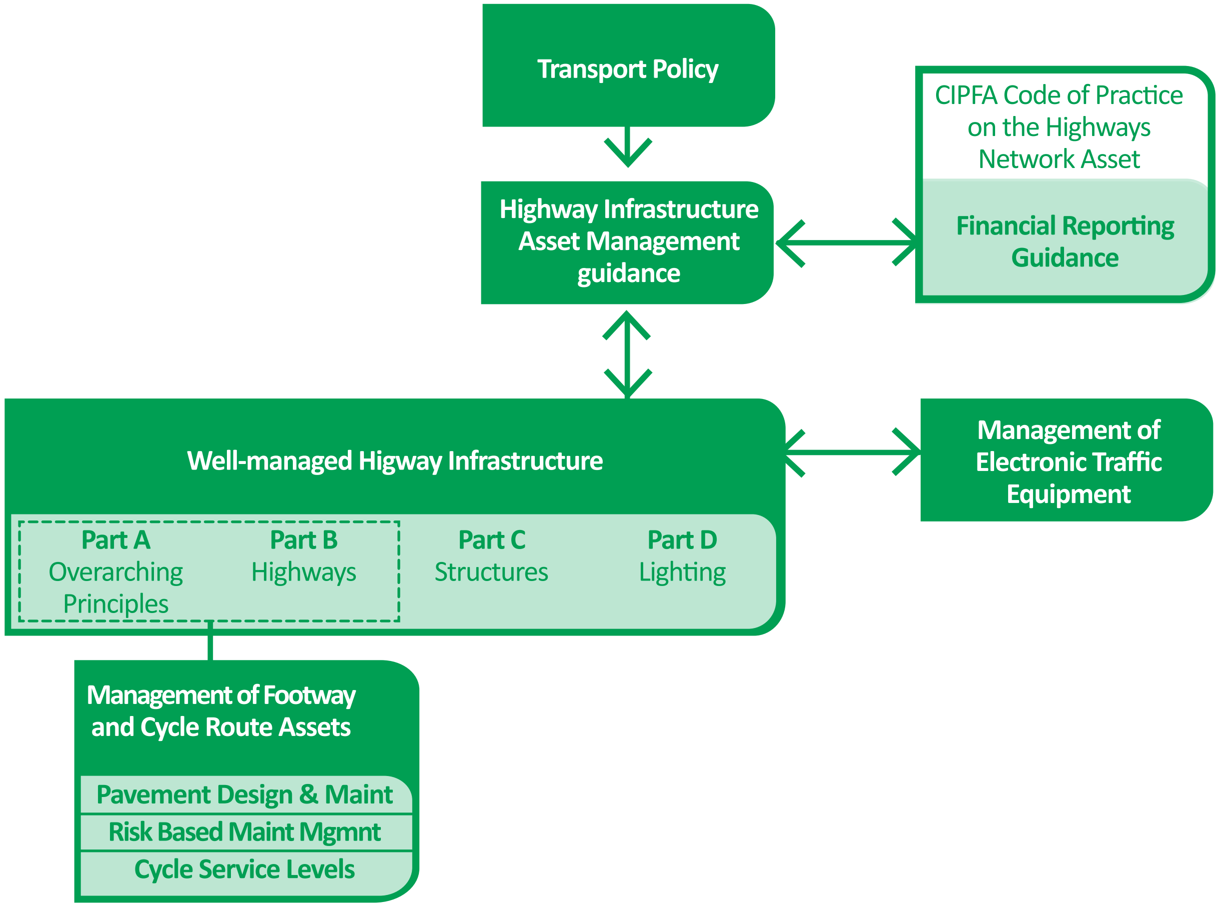

Figure 1 - Relationship between outputs of research project and new Code of Practice

Amongst other things, the new code of practice advocates the adoption of a risk based approach to all aspects of highway asset management and Task 2 therefore focussed on producing specific guidance and tools to support the adoption of a risk based approach to the management of the maintenance of walking and cycling infrastructure from the point of view of safety, serviceability and sustainability. The outputs of Task 2 are:

- Guidance on risk based maintenance management of footways and cycle routes[1] (this document); and
- Footway Safety Risk Tool (see Appendix C) that quantifies and compares the cost and effectiveness, in terms of numbers of potential accidents mitigated, of different safety inspection and maintenance response regimes.

It is important to note that the chance of an accident occurring on a footway or cycle route as a result of a defect is extremely low; research suggests that, on average, ten accidents will occur if a billion people pass over a 20mm defect on a footway, and fewer than two of these accidents will result in a claim against a highway authority (Bird, 2006). However, this does mean that there is limited data available currently from which to develop statistically rigorous relationships between defects, accidents and claims and this has limited the scope of this research project. Furthermore, the claims data that is available is of variable quality and isn't structured in a way that allows systematic analysis.

Authorities are encouraged to collect local data to support the risk based approach advocated by Well Maintained Highway Infrastructure (UKRLG, 2016) and to provide evidence to justify the decisions that have been made as a result. It is recognised that many authorities will initially need to make some assumptions in order to implement their risk based approach and it is recommended that, where practical, these assumptions should be tested, and the decisions based upon them be reviewed and amended if necessary, once local data is available. Such data collection needs to be proportionate but it is intended that this guidance document provides a framework and tools to get started.

A number of examples where authorities might wish to carry out their own analysis are given below:

- Develop a data driven approach to setting inspection frequencies based on level of use, age and/or condition of the asset by collecting and analysing the number of defects and/or claims by different age or condition bands; If it was identified that very few defects occur on assets known to be in a good condition, it may be appropriate to consider whether inspections of these assets could be carried out less frequently.
- Carry out sample pedestrian counts around facilities of different type to determine the effect of their presence on level of use.
- Analyse the proportion of defects that are reported by the public compared to those picked up during scheduled inspections to see whether a fully reactive system could be adopted on some parts of the network; this may vary by geographic area.
- Adjust inspection frequencies based on an analysis of the number of historic defects identified;
- Analyse historic defects and claims records to identify factors influencing likelihood and/or impact of an accident occurring, use this to prioritise data collection, combine inspections, and to implement a range of inspection frequencies and response times based on risk;
- Analyse claims by profile and location of claimants and use to set appropriate inspection policies; If there are socio-economic factors which make claims more likely in a particular area, there may be a cost benefit to carrying out more frequent inspections or introducing more stringent repair criteria in that area;
- Investigate seasonal impacts, for example there may be more defects occurring in the winter but there may also be fewer pedestrians;
- Investigate the impact of defects on level of use which, in turn, will impact on social inclusion, economic growth and public health.

Moreover, the availability of a richer sets of local data would support future national research into footway and cycle route management and maintenance, and would allow more sophisticated risk based tools to be developed.

Fundamentally, risk based maintenance management is a key component of effective asset management and supports long term investment planning for assets – like footways and cycle routes – that don't deteriorate in a linear way with use. One benefit of adopting a risk based approach is that authorities will be able to establish maintenance management regimes that are appropriate to their particular circumstances. This could potentially reduce the cost of inspections and reactive maintenance, freeing up funding for more sustainable planned maintenance which would improve the overall condition of the network and reduce the likelihood of defects forming, but does require authorities to be able to justify these decisions. The guidance and tool have been developed to help authorities make those decisions.

[1] The FCMG research project refers to 'cycletracks' while the new code of practice refers to 'cycle routes'. Formally, a cycletrack is a specific type of cycle route and the generic name has been used in this guidance to align with the code of practice.

2 WELL MANAGED HIGHWAY INFRASTRUCTURE

This guidance has been developed to assist highway authorities adopt the risk based approach advocated by *Well Managed Highway Infrastructure: A Code of Practice* (UKRLG, 2016) for the management of maintenance on footways and cycle routes and, in particular, has been designed to support the following specific recommendations made in the Code of Practice:

RECOMMENDATION 7 – RISK BASED APPROACH
A risk based approach should be adopted for all aspects of highway infrastructure maintenance, including setting levels of service, inspections, responses, resilience, priorities and programmes.

RECOMMENDATION 14 – RISK MANAGEMENT
The management of current and future risks associated with assets should be embedded within the approach to asset management. Strategic, tactical and operational risks should be included as should appropriate mitigation measures. (HIAMG Recommendation 11)

RECOMMENDATION 16 – INSPECTIONS
A risk based inspection regime, including regular safety inspections, should be developed and implemented for all highway assets.

RECOMMENDATION 18 – MANAGEMENT SYSTEMS AND CLAIMS
Records should be kept of all activities, particularly safety and other inspections, including the time and nature of any response, and procedures established to ensure efficient management of claims whilst protecting the authority from unjustified or fraudulent claims.

RECOMMENDATION 19 – DEFECT REPAIR
A risk based defect repair regime should be developed and implemented for all highway assets.

3 RISK BASED APPROACH TO MAINTENANCE MANAGEMENT FOR FOOTWAYS AND CYCLE ROUTES

The Code of Practice defines the following four maintenance objectives:

Network Safety	• Complying with statutory obligations; and • Meeting users' needs for safety.
Customer Service	• User experience/satisfaction; • Communication; • Information; and • Levels of service.
Network Serviceability	• Ensuring availability; • Achieving integrity; • Maintaining reliability; • Resilience; and • Managing condition.
Network Sustainability	• Minimising cost over time; • Maximising value to the community; and • Maximising environmental contribution.

The following interpretations have been made for the purposes of this guidance:

i. The primary risks in terms of 'Network Safety' relate to personal injury resulting from surface defects or conditions that may result in liability claims against the authority. General guidance on the management of highway liability claims is available in *Well Managed Highway Liability Risk* (IHE, 2017).

ii. 'Customer Service' and 'Network Serviceability' have been combined into a single measure of the user experience or satisfaction with the service provided by the footway or cycle route referred to as 'Serviceability'.

iii. 'Network Sustainability' is assumed to relate primarily to the use of condition data for the footway or cycle route as this is likely to determine the greatest risk to the long-term sustainability of the asset.

The risk based approach to maintenance management described in this guidance applies equally to managing the safety, serviceability or sustainability risks on the network. It is in accordance with the risk management principles and guidelines set out in *ISO 31000:2009* (BSI, 2009) and follows the same general steps of; identify, analyse, evaluate and manage the risks. However, the risks to safety, serviceability and sustainability should be identified and considered separately as they will differ and will require separate approaches to risk mitigation. The overall approach is illustrated in Figure 2.

The described approach is generic and can be applied to footways, cycle routes or, indeed, any other asset type.

3.1 DEFINE HIERARCHIES

As defined in Section A.4.3 of the Code of Practice, a network hierarchy based on asset function is the foundation of a risk based maintenance strategy.

While the Code says that the hierarchy adopted should reflect the highway network as a whole, including the collective needs, priorities and actual use of each infrastructure asset, it also recognises that different asset types may have their own hierarchies as long as they can be considered in relation to others and to the whole highway network. The Code also notes that it is important to consider the hierarchy of neighbouring authorities in order to provide reasonable continuity of levels of service.

Figure 2 - Management of safety, service and sustainability risks

The hierarchies in the Code provide a common starting point for the risk based approach to maintenance management described in this guidance.

3.1.1 FOOTWAYS

The primary risk factor for footways is the level of use and the hierarchy should reflect this. Appropriate levels of service for safety, serviceability and sustainability can then be set for each category in the hierarchy as a baseline that can be varied to reflect local risk factors.

Section A.4.3.14 of the Code lists the established footway hierarchy and this should be used by authorities as a starting point from which to develop appropriate local hierarchies that best suit their particular circumstances.

When assigning footways to particular categories, authorities should ideally use actual pedestrian counts – whether network-wide or on a sample basis- but, where this isn't possible, other factors may be used as a proxy for level of use. These might include:

- Importance of the footway in terms of network connectivity; or
- Proximity of schools, hospitals, transport interchanges, tourist locations or other establishments attracting higher than normal numbers of pedestrians.

Authorities should have a programme to test any assumptions that have been made and refine any resulting decisions – for example, to determine if there is a higher level of pedestrian use outside of a school – so that the risk analysis is, as far as possible, based on factual evidence.

3.1.2 CYCLE ROUTES

The categories of cycle route provided in section A.4.3.17 of the Code are descriptions of different types of cycle route rather than a functional hierarchy as such.

As with footways, the cycle route hierarchy should be determined by overall level of use as this is the primary risk factor. Again, it is recommended that user counts, whether network-wide or on a sample basis, are undertaken to assign cycle routes to a particular category as far as possible. Where this isn't possible, similar factors to those given for footways could be used as a proxy. In this case, these assumptions should again be tested to ensure the risk assessment is, as far as possible, based on factual evidence.

More advice on defining an appropriate local cycle route hierarchy is provided in Volume 3- Cycle Service Levels and Condition Assessment.

3.1.3 REVIEW HIERARCHIES

Network characteristics and functionality change over time as a result of development or change of use. Authorities should therefore regularly review these changes at a network level to decide whether or not they affect the hierarchy.

For temporary or seasonal changes, for example from development work or increases in tourism at certain times of year, authorities may wish to carry out additional safety inspections prior to, during or after the change occurring if the change is likely to increase the category of the footway or cycle route. The authority should be capable of evidencing the reason for any such changes.

However, given the costs associated with changing hierarchy, which include the cost and impact of changing inspection and maintenance schedules, updating section attributes in pavement and maintenance management systems, as well as potential contractual changes, authorities should decide whether the likely costs can be balanced against the potential benefits.

3.2 IDENTIFY RISKS

Having defined hierarchies for footways and cycle routes, the next step is to identify factors that could potentially impact on the safety, serviceability or sustainability of the network.

The level of granularity at which risks factors are identified may reflect the availability of available data but, in any case, separate risks should be identified for safety, serviceability and sustainability, and for footways and cycle routes.

> The Footway Safety Risk Tool has been designed to support a network level analysis of non-emergency safety risks and therefore uses pedestrian flow, construction and likelihood of accidents as the primary factors impacting on safety risk.

The main risk factors are included in Appendix A. Authorities should include any additional local risk factors that reflect the particular characteristics of their network and the demographics and priorities of users and the wider community.

However, as with the hierarchy, any assumptions should be tested and analysed.

This may involve a user consultation exercise, a desk analysis of historic complaints and accidents, or, where such data is not available, the judgement and local knowledge of experienced members of staff. Records should be kept of any decisions and the reasoning behind them.

3.3 ANALYSE RISKS

Once safety, serviceability and sustainability risk factors have been identified, the next step is to analyse them to assess their relative importance and weighting.

It is recommended that a structured approach such as pairwise comparison (see Appendix B) is used to provide a robust and reasonably objective way of assessing and weighting the relative importance of the different risk factors.

The presence of localised risk factors can then be analysed using section data, or spatially using a GIS, to define a weighted safety, serviceability or sustainability risk rating for each section of footway or cycle route. Data for analysis may be available from existing asset inventory, maintenance management or pavement management systems. Where data isn't available, then authorities should put in place a programme to collect it, using the risk analysis to help prioritise.

A worked example is shown below.

As an example, assuming an authority has analysed historic claims and identified the following safety risk factors:

- Asset age (works records)
- General condition (e.g. DVI or FNS)
- Highway trees (inventory data)
- History of defects (maintenance management system)
- Construction type (asset inventory)
- Vulnerable users (e.g. local knowledge or planning use information)

Using a pairwise comparison and a five-point scale, the relative weighting of these factors was found to be:

	Asset Age	General Condition	Construction type	Highway trees	History of defects	Vulnerable users	Total	Rank
Asset Age		2	2	4	3	4	15	3
General Condition	**4**		**3**	**4**	**4**	**4**	**19**	**1**
Construction type	4	3		4	4	4	19	1
Highway trees	2	2	2		2	3	11	5
History of defects	3	2	2	4		4	15	3
Vulnerable users	2	2	2	3	2		11	5
TOTAL							**90**	

This resulted in the following risk weightings:

	Weighting	Value	Risk Score	Weighted Risk Score
Asset Age	17%	As New	1	0.17
		Moderate	2	0.33
		Mature	3	0.50
General Condition	21%	As New	1	0.21
		Moderate	2	0.42
		Poor	3	0.63
Construction type	21%	Bituminous	1	0.21
		Concrete	2	0.42
		Flags	3	0.63
Highway trees	12%	None	1	0.12
		Young	2	0.24
		Mature	3	0.37
History of defects	17%	Low	1	0.17
		Medium	2	0.33
		High	3	0.50
Vulnerable users	12%	Low	1	0.12
		Medium	2	0.24
		High	3	0.37

So, in this example, a flagged footway that is mature, in generally poor condition, with mature trees, a high history of defects, and has a relatively high proportion of vulnerable users would have a weighted risk score of:

0.50 + 0.63 + 0.63 + 0.37 + 0.50 + 0.37 = 3.00

Conversely, a bituminous footway that is new, in generally good condition, with no trees, a low history of defects, and has a relatively low proportion of vulnerable users would have a weighted risk score of:

0.17 + 0.21 + 0.21 + 0.12 + 0.17 + 0.12 = 1.00

Analysing the network in this way will enable an authority to assign a safety risk rating to each section of the footway or cycle route network. The same approach can be applied to serviceability and sustainability risks.

Figure 3 - Example calculation of weighted safety risk ratings.

3.4 EVALUATE RISKS

Having analysed the network to determine safety, serviceability or sustainability risk ratings for each section of footway, the authority should next identify appropriate risk mitigations. These will typically involve:

- Inspection or survey frequencies;
- Defects/service impairments and investigatory levels; and
- Maintenance response.

Authorities can use the Footway Safety Risk Tool to assess a range of inspection and risk mitigation regimes. When doing so, due consideration should be given to the overall cost of the proposed inspection and maintenance regime and the practicality of carrying out the surveys, including other surveys and inspections scheduled to be undertaken on adjacent assets.

The Footway Safety Risk Tool allows authorities to define inspection frequencies, investigatory levels and maintenance response times for safety defects, including costs, and compare the effectiveness of up to three different options.

The authority will typically be targeting higher inspection or survey frequencies, quicker maintenance response or, in exceptional circumstances, lower investigatory levels on those sections with the highest risk rating.

Safety inspections are well established covering both footways and cycle routes and an inspector will be looking for any defect that presents a safety risk. Similarly, for footways, established condition surveys exist. However, when defining service inspections, or cycle route condition surveys, authorities should consider the service or sustainability risk factors identified in Section 3.2.

3.5 MANAGE RISKS

Risks are managed and mitigated through a regime of inspections and surveys to assess safety, serviceability and condition, which may be carried out separately or in combination, and appropriate maintenance responses from immediate response through programmed repair to planned maintenance schemes.

3.5.1 SAFETY

Safety risks are managed by carrying out safety inspections and identifying and responding to defects and/or through a reactive system in response to user reported defects. Inspectors should consider the risk presented by a defect when recording its presence on site. However, one of the advantages of the this risk based approach is that that location specific factors will have been taken into account (including the response time), allowing the inspector to focus on the risk presented by the defect itself, due to its dimensions and position in the footway or cycle route.

Depending on the level of risk, defects may require reactive maintenance (including making safe, temporary or permanent repair) or, where a temporary repair has been completed or the defect presents a lower level of risk, will be considered for planned maintenance (see Volume 1- Pavement Design & Maintenance).

3.5.2 SERVICEABILITY

Serviceability risks are managed by carrying out service inspections and identifying and responding to service impairments. Details of potential network level service inspections for cycle routes are given in Volume 3. Inspectors should consider the relative priority of a service impairment when recording its presence on site, for example due to its dimensions and position in the footway or cycle route.

Depending on the level of risk, service impairments may require reactive maintenance, variation in cyclic maintenance frequencies (e.g. cutting back of vegetation, gulley emptying or cleaning) or, in extreme circumstances, may be considered for planned maintenance (see Volume 1- Pavement Design & Maintenance).

3.5.3 SUSTAINABILITY

Sustainability risks are managed by carrying out condition inspections by using established condition surveys such as DVI or FNS, or a bespoke cycle track condition survey such as that described in Volume 3, and identifying and responding to condition impairments.

Depending on the level of risk, condition impairments may require reactive maintenance, or may be considered for planned maintenance (see Volume 1- Pavement Design & Maintenance).

3.6 REVIEW AND UPDATE

It is important that authorities continuously monitor the effectiveness of the inspection and maintenance regime and, where necessary adjust it, to ensure that:

- It is continuing to provide an effective mitigation against risks on the network;
- There is continued compliance with the approach within the authority and its supply chain; and
- That it continues to meet evolving needs of the network (e.g. changing hierarchy following development).

4 USING THE FOOTWAY SAFETY RISK TOOL

It is recognised that the effective management of safety risks, particularly on footways, is a priority for local authorities as these relate to personal injury accidents resulting from trips and slips on surface defects. General guidance on the management of highway liability claims is available in *Well Managed Highway Liability Risk* (IHE, 2017).

As part of this project, a tool has been developed to assist local authorities in the management of footway non-emergency safety defects that can be used at either a network or local level. A more detailed description tool is given Appendix C.

Local authorities should be aware that other tools are available, such as the walking route audit tool, that provide a wider focus on footway condition than just safety[2].

2 Walking route audit tool

4.1 NETWORK LEVEL ASSESSMENT

4.1.1 IDENTIFY RISKS

The first step in using the tool is to divide the network into homogeneous risk bands. The tool assumes that, at a network level, the main risk factors are likely to be:

- Pedestrian flow;
- Construction (i.e. flags, bituminous, small element blocks or concrete); and
- History of accidents (i.e. locations with a higher than average number of claims).

If an authority is using the existing footway hierarchy as a proxy for pedestrian flow, and there are no locations with a higher than average history of accidents, then there will be a maximum of 5 x 4 = 20 homogeneous risk bands as shown below.

Category	Construction	Risk Band
1a	Flags	1
	Bituminous	2
	Blocks	3
	Concrete	4
1	Flags	5
	Bituminous	6
	Blocks	7
	Concrete	8
2	Flags	9
	Bituminous	10
	Blocks	11
	Concrete	12
3	Flags	13
	Bituminous	14
	Blocks	15
	Concrete	16
4	Flags	17
	Bituminous	18
	Blocks	19
	Concrete	20

Figure 4 - Footway safety risk bands (assuming existing hierarchy)

However if, in practice, not all constructions are present for each category of footway then fewer bands will be needed. Alternatively, if there are wide ranges of pedestrian flows within a category, then some categories may need to be sub-divided.

For example, if an authority has a network with the following characteristics:

	Category				
Construction	**1**	**2**	**3**	**4**	**Length (Km)**
Blocks	4.2	1.0	10.4	18.0	33.6
Bituminous	1.2	7.2	172.9	573.4	754.7
Concrete	0.1	0.1	1.9	13.0	15.1
Flags	3.7	2.7	40.2	156.9	203.5
Length (Km)	9.2	11	225.5	761.3	1,006.8
Flow/Day	10,000+	3,000- 10,000	1,000- 3,000	<1,000	

Assuming two parts of the network have a higher than average history of accidents (3 FG+ and 4 FG+), and two have significant differences in pedestrian flow within Category 1 and Category 2 footways (1 FG+ and 2 BT+), then the network could be divided into 20 homogeneous risk bands as shown below:

Risk Band	Name	Category	Construction	Flow/Day	Accident History	Length (Km)
1	1_FG+	1	Flagged	15,000	Average	0.7
2	1_FG	1	Flagged	10,000	Average	3.0
3	1_BP	1	Block	10,000	Average	4.2
4	1_BT	1	Bituminous	10,000	Average	1.2
5	1_CR	1	Concrete	10,000	Average	0.1
6	2_FG	2	Flagged	7,500	Average	2.7
7	2_BP	2	Block	7,500	Average	1.0
8	2_BT+	2	Bituminous	10,000	Average	0.6
9	2_BT	2	Bituminous	7,500	Average	6.6
10	2_CR	2	Concrete	7,500	Average	0.1
11	3_FG+	3	Flagged	2,000	High	1.2
12	3_FG	3	Flagged	2,000	Average	39.0
13	3_BP	3	Block	2,000	Average	10.4
14	3_BT	3	Bituminous	2,000	Average	172.9
15	3_CR	3	Concrete	2,000	Average	1.9
16	4_FG+	4	Flagged	500	High	56.0
17	4_FG	4	Flagged	500	Average	100.9
18	4_BP	4	Block	500	Average	18.0
19	4_BT	4	Bituminous	500	Average	573.3
20	4_CR	4	Concrete	500	Average	13.0
TOTAL						1,006.8

Figure 5 - Example identifying homogeneous risk bands

4.1.2 ANALYSE RISKS

Having divided the network into homogenous risk bands, the Footway Safety Risk Tool, which is based on research into the relationship between trip height and accident risk (Bird, 2006), can be used to provide an objective estimate of unmitigated risk at a network level or for individual risk bands.

Using the Footway Safety Risk Tool to analyse the network above, gives the following indicative level of unmitigated risk for each risk band:

Risk Band	Name	Flow/Day	Length (Km)	Risk Exposure per Year	No of Accidents per Year	No of Accidents per 100km Year
TOTAL			**1,006.8**	**£29,357,900**	**4,890**	486
1	1_FG+	15,000	0.7	£271,200	45	6,458
2	1_FG	10,000	3.0	£774,900	129	4,305
3	1_BP	10,000	4.2	£278,800	46	1,107
4	1_BT	10,000	1.2	£77,800	13	1,109
5	1_CR	10,000	0.1	£8,600	1	2,706
6	2_FG	7,500	2.7	£1,060,100	177	6,458
7	2_BP	7,500	1.0	£97,800	16	1,661
8	2_BT+	10,000	0.6	£79,800	13	2,217
9	2_BT	7,500	6.6	£662,600	110	1,663
10	2_CR	7,500	0.1	£13,600	2	4,059
11	3_FG+	2,000	1.2	£186,000	31	2,583
12	3_FG	2,000	39.0	£6,044,600	1,007	2,583
13	3_BP	2,000	10.4	£415,600	69	664
14	3_BT	2,000	172.9	£6,900,500	1,150	665
15	3_CR	2,000	1.9	£189,200	32	1,624
16	4_FG+	500	56.0	£2,169,900	362	646
17	4_FG	500	100.9	£3,909,600	652	646
18	4_BP	500	18.0	£179,500	30	166
19	4_BT	500	573.3	£5,721,200	954	166
20	4_CR	500	13.0	£316,600	53	406

This analysis suggests that, for this network, Category 1 block and bituminous footways could represent a lower level of risk in terms of potential personal injury accidents than Category 2 footways or even Category 3 concrete and flagged footways. This should be taken into account when considering in the inspection and maintenance regime.

Risk exposure is calculated from the likelihood of an accident resulting in a claim and the typical cost of a successful claim against the authority.

Figure 6 - Example analysing risks at a network level

The unmitigated risk exposure represented here and in the following figures is the risk exposure if no inspections are undertaken. It is based on the resurfacing interval, the surface type, the pedestrian flow and the length of footway, see Appendix C.

Authorities should look at the results of this analysis to consider the level of risk (in terms of the overall risk exposure or number of potential personal injury accidents per km) that they are prepared to accept at a network level and the relative level of risk for each risk band.

4.1.3 EVALUATE RISKS

At a network level, the Footway Safety Risk Model has been developed to assist authorities in evaluating the risks and defining an appropriate risk mitigation regime comprising:

- Survey frequency;
- Defect threshold/investigatory level; and
- Maintenance response time (where not an emergency response).

An example is provided in Figure 7.

Based on the previous example, the following risk mitigation regime has been defined which reflects the previous Code of Practice (i.e. this takes no account of risk in setting inspection frequencies, investigatory levels or response times).

Risk Band	Name	Defect Threshold (mm)	Safety Inspection Interval (days)	Maintenance Response time (days)
1	**1_FG+**	**20**	**30**	**1**
2	1_FG	20	30	1
3	1_BP	20	30	1
4	1_BT	20	30	1
5	1_CR	20	30	1
6	2_FG	20	90	7
7	2_BP	20	90	7
8	2_BT+	20	90	7
9	2_BT	20	90	7
10	2_CR	20	90	7
11	3_FG+	40	180	28
12	3_FG	40	180	28
13	3_BP	40	180	28
14	3_BT	40	180	28
15	3_CR	40	180	28
16	4_FG+	40	365	28
17	4_FG	40	365	28
18	4_BP	40	365	28
19	4_BT	40	365	28
20	4_CR	40	365	28

Figure 7 - Example risk mitigation regime

By setting inspection frequencies, defect thresholds and response times for each risk band, as well as defining typical inspection and maintenance costs, the user is able to define an appropriate risk management regime and can see, for the whole network or for an individual risk band:

- Total unmitigated risk exposure (expressed as a cost or in terms of number of accidents);
- Value of risk mitigated (based on the adopted risk mitigation regime);
- Value of residual risk (based on the adopted risk mitigation regime);
- Cost of risk mitigation (i.e. cost of the proposed inspection and maintenance regime); and
- Mitigation efficiency (mitigated risk/cost of risk mitigation).

Example results from this evaluation are given in Figure 8. Authorities should use this information to:

- Consider the effectiveness of their current inspection and maintenance regimes in mitigating safety risk compared to alternative regimes (see Figure 7 and Figure 8);
- Compare alternative inspection and maintenance regimes that may be more effective (see Figure 9 and Figure 10);
- Assess the level of residual risk at a network level and for each risk band to decide if they are comfortable accepting this; and
- Consider the balance of residual risk between risk bands and whether they should be equalised.

4.1.4 MANAGE RISKS

Before implementation, the proposed inspection and maintenance regime should be reviewed and rationalised to ensure that it is practical to implement, including the relative priority of the adjacent carriageway or cycle route.

Safety risks are managed by carrying out safety inspections and identifying and responding to defects. Inspectors should consider the risk presented by a defect when recording its presence on site, for example due to its dimensions and position in the footway or cycle route.

Depending on the level of risk, safety defects may require reactive maintenance (including making safe, temporary or permanent repair) or, where a temporary repair has been completed or the defect presents a lower level of risk, may be considered for planned maintenance (See Volume 1- Pavement Design & Maintenance).

Risk Band	Name	Flow/ Day	Length (Km)	Unmitigated Risk: Risk Exposure per Year	Unmitigated Risk: No of Accidents per Year	Unmitigated Risk: No of Accidents per 100km Year	Mitigated Risk: Risk Exposure per Year	Mitigated Risk: No of Accidents per Year	Mitigated Risk: No of Accidents per 100km Year	Mitigation Cost	Mitigation Efficiency
TOTAL			**1,006.8**	**£29,357,900**	**4,890**	**486**	**£3,738,600**	**620**	**62**	**£211,300**	**121.2**
1	1_FG+	15,000	0.7	£271,200	45	6,458	£4,800	1	113	£1,100	242.2
2	1_FG	10,000	3.0	£774,900	129	4,305	£13,700	2	76	£4,700	162.0
3	1_BP	10,000	4.2	£278,800	46	1,107	£4,900	1	19	£5,300	51.7
4	1_BT	10,000	1.2	£77,800	13	1,109	£1,900	0	28	£1,500	50.6
5	1_CR	10,000	0.1	£8,600	1	2,706	£100	0	48	£100	85.0
6	2_FG	7,500	2.7	£1,060,100	177	6,458	£21,500	4	131	£2,100	494.6
7	2_BP	7,500	1.0	£97,800	16	1,661	£2,000	0	34	£500	191.6
8	2_BT+	10,000	0.6	£79,800	13	2,217	£2,300	0	62	£300	258.3
9	2_BT	7,500	6.6	£662,600	110	1,663	£18,500	3	47	£3,300	195.2
10	2_CR	7,500	0.1	£13,600	2	4,059	£300	0	82	£-	-
11	3_FG+	2,000	1.2	£186,000	31	2,583	£22,900	4	318	£500	326.2
12	3_FG	2,000	39.0	£6,044,600	1,007	2,583	£743,200	124	318	£15,300	346.5
13	3_BP	2,000	10.4	£415,600	69	664	£51,100	9	82	£2,500	145.8
14	3_BT	2,000	172.9	£6,900,500	1,150	665	£1,054,600	176	102	£41,700	140.2
15	3_CR	2,000	1.9	£189,200	32	1,624	£23,300	4	200	£700	237.0
16	4_FG+	500	56.0	£2,169,900	362	646	£283,000	47	84	£16,300	115.8
17	4_FG	500	100.9	£3,909,600	652	646	£509,900	85	84	£29,400	115.6
18	4_BP	500	18.0	£179,500	30	166	£23,500	4	22	£2,400	65.0
19	4_BT	500	573.3	£5,721,200	954	166	£915,800	153	27	£80,100	60.0
20	4_CR	500	13.0	£316,600	53	406	£41,300	7	53	£3,500	78.7

This shows that, in the example, the risk mitigation regime is likely to reduce the number of accidents across the whole network from 4,890 per year to 620 per year at an indicative cost of £211,300. After mitigation, the risk on Category 3 footways (expressed as number of accidents per year per 100km) is higher than on other types of footway which suggests that further refinement of the risk mitigation regime may be necessary.

Figure 8 - Results of example risk analysis

4.1.5 REVIEW AND UPDATE

It is important that authorities continuously monitor the effectiveness of the inspection and maintenance regime and, where necessary adjust it, to ensure that:

- It is providing an effective mitigation against safety risks on the network;
- There is compliance with the approach; and
- That it continues to meet evolving needs of the network (e.g. reviewing hierarchy following development)

The risk mitigation regime in the example is adjusted, on a risk basis. Here, the inspection frequency of risk bands 11, 12 and 15 has been increased, while that of risk bands 3, 4 and 10 has been decreased. The maintenance response time has also been changed for risk bands 3, 4, 6 and 10. Authorities may also choose to adjust the defect threshold.

Risk Band	Name	Defect Threshold (mm)	Safety Inspection Interval (days)	Maintenance Response time (days)
1	**1_FG+**	**20**	**30**	**1**
2	1_FG	20	30	1
3	1_BP	20	90	7
4	1_BT	20	90	7
5	1_CR	20	30	1
6	2_FG	20	30	1
7	2_BP	20	90	7
8	2_BT+	20	90	7
9	2_BT	20	90	7
10	2_CR	20	180	28
11	3_FG+	40	90	28
12	3_FG	40	90	28
13	3_BP	40	180	28
14	3_BT	40	180	28
15	3_CR	40	90	28
16	4_FG+	40	365	28
17	4_FG	40	365	28
18	4_BP	40	365	28
19	4_BT	40	365	28
20	4_CR	40	365	28

Figure 9 - Example adjusted risk mitigation regime

Risk Band	Name	Flow/ Day	Length (Km)	Risk exposure	No. of accidents per year	No. of accidents per 100 km per year	Risk exposure	No. of accidents per year	No. of accidents per 100 km per year	Mitigation cost	Mitigation efficiency
TOTAL			**1,006.8**	**£29,357,900**	**4,890**	**486**	**£3,383,600**	**560**	**56**	**£217,700**	**117.8**
1	1_FG+	15,000	0.7	£271,200	45	6,458	£3,600	1	85	£1,100	242.2
2	1_FG	10,000	3.0	£774,900	129	4,305	£10,300	2	57	£4,700	162.0
3	1_BP	10,000	4.2	£278,800	46	1,107	£3,700	1	15	£2,000	135.6
4	1_BT	10,000	1.2	£77,800	13	1,109	£1,600	0	23	£600	125.2
5	1_CR	10,000	0.1	£8,600	1	2,706	£100	0	36	£100	85.0
6	2_FG	7,500	2.7	£1,060,100	177	6,458	£14,000	2	85	£4,300	242.7
7	2_BP	7,500	1.0	£97,800	16	1,661	£1,300	0	22	£500	191.6
8	2_BT+	10,000	0.6	£79,800	13	2,217	£1,700	0	47	£300	258.3
9	2_BT	7,500	6.6	£662,600	110	1,663	£13,900	2	35	£3,300	195.2
10	2_CR	7,500	0.1	£13,600	2	4,059	£200	0	54	£-	-
11	3_FG+	2,000	1.2	£186,000	31	2,583	£21,100	4	293	£700	234.0
12	3_FG	2,000	39.0	£6,044,600	1,007	2,583	£685,400	114	293	£23,100	230.5
13	3_BP	2,000	10.4	£415,600	69	664	£47,100	8	75	£2,500	145.8
14	3_BT	2,000	172.9	£6,900,500	1,150	665	£990,900	165	96	£41,700	140.2
15	3_CR	2,000	1.9	£189,200	32	1,624	£21,500	4	184	£1,100	151.5
16	4_FG+	500	56.0	£2,169,900	362	646	£246,000	41	73	£16,300	115.8
17	4_FG	500	100.9	£3,909,600	652	646	£443,300	74	73	£29,400	115.6
18	4_BP	500	18.0	£179,500	30	166	£20,400	3	19	£2,400	65.0
19	4_BT	500	573.3	£5,721,200	954	166	£821,600	137	24	£80,100	60.0
20	4_CR	500	13.0	£316,600	53	406	£35,900	6	46	£3,500	78.7

Figure 10 - Example of impact of revising risk mitigation regime

4.2 LOCAL LEVEL ANALYSIS

Where more detailed information is available, either held against each section or within a GIS, authorities may also wish to consider other, more localised probability and impact factors to further refine their risk analysis and response.

4.2.1 IDENTIFY RISKS

Using an analysis of historic accidents, or their own experienced judgement, authorities may wish to consider additional factors that might impact on the safety of the network. These will depend on the particular characteristics of the network and its users, but could include the examples given in Appendix A.

4.2.2 ANALYSE RISKS

Where localised safety risk factors have been identified, the next step is to analyse them to assess their relative importance and weighting in the same way as described in Section 3.3.

The localised safety risk factors can then be analysed using section data, or spatially using a GIS, to define a weighted safety risk rating for each section of footway or cycle route.

Authorities can use these local factors to further refine the risk bands identified at a network level (see Figure 11 below).

4.2.3 EVALUATE RISKS

The locally adjusted risk weightings can be used to refine the analysis by identifying additional risk bands or reassigning sections from a lower to a higher risk band, or vice versa, and seeing the effect on indicative inspection and maintenance costs.

It should be noted that, introducing additional risk bands is likely to result in a more granular inspection and maintenance regime, and which should be reviewed and rationalised to ensure that it is practical to implement, including the relative priority of the adjacent carriageway or cycle route.

4.2.4 MANAGE RISKS

As with the network level assessment, safety risks are managed by carrying out safety inspections and identifying and responding to defects. Inspectors should consider the risk presented by a defect when recording its presence on site. However, one of the advantages of the local level assessment is that location specific factors will already have been taken into account (including the response time), hence the inspector need only consider the risk presented by the defect height and position in the footway or cycle route.

Depending on the level of risk, safety defects may require reactive maintenance or will be considered for planned maintenance as discussed earlier.

4.2.5 REVIEW AND UPDATE

As with the network level assessment, it is important that authorities continuously monitor the effectiveness of the inspection and maintenance regime and, where necessary adjust it, to ensure that:

- It is continuing to provide an effective mitigation against safety risks on the network;
- There is compliance with the approach and, if not, why not; and
- That it continues to meet evolving needs of the network (e.g. reviewing hierarchy following development).

In the example below, the weighted risk scores, based on local risk factors, have been used to further refine the risk bands and weighted risks score derived from a network level analysis.

In this example, an authority has added +10% to each network level risk score where the local weighted risk score is 'high', 0% where the local risk score is medium and-10% where the local risk score is 'low'. This is shown below for the first eight risk bands.

Band	Length	Name	Risk / km	Construction	Flow	Accident History	Local Risk Factor	Adjusted Risk / km	Adjusted Risk Band
1	3.7	1_FG	4.3	Flagged	1000	Average	H	4.7	1.0
							M	4.3	1.0
							L	3.9	1.0
2	4.2	1_BP	1.1	Block	1000	Average	H	1.2	5.0
							M	1.1	5.0
							L	1.0	5.0
3	1.7	1_BT	0.8	Bituminous	1000	Average	H	0.8	6.0
							M	0.8	6.0
							L	0.7	6.0
4	0.1	1_CR	2.7	Concrete	1000	Average	H	3.0	2.0
							M	2.7	3.0
							L	2.5	3.0
5	2.7	2_FG	3.2	Flagged	750	Average	H	3.6	1.0
							M	3.2	2.0
							L	2.9	2.0
6	1.0	2_BP	0.8	Block	750	Average	H	0.9	5.0
							M	0.8	6.0
							L	0.8	6.0
7	6.6	2_BT	0.8	Bituminous	750	Average	H	0.9	5.0
							M	0.8	6.0
							L	0.8	6.0
8	0.1	2_CR	2.0	Concrete	750	Average	H	2.2	4.0
							M	2.0	4.0
							L	1.8	4.0

This results in a very granular analysis of the network which is then rationalised into six risk bands. In this example, this analysis suggests that Category 2, flagged footways with a high local risk score, should be considered as part of Risk Band 1 which includes all Category 1, flagged footways.

Figure 11 - Example of local level refinement

5 REFERENCES

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APPENDIX A
FOOTWAY AND CYCLE ROUTE RISK FACTORS

Footways - Safety Risk Factors

- Age of asset
- Amount of ironwork
- Construction type
- General condition
- Geometry
- Gradient/steps
- Highway trees (i.e. leading to root damage)
- Level of use
- Presence of lighting
- Presence of utilities reinstatements
- Proportion of vulnerable users
- Proximity to other hazard (e.g. water body)
- Proximity to road
- Restricted width
- Risk of surface contamination or slipping (e.g. leaf-fall)
- Security (e.g. hostile vehicle protection)
- Shared use
- Temporary/seasonal factors (e.g. footway is adjacent to development site)
- Temporary factors (e.g. sporting events, or seasonal changes in use)
- Type of use (e.g. utility, leisure)
- Vegetation (i.e. overgrowth intruding on the footway)
- Vehicle crossovers/risk of overrun

Footways - Serviceability Risk Factors

- Age of asset
- Amount of ironwork
- Cleanliness
- Flooding
- General appearance
- General condition
- History of complaints
- Lighting
- Litter
- Network connectivity
- Presence of utilities reinstatements
- Proportion of vulnerable users
- Quality of signing
- Surface material
- Temporary/seasonal factors
- Type of use
- Vegetation

Footways - Sustainability Risk Factors

- Age of asset
- Construction
- Highway trees
- History of defects
- History of flooding incidents
- Maintenance history
- Presence of utilities reinstatements
- Security (e.g. hostile vehicle protection)
- Surface material
- Temporary/seasonal factors
- Vehicle overrun from cross-overs, delivery areas, loading bays, etc.

Cycle Routes - Safety Risk Factors

- Age of asset
- Amount of ironwork
- Construction/surface material
- Cleanliness and presence of debris
- General condition (i.e. dynamic risk assessment)
- Geometry
- Gradient
- Height/head clearance
- Highway trees (i.e. leading to root damage)
- Interaction with pedestrians and other users
- Level of use
- Presence of lighting
- Presence of utilities reinstatements
- Proportion of vulnerable users (e.g. promoted as a safe route to school)
- Proximity to other hazard (e.g. water body)
- Proximity to road
- Restricted width
- Risk of surface contamination or slipping (e.g. leaf-fall)
- Security (e.g. hostile vehicle protection)
- Shared use
- Skidding resistance
- Speed
- Temporary/seasonal factors (e.g. cycle route is adjacent to development site)
- Type of use (e.g. utility, leisure)
- Vegetation (i.e. overgrowth intruding on the footway)
- Vehicle crossovers/risk of overrun

Cycle Routes - Serviceability Risk Factors

- Age of asset
- Amount of ironwork
- Cleanliness
- Construction
- Flooding
- General appearance
- General condition
- Headroom/clearance
- Interaction with other users
- Lighting
- Litter
- Network connectivity
- Presence of utilities reinstatements
- Proportion of vulnerable users
- Quality of signing
- Temporary/seasonal factors
- Type of use
- Use of material
- Vegetation

Cycle Routes - Sustainability Risk Factors

- Age of asset
- Construction
- Highway trees
- History of defects
- History of flooding incidents
- Maintenance history
- Presence of utilities reinstatements
- Temporary/seasonal factors
- Vehicle overrun from cross-overs, delivery areas, loading bays, etc.

APPENDIX B – PAIR-WISE COMPARISON

Pair-wise, or Paired, Comparison is a robust and relatively objective way of assessing the relative importance of different attributes. Whilst is can be time-consuming to complete, it is highly effective in achieving a consensus and can be a useful technique for weighting different probability and impact factors within a risk based approach to asset management.

1. IDENTIFY RISK FACTORS

The first step is to identify the different factors that affect the probability and impact of a risk occurring, whether that is a risk to the safety, serviceability or sustainability of the footway or cycle route. It is recommended that probability and impact factors are considered separately as some factors may affect both the probability and impact of a risk occurring.

Potential risk factors for footways and cycle routes are included in Appendix A. However, authorities are strongly recommended to identify additional factors that are important on their own networks, either by analysing historic data or through their local knowledge. Temporary or seasonal risk factors should also be considered as should dynamic factors such as the effect that surface condition could have on safety or serviceability.

2. WEIGHT RISK FACTORS

Having identified the relevant risk factors, the next step is to carry out a pair-wise comparison to weight them. This method ranks the risk factors by comparing all possible pairs of factors and ranking the relative importance of each factor in each pair using a pair-wise comparison matrix such as that in Figure 12 . The results are totalled and translated into percentages. The comparison can be done collectively with the consensus importance recorded or with the average of individual team members' results.

	A	B	C	D	E	F	G	H	Score	%
A										
B										
C										
D										
E										
F										
G										
H										
TOTAL										

5 = Much more important
4 = More important
3 = About the same
2 = Less important
1 = Much less important

Figure 12 - Example pair-wise comparison matrix

WORKED EXAMPLE

A worked example is shown in Figure 13. In this worked example, 'History of defects' is the most important risk factor with a weighting of 20%, closely followed by 'Condition' and 'Vulnerable users', both with a weighting of 19%.

Pair-wise Comparison - Probability Factors

	Age of asset	Condition	Highway trees	History of defects	Lighting	Vulnerable users	**Score**	**%**
Age of asset		3	2	2	3	2	12	13%
Condition	3		4	3	4	3	17	19%
Highway trees	4	2		3	4	2	15	17%
History of defects	4	3	3		4	4	18	20%
Lighting	3	2	2	2		2	11	12%
Vulnerable users	4	3	4	2	4		17	19%
TOTAL							**90**	**100%**

5 = Much more important
4 = More important
3 = About the same
2 = Less important
1 = Much less important

Figure 13 - Example pair-wise comparison

3. DETERMINE RISK SCORE

Each of the risk factors identified in step one will either be binary (i.e. yes/no) or will have a range of potential values (e.g. high/medium/low). Authorities may wish to assign a score to each of these potential values. For example, if the presence of highway trees is a risk factor, and if the data is available, then an authority may wish to differentiate between 'No trees (risk score = zero)', 'Young trees (risk score = 1)' or 'Mature trees (risk score = 2)'.

The weighting for each risk factor is combined with the score to determine a weighted risk score as illustrated in the worked example below.

	Weighting	Value	Risk Score	Weighted Risk Score
Age of asset	13%	As New	1	0.13
		Moderate	2	0.27
		Mature	3	0.40
Condition	19%	As New	1	0.19
		Moderate	2	0.38
		Poor	3	0.57
Highway trees	17%	None	0	0.00
		Young	1	0.17
		Mature	2	0.33
History of defects	20%	Low	1	0.20
		Medium	2	0.40
		High	3	0.60
Lighting	12%	Yes	0	0.00
		No	2	0.24
Vulnerable users	19%	Low	1	0.19
		Medium	2	0.38
		High	3	0.57

Figure 14 - Calculating weighted risk scores

4. ANALYSE NETWORK

Authorities can now analyse their networks on the basis of the weighted risk score for each risk factor to determine the overall risk score for each section. This can be done either spatially or on a section basis. Again, the weighted scores for probability and impact factors should be combined into a single weighted risk score.

In the worked example above, the overall risk score for a section could range between 0.71 (i.e. 0.13 + 0.19 + 0.00 + 0.20 + 0.00 + 0.19) and 2.17 (i.e. 0.40 + 0.57 + 0.33 + 0.60 + 0.24 + 0.57).

This analysis can be completed for safety, serviceability and sustainability of footways, cycle routes, or indeed any asset.

APPENDIX C FOOTWAY SAFETY RISK TOOL

OVERVIEW

The Footway Safety Risk Tool has been developed to assist authorities in setting up a risk based regime of inspections and maintenance response for safety defects on footways that don't require an immediate response.

The tool is based on published research (Bird, 2006) that looked at the link between footway defects and likelihood of an accident. By categorising the network into 'risk bands' based on construction and number of pedestrians, the tool calculates the likelihood of a defect occurring on a given construction, the likelihood of an accident occurring as a result of that defect based on the number of pedestrians, and the likelihood of that accident resulting in a claim.

Users can define different inspection frequencies, investigatory levels/defect thresholds and response times for each risk band and, by providing cost information for inspections, maintenance response and claims, can compare the cost and effectiveness of a number of different maintenance regimes.

POTENTIAL FUTURE DEVELOPMENT OF THE FOOTWAY SAFETY RISK TOOL

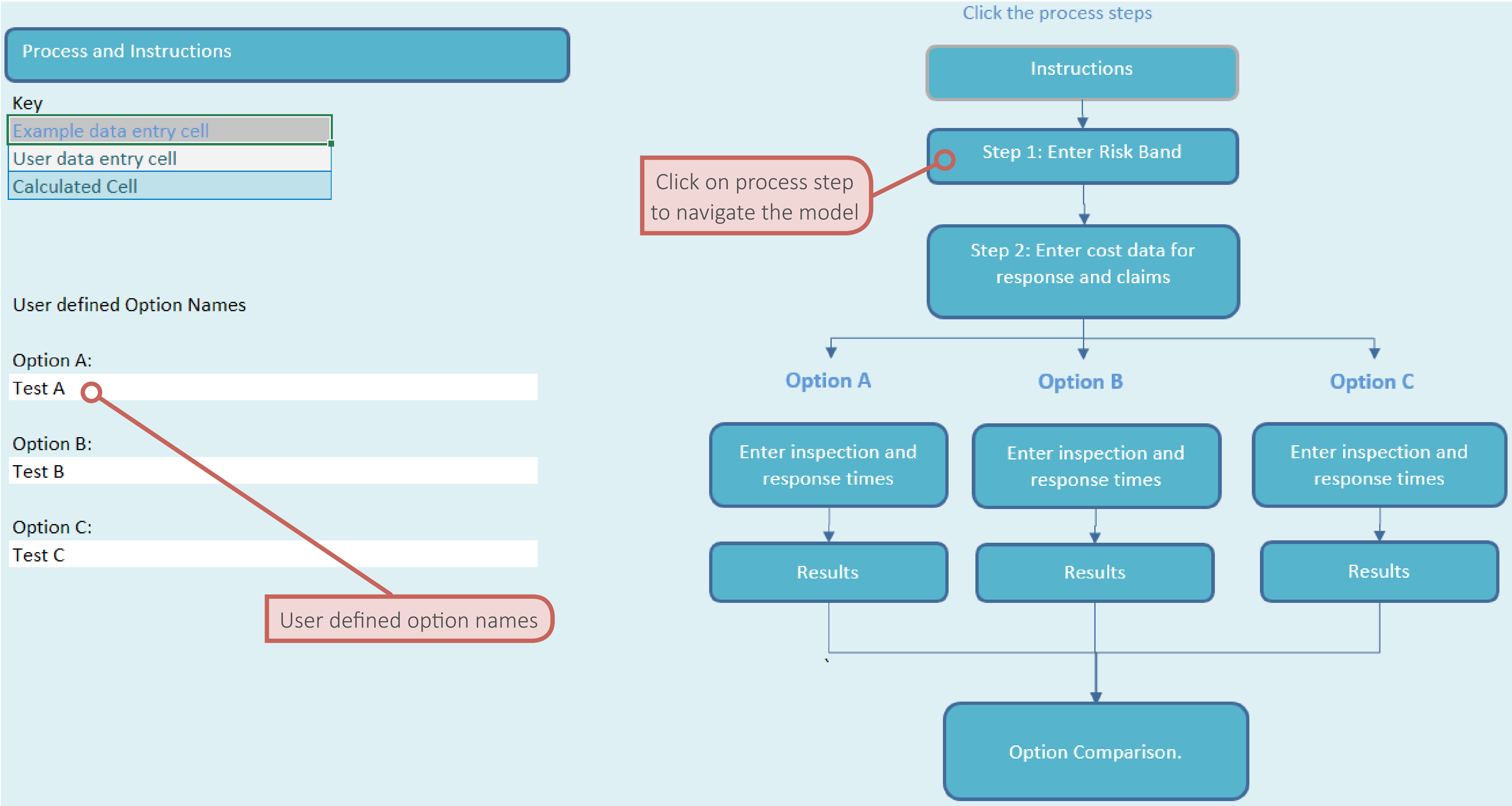
A number of further enhancements of the Footway Safety Risk Tool have been identified that should be considered for future funding. These are:

- Developing the tool to include multiple intervention levels and response times for each risk band;
- Developing a more sophisticated modelling of maintenance response; and
- Examining the relationship between general condition and number of defects.

INSTRUCTIONS FOR USING THE FOOTWAY SAFETY RISK TOOL (R5.0)

STEP 0: INSTRUCTIONS

Step 0 shows the process as a diagram, which be used to navigate through the tool, and allows users to define names for up the three options, each of which corresponding to a different inspection and maintenance regime. The page also includes boxes providing (i) instructions and background, (ii) advice on interpretation of risk charts and (iii) version details.



STEP 1: ENTER RISK BANDS

Step 1 allows users to divide the network into up to 20 homogeneous risk bands based on construction, average daily pedestrian flow (based on counts or other local information, see Section 3.1.1) and, if desired, the history of accidents (i.e. parts of the network where the number of defects resulting in claims is different from the default of 17%). Users may also enter an expected surface life, which indicates the number of years before the surface is likely to be replaced and is used to limit the risk calculation, and the length of network in each risk band.

Step 1: Set up Risk Band in the table below:

Process and Instructions

Go to Step 2: Risk Management Activities

Tips: Show Hide

Hide rows Unhide rows

Risk Band

	Name	Construction	Pedestrian Flow (number per day) Average	Expected Claim Ratio User defined	Expected Claim Ratio Use default (recommended)	Claim Ratio Used	Expected Surface Life (years)	Length (km)
Example	Type 1A	Block	100	17%	☑ TRUE	17%	25	10.0
1	1_FG+	Flagged	15,000		☑ TRUE	17%	20	0.7
2	1_FG	Flagged	10,000		☑ TRUE	17%	20	3.0
3	1_BP	Block	10,000		☑ TRUE	17%	20	4.2
4	1_BT	Bituminous	10,000		☑ TRUE	17%	20	1.2
5	1_CR	Concrete	10,000		☑ TRUE	17%	20	0.1
6	2_FG	Flagged	7,500		☑ TRUE	17%	40	2.7
7	2_BP	Block	7,500		☑ TRUE	17%	40	1.0
8	2_BT+	Bituminous	10,000		☑ TRUE	17%	40	0.6
9	2_BT	Bituminous	7,500		☑ TRUE	17%	40	6.6
10	2_CR	Concrete	7,500		☑ TRUE	17%	40	0.1
11	3_FG+	Flagged	2,000		☐ FALSE	20%	60	1.2
12	3_FG	Flagged	2,000		☑ TRUE	17%	60	39.0
13	3_BP	Block	2,000		☑ TRUE	17%	60	10.4
14	3_BT	Bituminous	2,000		☑ TRUE	17%	60	172.9
15	3_CR	Concrete	2,000		☑ TRUE	17%	60	1.9
16	4_FG+	Flagged	500		☐ FALSE	20%	60	56.0
17	4_FG	Flagged	500		☑ TRUE	17%	60	100.9

Users can select from four construction types

Typical pedestrian flow for the risk band (measured in pedestrians/day/km). Split band if range is too wide

Identify any bands where the likelihood of a defect resulting in a claim differs from the default 17%

Time before surface replaced. This is used to calculate the total exposure time for unmitigated defects rather than maintenance planning. Should be based on actual calculated resurfacing frequencies rather than expected service lives for different surfaces.

STEP 2: ENTER COST DATA

In Step 2, users should enter costs for carrying out safety inspections and typical costs for carrying out reactive maintenance on different footway constructions. Users may also provide details of the average cost of a third party claim on a footway or can use the default figure provided (Zurich Municipal Insurance, 2017).

Step 2: Enter cost data for response and claims:

Cost of safety inspection

Tips: Show Hide

Cost item	Type	Cost	Unit
Inspection costs		£ 100	Average £ per km
Response per defect	Bituminous	£ 60	Average £ for the repair of one defect identified by a inspection
	Block	£ 50	
	Concrete	£ 100	
	Flagged	£ 70	

Cost of permanently repairing a defect on each construction type.

Item	Item	Unit	Use default?	Default	Values Used
Cost of claim	£ -	Average cost of a claim (£)	☑ TRUE	£6,000	£6,000

Average cost of a claim (total cost of claims/number of settled)

STEP 3: ENTER INSPECTION AND RESPONSE TIMES

Step 3 allows users to define a risk mitigation regime for each option, in line with *Well Managed Highway Infrastructure* (UKRLG, 2016) by specifying a defect threshold (i.e. investigatory level), a safety inspection frequency and a maintenance response time for each homogeneous risk band. Users can copy data from a different option to use as a starting point.

Users can copy intervention data from another option

Step 3: Option A: Enter inspection and response time

Back to Step 2.

Option A: Go to Step 4: Results

Option name: Test A

Tips: Show Hide

Select intervention data to copy from: None selected

Copy data

Hide rows Unhide rows

	Name	Risk Band	Defect Threshold (mm)	Safety Inspection Interval (days)	Maintenace Response time (days)
Example	Type 1A	Block: 100 Footfall: CR 0.17: 10 km	20	28	2.0
1	1_FG+	Flagged: 15000 Footfall: CR 0.17: 0.7 km	20	30	1.0
2	1_FG	Flagged: 10000 Footfall: CR 0.17: 3 km	20	30	1.0
3	1_BP	Block: 10000 Footfall: CR 0.17: 4.198 km	20	90	7.0
4	1_BT	Bituminous: 10000 Footfall: CR 0.17: 1.17 km	20	90	7.0
5	1_CR	Concrete: 10000 Footfall: CR 0.17: 0.053 km	20	30	1.0
6	2_FG	Flagged: 7500 Footfall: CR 0.17: 2.736 km	20	30	1.0
7	2_BP	Block: 7500 Footfall: CR 0.17: 0.982 km	20	90	7.0
8	2_BT+	Bituminous: 10000 Footfall: CR 0.17: 0.6 km	20	90	7.0
9	2_BT	Bituminous: 7500 Footfall: CR 0.17: 6.64 km	20	90	7.0
10	2_CR	Concrete: 7500 Footfall: CR 0.17: 0.056 km	20	180	28.0
11	3_FG+	Flagged: 2000 Footfall: CR 0.2: 1.2 km	40	90	28.0
12	3_FG	Flagged: 2000 Footfall: CR 0.17: 39 km	40	90	28.0
13	3_BP	Block: 2000 Footfall: CR 0.17: 10.427 km	40	180	28.0
14	3_BT	Bituminous: 2000 Footfall: CR 0.17: 172.888 kı	40	180	28.0
15	3_CR	Concrete: 2000 Footfall: CR 0.17: 1.942 km	40	90	28.0
16	4_FG+	Flagged: 500 Footfall: CR 0.2: 56 km	40	365	28.0
17	4_FG	Flagged: 500 Footfall: CR 0.17: 100.9 km	40	365	28.0

Safety inspection interval

Defect threshold/ investigatory level

Maintenance response time

STEP 4: RESULTS

Step 4 has two tabs, providing summary and detailed results for that option. The summary tab includes a table showing indicative annual figures for the number of accidents and potential cost of claims for (i) the unmitigated risk exposure (i.e. without any inspection and maintenance regime in place), (ii) the amount of risk mitigated by the inspection and maintenance regime and (iii) the residual. Also provided are the indicative cost and efficiency (i.e. the amount of risk mitigated by each pound spent) of the inspection and maintenance regime. Figures are provided at a network level and for each risk band.

It should be noted that the cost of claims is the maximum potential exposure, the repudiation rate will depend on the effectiveness of the risk management regime.

Step 4: Network Level Results

Instructions

Back to Step 3 Safety interventions and response

Go to Option Comparison

Option name: Test A

Hide rows | Unhide rows

Average annual estimates

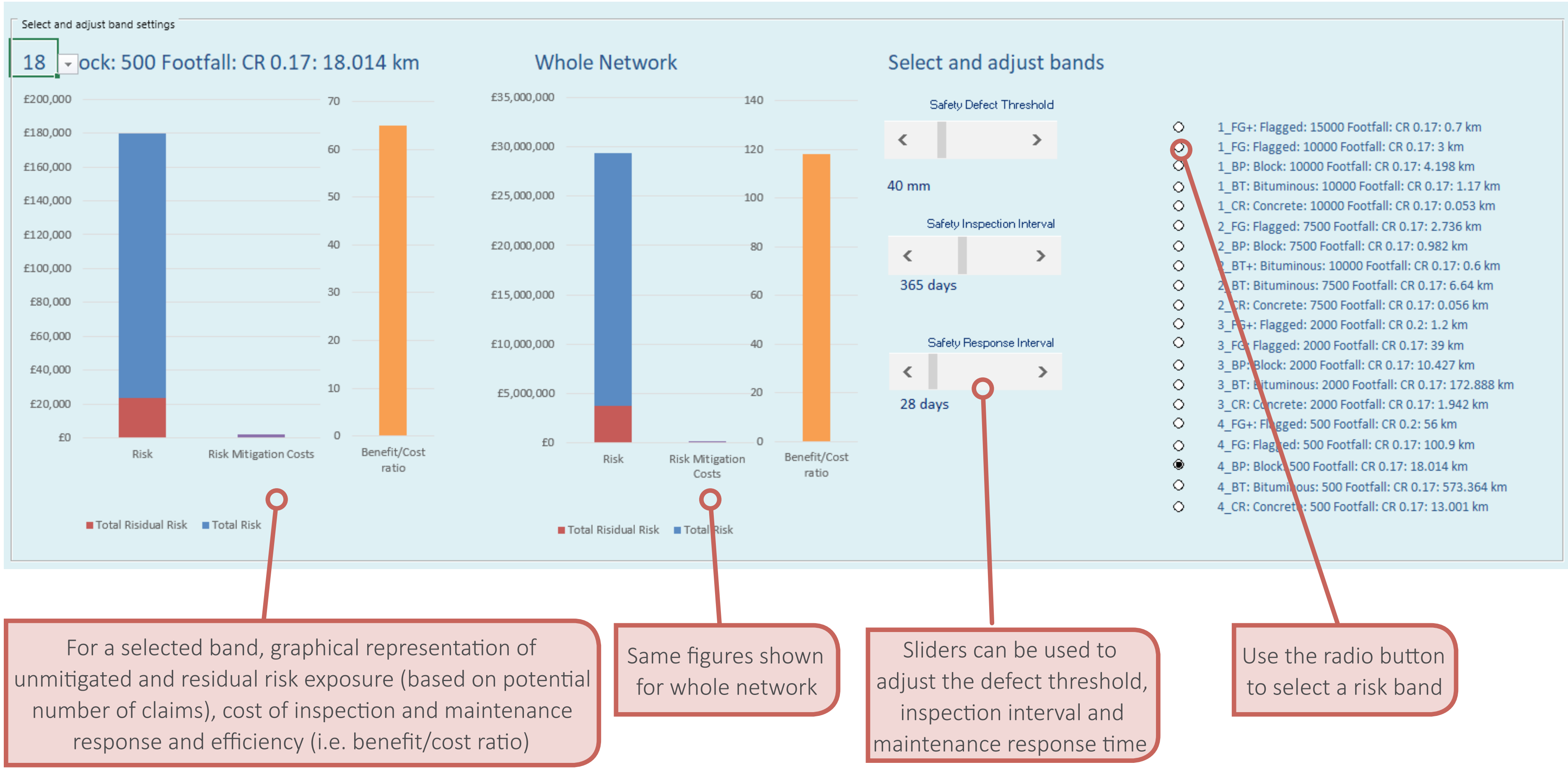
			Total potential risk exposure		Residual Risk		Risk mitigated		Risk mitigation costs	Residual Risk Rank	Risk mitigation efficiency	
	Name	Risk Group	Risk exposure (R0)	Number of accidents (N0)	Risk exposure R = (R1+R2)	Number of accidents N = (N1+N2) Risk	Risk mitigated (RM1)	Number of accidents mitigated (NM1)	C1	Based on R = (R1+R2)	(R0-(R1+R2))/C1	
Row	Total	Whole Network	£ 29,357,900	4,890	3,713,500	620	25,644,400	4,270	£ 217,700	999	117.8	
1	1_FG+	Flagged: 15000 Footfall: CR 0.17: 0.7 km	£ 271,200	45.2	£ 4,800	0.8	266,400	44.4	£ 1,100	15	242.2	
2	1_FG	Flagged: 10000 Footfall: CR 0.17: 3 km	£ 774,900	129.2	£ 13,700	2.3	761,200	126.9	£ 4,700	13	162.0	
3	1_BP	Block: 10000 Footfall: CR 0.17: 4.198 km	£ 278,800	46.5	£ 7,600	1.3	271,200	45.2	£ 2,000	14	135.6	
4	1_BT	Bituminous: 10000 Footfall: CR 0.17: 1.17 k	£ 77,800	13.0	£ 2,700	0.5	75,100	12.5	£ 600	16	125.2	
5	1_CR	Concrete: 10000 Footfall: CR 0.17: 0.053 kr	£ 8,600	1.4	£ 100	0.0	8,500	1.4	£ 100	20	85.0	
6	2_FG	Flagged: 7500 Footfall: CR 0.17: 2.736 km	£ 1,060,100	176.7	£ 16,300	2.7	1,043,800	174.0	£ 4,300	12	242.7	Selected
7	2_BP	Block: 7500 Footfall: CR 0.17: 0.982 km	£ 97,800	16.3	£ 2,000	0.3	95,800	16.0	£ 500	18	191.6	
8	2_BT+	Bituminous: 10000 Footfall: CR 0.17: 0.6 kr	£ 79,800	13.3	£ 2,300	0.4	77,500	12.9	£ 300	17	258.3	
9	2_BT	Bituminous: 7500 Footfall: CR 0.17: 6.64 kr	£ 662,600	110.4	£ 18,500	3.1	644,100	107.3	£ 3,300	11	195.2	
10	2_CR	Concrete: 7500 Footfall: CR 0.17: 0.056 km	£ 13,600	2.3	£ 400	0.1	13,200	2.2	£ -	19	-	
11	3_FG+	Flagged: 2000 Footfall: CR 0.2: 1.2 km	£ 186,000	31.0	£ 22,200	3.7	163,800	27.3	£ 700	10	234.0	
12	3_FG	Flagged: 2000 Footfall: CR 0.17: 39 km	£ 6,044,600	1,007.4	£ 721,100	120.2	5,323,500	887.2	£ 23,100	3	230.5	
13	3_BP	Block: 2000 Footfall: CR 0.17: 10.427 km	£ 415,600	69.3	£ 51,100	8.5	364,500	60.7	£ 2,500	6	145.8	
14	3_BT	Bituminous: 2000 Footfall: CR 0.17: 172.88	£ 6,900,500	1,150.1	£ 1,054,600	175.8	5,845,900	974.3	£ 41,700	1	140.2	
15	3_CR	Concrete: 2000 Footfall: CR 0.17: 1.942 km	£ 189,200	31.5	£ 22,600	3.8	166,600	27.8	£ 1,100	9	151.5	

In this example, the construction, length and level of use of the network could result in 4,890 personal injury accidents per year at a total potential cost of nearly £30M

This particular inspection and maintenance regime would mitigate 4,270 accidents leaving a residual risk exposure of £3.7M.

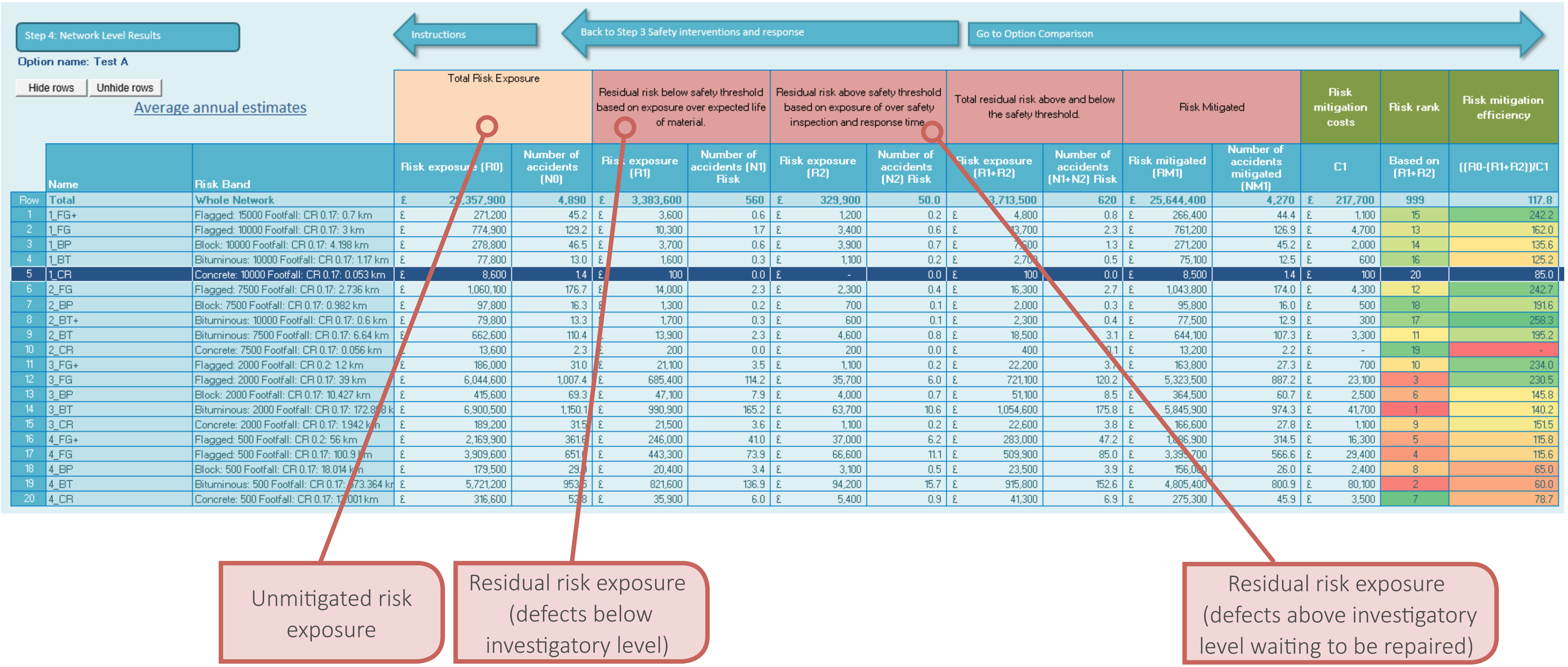
This particular inspection and maintenance regime would cost approximately £218K with an efficiency of 118.

The summary tab also includes a graphical representation showing, at a network and for each individual risk band, the indicative unmitigated and residual risk, the risk mitigation costs and efficiency. Users can select individual risk bands and adjust the defect threshold, inspection interval and maintenance response times using the sliders and see the effect on the graphs.



STEP 4: DETAILED RESULTS

Step 4 also includes a tab showing a more detailed breakdown of results. As well as the total unmitigated risk exposure and amount of risk mitigated, both expressed in terms of potential numbers of accidents and cost of claims, the table also includes the residual broken down by (i) residual risk below defect threshold, based on exposure over expected life of material, and (ii) the residual risk above the defect threshold based on exposure over safety inspection and response time. As well as the indicative risk mitigation cost and efficiency, the detailed analysis includes possible cost of claims (based on likelihood of an accident resulting in a claim) and the mitigated and unmitigated accident rate in terms of accidents per yer per 100km of network. All figures are calculated for the each risk band and for the whole network.



			Total Risk Exposure		Residual risk below safety threshold based on exposure over expected life of material.		Residual risk above safety threshold based on exposure of over safety inspection and response time		Total residual risk above and below the safety threshold.		Risk Mitigated		Risk mitigation costs	Risk rank	Risk mitigation efficiency
Row	Name	Risk Band	Risk exposure (R0)	Number of accidents (N0)	Risk exposure (R1)	Number of accidents (N1) Risk	Risk exposure (R2)	Number of accidents (N2) Risk	Risk exposure (R1+R2)	Number of accidents (N1+N2) Risk	Risk mitigated (RM1)	Number of accidents mitigated (NM1)	C1	Based on (R1+R2)	((R0-(R1+R2))/C1
	Total	Whole Network	£ 2[illegible],357,900	4,890	£ 3,383,600	560	£ 329,900	50.0	£ [illegible]3,713,500	620	£ 25,644,400	4,270	£ 217,700	999	117.8
1	1_FG+	Flagged: 15000 Footfall: CR 0.17: 0.7 km	£ 271,200	45.2	£ 3,600	0.6	£ 1,200	0.2	£ 4,800	0.8	£ 266,400	44.4	£ 1,100	15	242.2
2	1_FG	Flagged: 10000 Footfall: CR 0.17: 3 km	£ 774,900	129.2	£ 10,300	1.7	£ 3,400	0.6	£ [illegible]3,700	2.3	£ 761,200	126.9	£ 4,700	13	162.0
3	1_BP	Block: 10000 Footfall: CR 0.17: 4.198 km	£ 278,800	46.5	£ 3,700	0.6	£ 3,900	0.7	£ 7,[illegible]00	1.3	£ 271,200	45.2	£ 2,000	14	135.6
4	1_BT	Bituminous: 10000 Footfall: CR 0.17: 1.17 km	£ 77,800	13.0	£ 1,600	0.3	£ 1,100	0.2	£ 2,70[illegible]	0.5	£ 75,100	12.5	£ 600	16	125.2
5	1_CR	Concrete: 10000 Footfall: CR 0.17: 0.053 km	£ 8,600	1.4	£ 100	0.0	£ -	0.0	£ 100	0.0	£ 8,500	1.4	£ 100	20	85.0
6	2_FG	Flagged: 7500 Footfall: CR 0.17: 2.736 km	£ 1,060,100	176.7	£ 14,000	2.3	£ 2,300	0.4	£ 16,300	2.7	£ 1,043,800	174.0	£ 4,300	12	242.7
7	2_BP	Block: 7500 Footfall: CR 0.17: 0.982 km	£ 97,800	16.3	£ 1,300	0.2	£ 700	0.1	£ 2,000	0.3	£ 95,800	16.0	£ 500	18	191.6
8	2_BT+	Bituminous: 10000 Footfall: CR 0.17: 0.6 km	£ 79,800	13.3	£ 1,700	0.3	£ 600	0.1	£ 2,300	0.4	£ 77,500	12.9	£ 300	17	258.3
9	2_BT	Bituminous: 7500 Footfall: CR 0.17: 6.64 km	£ 662,600	110.4	£ 13,900	2.3	£ 4,600	0.8	£ 18,500	3.1	£ 644,100	107.3	£ 3,300	11	195.2
10	2_CR	Concrete: 7500 Footfall: CR 0.17: 0.056 km	£ 13,600	2.3	£ 200	0.0	£ 200	0.0	£ 400	[illegible].1	£ 13,200	2.2	£ -	19	-
11	3_FG+	Flagged: 2000 Footfall: CR 0.2: 1.2 km	£ 186,000	31.0	£ 21,100	3.5	£ 1,100	0.2	£ 22,200	3.[illegible]	£ 163,800	27.3	£ 700	10	234.0
12	3_FG	Flagged: 2000 Footfall: CR 0.17: 39 km	£ 6,044,600	1,007.4	£ 685,400	114.2	£ 35,700	6.0	£ 721,100	120.2	£ 5,323,500	887.2	£ 23,100	3	230.5
13	3_BP	Block: 2000 Footfall: CR 0.17: 10.427 km	£ 415,600	69.3	£ 47,100	7.9	£ 4,000	0.7	£ 51,100	8.5	£ 364,500	60.7	£ 2,500	6	145.8
14	3_BT	Bituminous: 2000 Footfall: CR 0.17: 172.8[illegible]8 k	£ 6,900,500	1,150.1	£ 990,900	165.2	£ 63,700	10.6	£ 1,054,600	175.8	£ 5,845,900	974.3	£ 41,700	1	140.2
15	3_CR	Concrete: 2000 Footfall: CR 0.17: 1.942 km	£ 189,200	31.5	£ 21,500	3.6	£ 1,100	0.2	£ 22,600	3.8	£ 166,600	27.8	£ 1,100	9	151.5
16	4_FG+	Flagged: 500 Footfall: CR 0.2: 56 km	£ 2,169,900	361.[illegible]	£ 246,000	41.0	£ 37,000	6.2	£ 283,000	47.2	£ 1,[illegible]86,900	314.5	£ 16,300	5	115.8
17	4_FG	Flagged: 500 Footfall: CR 0.17: 100.9 km	£ 3,909,600	651.[illegible]	£ 443,300	73.9	£ 66,600	11.1	£ 509,900	85.0	£ 3,39[illegible],700	566.6	£ 29,400	4	115.6
18	4_BP	Block: 500 Footfall: CR 0.17: 18.014 km	£ 179,500	29.[illegible]	£ 20,400	3.4	£ 3,100	0.5	£ 23,500	3.9	£ 156,0[illegible]	26.0	£ 2,400	8	65.0
19	4_BT	Bituminous: 500 Footfall: CR 0.17: [illegible]73.364 km	£ 5,721,200	953.5	£ 821,600	136.9	£ 94,200	15.7	£ 915,800	152.6	£ 4,805,400	800.9	£ 80,100	2	60.0
20	4_CR	Concrete: 500 Footfall: CR 0.17: 1[illegible].001 km	£ 316,600	52.8	£ 35,900	6.0	£ 5,400	0.9	£ 41,300	6.9	£ 275,300	45.9	£ 3,500	7	78.7

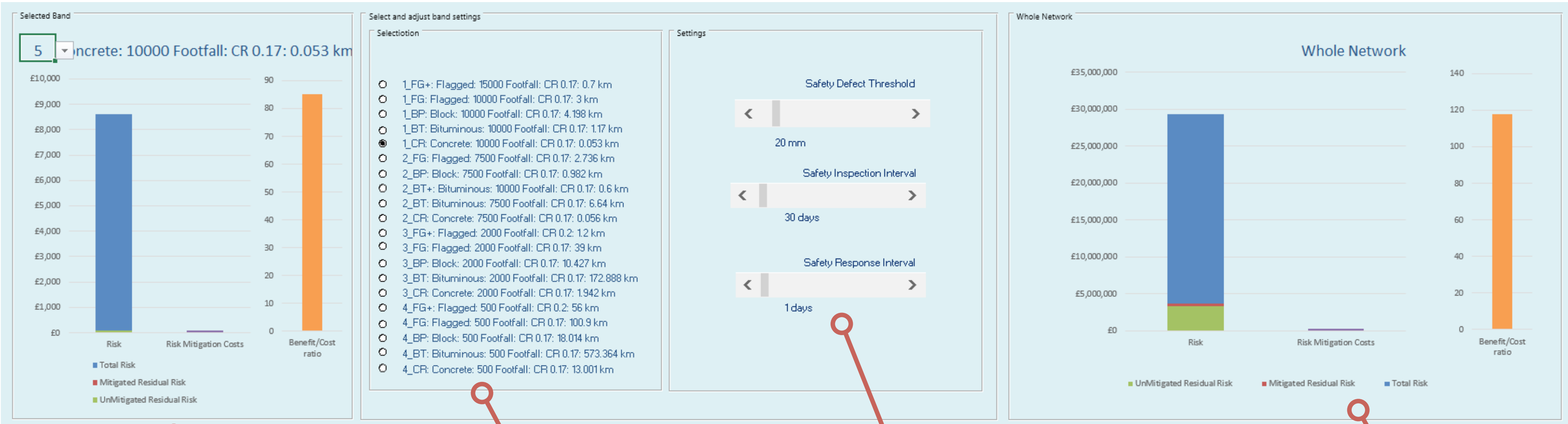
	Claim Risk Cost Based on Claim Ratio (CR) entered in Step 1		
	CR	Claim Cost based on total risk exposure (RO x CR)	Claim Cost based on total residual risk exposure [(R1+R2) x CR]
		£ 5,061,500	£ 640,400
	17%	£ 46,100	£ 800
	17%	£ 131,700	£ 2,300
	17%	£ 47,400	£ 1,300
	17%	£ 13,200	£ 500
Selected	17%	£ 1,500	£ -
	17%	£ 180,200	£ 2,800
	17%	£ 16,600	£ 300
	17%	£ 13,600	£ 400
	17%	£ 112,600	£ 3,100
	17%	£ 2,300	£ 100
	20%	£ 37,200	£ 4,400
	17%	£ 1,027,600	£ 122,600
	17%	£ 70,700	£ 8,700
	17%	£ 1,173,100	£ 179,300
	17%	£ 32,200	£ 3,800
	20%	£ 434,000	£ 56,600

	Total potential risk exposure	Total residual risk
Total length km (L)	Number of accidents per 100 km per year (N0/L) * 100)	Number of accidents per 100 km per year (N1+N2)/L) * 100)
1,006.9		
0.7	6,457.9	113.4
3.0	4,305.3	75.6
4.2	1,107.1	30.2
1.2	1,108.7	38.8
0.1	2,706.2	47.5
2.7	6,457.9	99.5
1.0	1,660.6	33.7
0.6	2,217.4	62.1
6.6	1,663.1	46.5
0.1	4,059.2	118.5
1.2	2,583.2	308.2
39.0	2,583.2	308.2
10.4	664.2	81.7
172.9	665.2	101.7
1.9	1,623.7	193.7
56.0	645.8	84.2

Potential cost of claims (based on likelihood of accident resulting in claim)

Mitigated and unmitigated accident rate per 100km

As with the summary tab, the detailed tab includes a graphical representation showing, at a network and for each individual risk band, the indicative unmitigated and residual risk, the risk mitigation costs and efficiency. Users can select individual risk bands and adjust the defect threshold, inspection interval and maintenance response times using the sliders and see the effect on the graphs.



Unmitigated, mitigated and residual risks for selected risk band

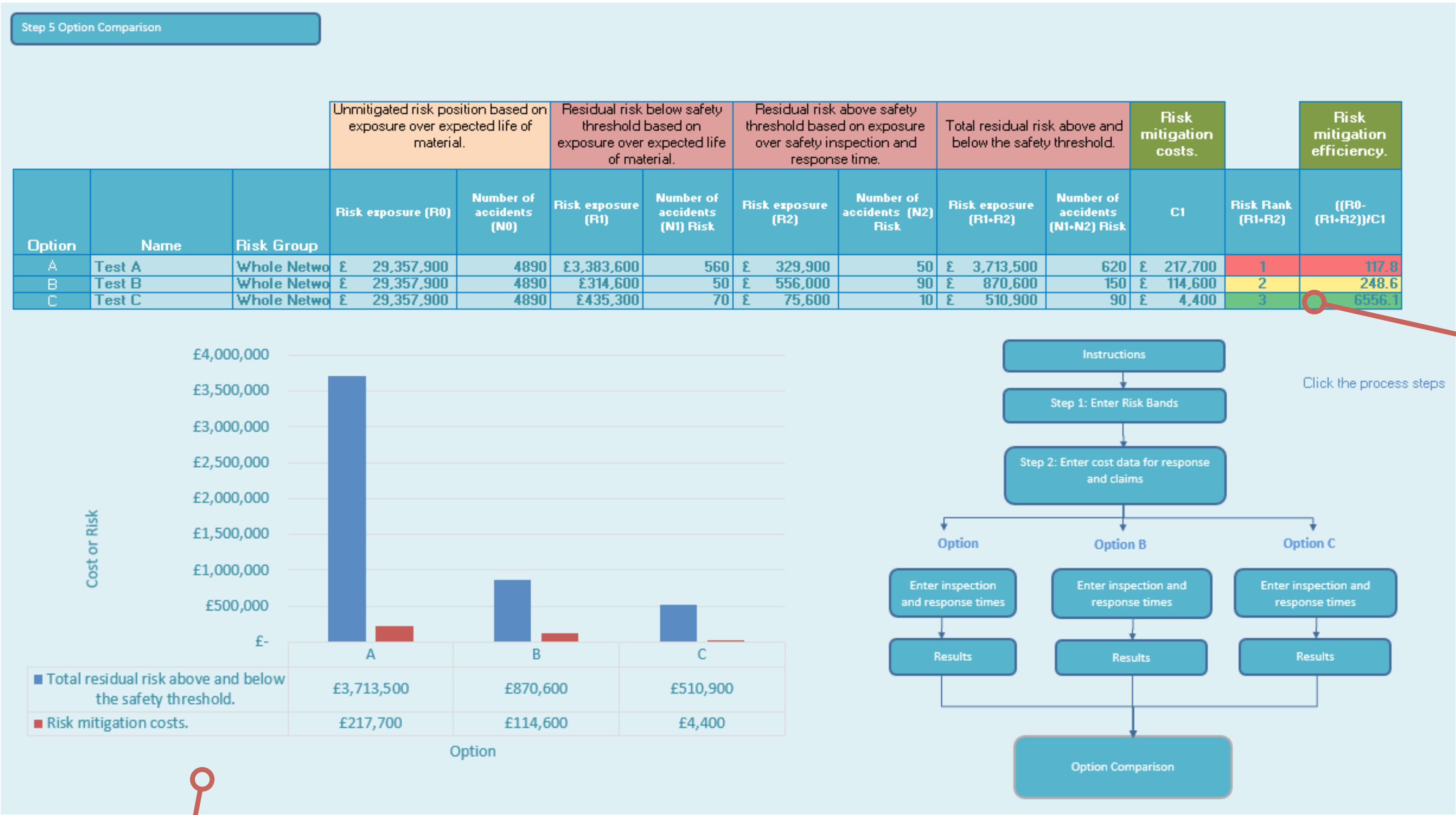
Use radio buttons or pull down list to select particular risk band

Sliders can be used to adjust the defect threshold, inspection interval and maintenance response time for selected risk band

Unmitigated, mitigated and residual risks for whole network

STEP 5: OPTION COMPARISON

The final step allows users to compare the three different inspection and maintenance scenarios at a network level in terms of unmitigated risk, mitigated risk and residual risk, as well as indicative risk mitigation costs and efficiency. The results are compared graphically and the process diagram can be used to navigate through the various steps if a user wishes to edit anything.



			Unmitigated risk position based on exposure over expected life of material.		Residual risk below safety threshold based on exposure over expected life of material.		Residual risk above safety threshold based on exposure over safety inspection and response time.		Total residual risk above and below the safety threshold.		Risk mitigation costs.		Risk mitigation efficiency.
Option	Name	Risk Group	Risk exposure (R0)	Number of accidents (N0)	Risk exposure (R1)	Number of accidents (N1) Risk	Risk exposure (R2)	Number of accidents (N2) Risk	Risk exposure (R1+R2)	Number of accidents (N1+N2) Risk	C1	Risk Rank (R1+R2)	((R0-(R1+R2))/C1
A	Test A	Whole Netwo	£ 29,357,900	4890	£3,383,600	560	£ 329,900	50	£ 3,713,500	620	£ 217,700	1	117.8
B	Test B	Whole Netwo	£ 29,357,900	4890	£314,600	50	£ 556,000	90	£ 870,600	150	£ 114,600	2	248.6
C	Test C	Whole Netwo	£ 29,357,900	4890	£435,300	70	£ 75,600	10	£ 510,900	90	£ 4,400	3	6556.1

Options are ranked by residual risk exposure and by mitigation efficiency

Three options can be compared at a network level

DETAILED DESCRIPTION OF MODEL CALCULATIONS

This section should be read in conjunction with *PPR 171 Development of a Risk Analysis Model for Footways and Cycletracks* (Bird, 2006) and is intended to provide explanation of the treatment of risk within the Footway Safety Risk Tool which supports decision making and risk modelling through the evaluation of alternative inspection and response regimes associated with pedestrian trips and falls.

The statistics for trips and falls and the treatment of risk was developed and explained in PPR 171. Task 2 of the footway and cycle track research project has revisited the previous model to provide a simplified tool and more open classification system. The underlying statistics and mechanics of the risk calculation remain unchanged and were not revisited or challenged as part of this work.

Treatment of risk in the FCMG tool

The chart below (Figure 15) shows defect height vs number of defects per year x probability of an accident for different pavement materials.

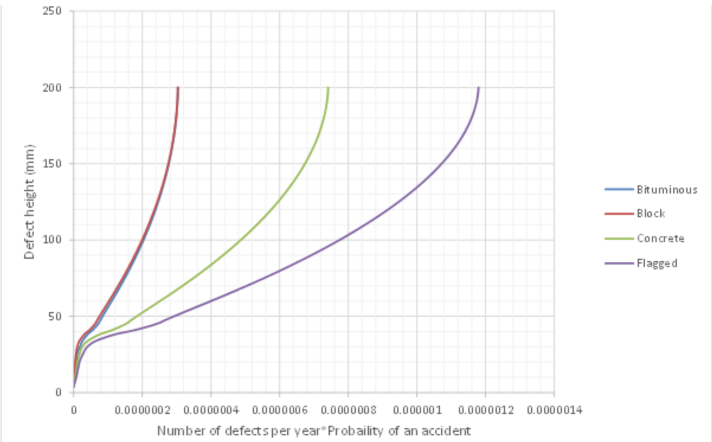


Figure 15 - Chart of defect height vs number of defects per year x probability of an accident

Risk: Number of accidents = $\Sigma(h = 5 \text{ to } 200) \{F \times t \times L \times Nd(h) \times Pa(h)\}$

Where:

h = defect height (mm)

F = pedestrian flow (pedestrians per day)

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

t = time of pedestrian exposure to defect (days)

$Nd(h)$ = number of defects, of height h, developing on the network per km per year

$Pa(h)$ = probability that one pedestrian will fall and injure themselves whilst walking past a defect of height h.

Risk costs = number of accidents x cost of an accident

Other things being equal, for any given section of the network, the risk of accidents may be mitigated by reducing the time (t) for which pedestrians are exposed to the number of defects (Nd) of height (h).

The exposure time (t) and height (h) are illustrated in Figure 16 where the exposure to defects above a defined height described as the Safety Threshold is managed through routine inspection and reactive response.

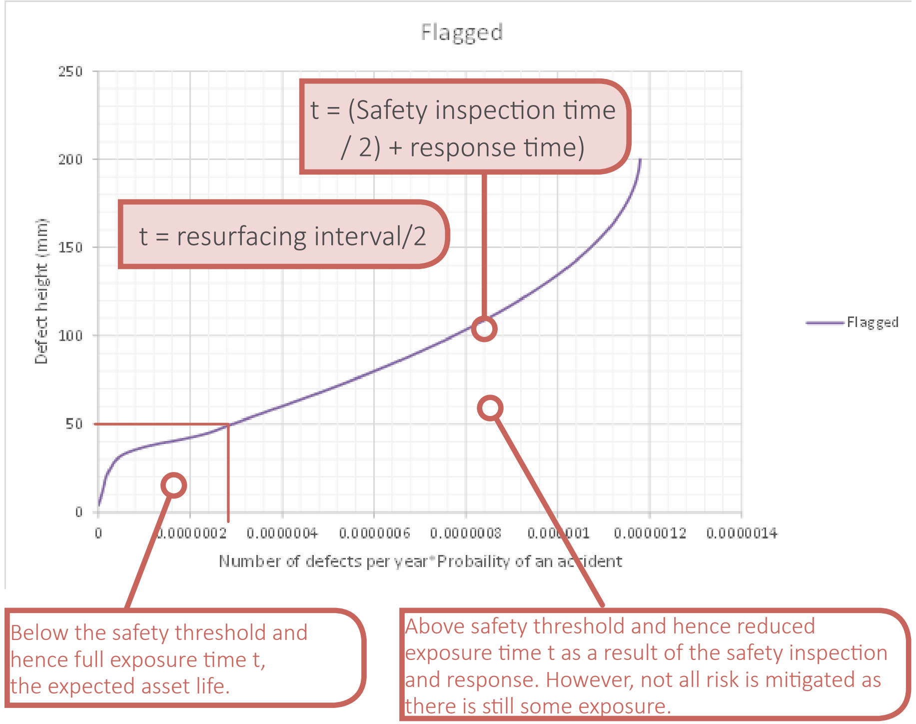


Figure 16 Chart illustrating the impact of exposure time (t).

Defects are assumed to grow linearly and hence exposure time t is approximated to half the actual period between interventions.

Examples of the risk calculation

Do nothing:

- Total risk = Exposure for time t = expected asset life for h = 5 to 200mm

Do something:

- Residual risk below safety threshold = Exposure for time t = expected asset life for h = 5 to 50mm
- Residual risk above the safety threshold = Exposure for time t = safety exposure time for h = >50 to 200mm
- Total residual risk = Residual risk below safety threshold + residual risk above the safety threshold
- Risk mitigated by safety inspections (i.e. above the safety threshold) = Total risk – Total residual risk

Note, Risk below the safety threshold remains unchanged as this is not affected by the safety inspection.

Treatments of unit in the tool

This section summarises the units used in the risk tool.

Number of accidents risk	F	L	t	Nd(h)	Pa(h)
				Probability function PF = Nd(h) * Pa(h)	
Indicated units, number of accidents per year	Number of people passing per day	km	Days or years with unit conversion to days.	Number of defects, of height h, developing on the network per km per year	probability that one pedestrian will fall and injure themselves whilst walking past a defect of height h

The tool uses a cumulative probability function to estimate Nd(h) x Pa(h) the X axis in Figure 16.

The units of the Probability Function are therefore the probability of 1 fall and injury per km per year per person passing up to defect height (h).

The calculation in the risk tool for an exposure time t in years is:

- Number of accidents per year = PF x(t x 365/2) x F x L, e.g. t = asset expected life = 50 years

The calculation in the risk tool for an exposure time t in days is:

- Number of accidents per year = PF x (t/2) x F x L, e.g. t = safety inspection interval 600 days

The calculation assumes that the risk exposure time (t) is used to estimate total number of people passing the defect before mitigation and hence this is applied to the probability function (PF). It is best to consider this in the following way because of the definition of the PF function units:

- Number of accidents per year = PF x Number of people passing a defect between risk mitigation activities which is the product of t, L and F where t is only used to estimate the number of people passing the defect and not the duration of the exposure to the risk.

Treatment of costs in the tool

Cost assumptions are annualised to costs per year. There is no discounting applied.

Response costs (RC) is:

- Number of defects per year per metre above the safety threshold x cost of fixing one defect above the safety threshold (£) x the length of pavement (km)
- Changing the response time affects risks by changing the duration of pedestrian exposure to defects above the safety threshold and this is seen in the risk level calculation.
- Changing the safety threshold and safety inspection interval will affect the number of defects and hence the need to respond and the total response cost.
- There is no premium applied to response costs for faster response times. This means that it does not cost more per defect to respond more quickly. It might be useful to think about the response cost being based on the number of responses per year that are needed rather that the speed of the response.