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Published Project Report
PPR386

A charge structure for trenching in the highway

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Transport Research Laboratory

PUBLISHED PROJECT REPORT PPR 386

A charge structure for trenching in the highway

by R W Jordan, B W Ferne, W McMahon and M Rahman (TRL)

Project Record:	**Long-term performance of reinstatements – stage 3**
Client:	**Transport for London (TfL) and County Surveyors' Society (CSS),** **(Mr R J Bayley), (Mr R I Elphick, OBE)**

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Executive summary

TRL Published Project Report PPR 386: A charge structure for trenching in the highway

Project Reference:	Long term performance of reinstatements – stage 3
Project Officers:	Mr R J Bayley, Transport for London Mr R I Elphick, OBE, County Surveyors' Society
Project Manager:	Mr R W Jordan, TRL Limited

The effect of utility works on the performance of highways* (i.e. carriageways and footways) has been examined over a number of years in studies conducted in Europe and North America. These studies have shown that trenching can have a detrimental effect on both the surface condition and the underlying structure of a highway, thereby shortening its service life. In the UK, there is also increasing political and public concern regarding the negative impact of reinstatement patches on the visual appearance of the nation's highways. For example, a report by the House of Commons Transport Committee into Local Roads and Pathways (2003) stated that:

> *"Several thousand street works are carried out in England every day, often at short notice. The patchwork surface repairs contribute significantly to the deteriorating appearance of the urban street scene."*

> *"The effect is an ugly patchwork quilt of different colour roads and paths. One does not have to walk far anywhere to see an example of where this has led to an uneven footpath with a loose surface or a road with a series of bumps or potholes."*

In addition to considering the visual deterioration, authorities have to undertake additional maintenance to ensure that highways meet appropriate levels of performance and safety because of the premature deterioration due to utility trenching. This in turn increases the levels of cost and inconvenience to the public. An explanation of authorities' concerns was included in the Regulatory Impact Assessment (RIA) for the Traffic Management Act 2004 which highlighted the need to establish a method of recovering funding to deal with the costs of the premature deterioration. The RIA commented that:

> "*There is a long term benefit of preserving the integrity of the highway and improving visual appearance. It is fair that those who play a part in shortening the life of the road and undermining its visual appearance contribute towards remedying the detrimental effects they are responsible for.*"

Supporting this position, Recommendation 20 of the Transport Committee report into Local Roads and Pathways (2003) reads:

> ".. *if the long term damage to roads is proven, local authorities should be able to reclaim these costs from Utility Companies. We expect the Department to bring forward powers through Section 78 of the New Roads and Street Works Act (NRSWA) to enable this.*"

The average reduction in the life of carriageways due to trenching that was measured in nine North American studies ranged from 20 to 56 per cent. Overall, the average reduction appeared to be just over 36 per cent. In the UK, the performance of 168 individual reinstatements reinstated according to the New Roads and Street Works Act 1991 Specification and their effects on the adjacent highway was reported by TRL. The deflections of the reinstatements and adjacent pavements were measured and a visual condition assessment was carried out over a period of six years. Approximately half of the reinstatements were on carriageways. Of these, 38 sites that were, with one

* The term 'highways' is synonymous with the term 'roads' in Scotland.

exception, in 'very good' or 'good' condition, had not been resurfaced during that period. From the analysis of the deflection measurements from the 38 sites, the median service life reduction of the pavement structure (i.e. ignoring the surface or visual condition) due to trenching is estimated to be 17 per cent. Although somewhat lower than the reduction determined in the North American studies, it must be emphasised that the excavation and reinstatement of the UK sites was monitored to ensure they were compliant with the Specification and, as mentioned above, they represented the better examples of the reinstatements within the population. The results also demonstrate the situation after only six years which is a small proportion of the service life of a pavement. It is concluded, therefore, that long term damage to carriageways and footways by trenching is clearly demonstrated and that local authorities should be able to reclaim the additional costs they incur because of trenching from those responsible. This would follow the principle that 'the polluter pays'.

In order to determine the magnitude of the additional maintenance costs being met by authorities, two different maintenance scenarios have been considered. The 'Baseline' scenario has been defined as the level of maintenance that is necessary for highways on which there are no trenching works. It represents the costs that are incurred by highway authorities irrespective of any trenching activity, simply to ensure acceptable levels of safety and performance. The 'Required' maintenance scenario has been defined as the level of maintenance that is necessary for highways that are subject to trenching works and are therefore deteriorating more rapidly. It represents the level of maintenance which is currently required on highways subject to trenching in order to maintain the network in an acceptable and safe condition. A whole-life cost approach has been used to determine the costs of the 'Baseline' and 'Required' scenarios over an accounting period of 40 years, and the additional maintenance costs due to the deterioration in the structural and surface condition of highways caused by trenching have been determined from the difference in the costs of the two scenarios. In addition, this approach has been used to calculate the additional costs associated with restoring the visual condition of footways.

Different maintenance treatments are used in different sections of highways, depending on the amount of traffic, the importance of the route and the amount of trenching. The annual additional maintenance costs have been calculated for a range of treatment options and it has been estimated that overall the additional maintenance costs (based on treatment costs in 2007/08) are £24.3m for the least heavily trafficked carriageways, £25.5m for the more heavily trafficked carriageways, and £20.3m for footways. The total additional maintenance costs of £70.1m represent 7.7 per cent of the capital expenditure on carriageway and footway maintenance by English local highway authorities in 2007/08.

The additional maintenance costs given above are considered to significantly underestimate the full impact of trenching on highways. No allowance has been made for patching or the need to use more costly maintenance treatments in trenched areas compared to untrenched areas. The assumed service life reductions and the areas of the highway around reinstatements that it was assumed are treated are also considered to be low for most reinstatements.

A charge structure has been developed that enables charges to be levied against those trenching the highway in order to recover the additional maintenance costs. The charges vary according to the condition of the highway prior to trenching, being eight times higher for those in the best condition than those in the worst condition. The highest charges for the least heavily trafficked and the most heavily trafficked carriageways are £28.74/m^2 and £45.48/m^2, respectively. On a similar basis, the highest charges are £11.95/m^2 for category 2 to 4 footways and £23.89/m^2 for category 1(a) and 1 footways. The charges should be increased annually in accordance with the Road Construction Tender Price Index from the base year of 2007/08. Although the total maintenance costs detailed above will vary according to the area of highway that is trenched each year, the charges do not vary because they are based on a unit area.

Provision has been made in Sections 55 and 57 of the Traffic Management Act 2004 whereby a highway authority may require an undertaker to carry out half- or full-width resurfacing. This could lead to inequitable costs being passed to the last undertaker to open the highway. Further problems would arise when the undertaker tried to recover some of the costs from other undertakers, some possibly no longer trading or having been taken over during the intervening years. Other problems would result if the 'last undertaker' attempted to recover the total costs from the customer requiring the work, as in the case of a service connection. Using charge rates to recover the additional maintenance costs is considered to be more practical and equitable than a requirement for one particular undertaker to carry out half- or full-width resurfacing.

Levying the charges developed in this project can be undertaken easily either as part of a permit charge under Section 55 of the Traffic Management Act 2004 or alternatively using the reinstatement notices that are already required under Section 78 of the New Roads and Street Works Act 1991. Incidentally, Section 78 is the only Section of the latter Act that has yet to be implemented.

Abstract

Studies have shown that utility trenching can have a detrimental effect on both the surface condition and the underlying structure of highways, thereby shortening their service lives. In the UK, there is also increasing political and public concern regarding the negative impact of reinstatement patches on the visual appearance of the nation's highways. Analysis of FWD data obtained from reinstatements in carriageways is reported. This estimated that the median reduction in the service life of the pavement structure due to trenching is 17 per cent. The additional maintenance costs incurred by highway authorities due the premature deterioration in the structural and surface condition of carriageways have been estimated assuming this service life reduction. Also, the additional maintenance costs incurred due to the premature deterioration in the structural, surface and visual condition of footways has been estimated assuming a 10 per cent service life reduction due to trenching. The costs for 2007/08 were estimated to be £49.8m for carriageways and £20.3m for footways, although these are considered to be low estimates of the full impact of trenching on highways. A charge structure has been developed that enables charges to be levied against those trenching the highway in order to recover these additional maintenance costs. The charges vary according to the highway condition, and are higher the better the condition. The highest charges for 2007/2008 were estimated to be £45.48/m^2 for Major carriageways (Type 0, 1, 2 and 3 roads), £28.74/m^2 for Minor carriageways (Type 4 roads), £23.89/m^2 for category 1(a) and 1 footways and £11.95/m^2 for category 2 to 4 footways. It is proposed that the charges be levied either as part of a permit charge under Section 55 of the Traffic Management Act 2004 or using the reinstatement notices already required under Section 78 of the New Roads and Street Works Act 1991. Using charge rates to recover the additional maintenance costs is considered to be more practical and equitable than a requirement for one particular undertaker to carry out half- or full-width resurfacing.

1 Introduction

The effect of utility works on the performance of highways[*] (i.e. carriageways, footways and cycle tracks) has been examined over a number of years in studies conducted in Europe and North America. These studies have shown that trenching can have a detrimental effect on both the surface condition and the underlying structure of a highway, thereby shortening its service life. In the UK, there is also increasing political and public concern regarding the negative impact of reinstatement patches on the visual appearance of the nation's highways.

As a consequence of the premature deterioration of highways due to utility trenching, authorities have to undertake additional maintenance to ensure that highways meet appropriate levels of performance and safety. This in turn increases the levels of cost and inconvenience to the public. This issue was highlighted by the House of Commons Transport Select Committee as part of their inquiry into highway maintenance, and it has also been considered within the Traffic Management Act 2004[1]. An explanation of the authorities' concerns was given in the associated Regulatory Impact Assessment (2003)[2], which highlighted the need to establish a method of recovering funding to deal with the costs of premature deterioration due to trenching. The RIA commented that "There is a long-term benefit of preserving the integrity of the highway and improving visual appearance. It is fair that those who play a part in shortening the life of the road and undermining its visual appearance contribute towards remedying the detrimental effects they are responsible for."

In 1993, TRL started what has become a three-stage study into the long-term performance of reinstatements and the adjacent highway which has involved the following:

> Stage 1 – A literature review on the impact of trenching on highways and series of tests on 2 major trial sites and 168 other reinstatements.
>
> Stage 2 – The development of a charge structure to recover some of the additional maintenance costs incurred by highway authorities because of the premature deterioration in the surface condition of highways due to trenching.
>
> Stage 3 – The modification of the charge structure developed in Stage 2 to recover some of the additional maintenance costs incurred by highway authorities because of the premature deterioration in the structural, surface and visual condition of highways due to trenching.

Section 2 of this report summarises the work carried out in Stage 1 and Section 3 describes more recent research undertaken in North America.

The development of the charge structure in Stage 2 is summarised in Section 4. An economic model was developed to determine the additional maintenance costs incurred by highway authorities to repair damage to the surface of highways as a result of utility trenching (McMahon *et al*, 2005)[3]. The charges proposed in Stage 2 for levying against those opening the highway were derived such that, over the service life of a typical carriageway or footway, the funding recouped through the charges would partially compensate the authorities for the additional maintenance costs resulting from trenching activity.

The main purpose of this report is to describe the work carried out in Stage 3, during which the charges reported by McMahon *et al* have been revised so that they account for the additional maintenance costs incurred by highway authorities due to the premature deterioration of the structural condition and appearance of highways as a result of trenching, as well as the premature deterioration of the surface condition. The results of a review of the charge structure developed in Stage 2 and its revision in Stage 3 are given in Sections 5 and 6, respectively. Section 7 gives details of the reduction in the service life of highways due to trenching that has been calculated from data obtained in

[*] The term 'highways' that is used throughout this report is synonymous with the term 'roads' in Scotland.

Stage 1. Section 8 explains how the estimates of the additional maintenance costs incurred by highway authorities that result from trenching have been calculated, and Section 9 describes the new charge structure based on those costs. The conclusions are presented in Section 10. Information on the lengths of highways in England and the ‘zone of influence’ around trenches that is subject to premature deterioration is given in Appendices A and B, respectively. Appendix C explains in detail how the additional maintenance costs due to trenching have been calculated.

Clearly, the provision of essential services such as clean water and sewerage, gas and electrical power, and telecommunications is vital to both the physical and economic health of the country. These utility services are provided through a vast network of infrastructure which, for historical and practical reasons, is largely buried beneath the nation’s highway network. Underground networks are generally considered to be beneficial aesthetically when compared to the overhead networks that are prevalent in some countries. The sheer scale of the utility network was illustrated by Bristow and Ling (1989)[4] who reported that by the mid 1980s the total length of underground utility mains in the UK exceeded that of the road network by a factor of about five. The factor is likely to be much higher today because of the installation of cable television and telecommunication networks in the 1990s. According to Bristow and Ling, the bulk of the network of pipes and cables lies beneath roads and is concentrated in urban areas.

In order to maintain, upgrade and expand the network of buried infrastructure, respond to the needs of new customers and economic development, and conduct diversionary works, the utility sector undertakes well over one million street works annually. This level of activity inevitably has an impact on the physical condition of the highway network which, in itself, is an extremely valuable asset that is vital to the nation’s economy and expensive to maintain. While the benefits associated with utilities are freely acknowledged, the purpose of this project was to examine the additional highway maintenance costs due to trenching works and so naturally the focus has been on the more ‘negative’ aspects of utility works rather than the benefits they provide.

2 Stage 1 - Background

2.1 Overview

The extent to which utility works can have an adverse impact on the performance and appearance of a highway was investigated in Stage 1 of this three-stage study. A comprehensive review of the literature was undertaken by Zohrabi and Burtwell (2003)[5] which reported that four possible kinds of damage were foreseen as a consequence of trenching activity:

1. The possibility of the excavation process weakening the adjacent pavement, which then further deteriorates after a reinstatement is completed.
2. The creation of a weak boundary between a reinstatement and the adjacent pavement.
3. A deteriorating pavement that may cause an adjacent trench to fail earlier than expected.
4. Surface deterioration and visual disbenefits arising from the works.

Therefore, it was concluded that the damage associated with utility works can occur at several levels – at depth within the structure of the pavement, deterioration of the surface condition, and a lowering of the aesthetic appearance of the streetscape.

2.2 Structural and surface deterioration

The review by Zohrabi and Burtwell (2003)[5] provided details of a number of studies in the UK which examined the effect of utility trenching on the service life of highways. For example, the effect of utility trenches on pavement performance at eight sites in Southampton and six sites in West Sussex was examined by Burtwell and Hurst (1995)[6]. The study involved structural assessment (using deflection measurements) and a detailed visual condition assessment of in-service and newly constructed trenches over a three- to four-year period. It was shown that the deflection measurements in trenched areas were higher than those in untrenched control sections on the same stretch of highway. In highway engineering, the deflection of a pavement under load is used as an indicator of the strength or competency of the various pavement layers and thus the data showed that the trenched areas were weaker than their control sections. In addition, the study found evidence to suggest that the presence of a trench can have a weakening effect on the pavement immediately adjacent to it. There is a ‘zone of influence’ around a reinstatement of size dependent on the depth of the trench. Cracking can occur in this zone because the edges of the trench are unsupported during excavation and because of subsequent differential movement between the reinstatement and the surrounding construction. Typically, the ‘zone of influence’ extends a distance equal to the depth of the trench from its edges (see Appendix B). There are overlapping ‘zones of influence’ where adjacent trenches are close to each other.

The performance of two major trials sites and 168 individual reinstatements and their effects on the adjacent pavements when they were reinstated according to the Specification for the Reinstatement of Openings in Highways (2002)[7] was reported by Steele *et al* (2003)[8]. The deflections of the reinstatements and the adjacent pavements were measured using a Falling Weight Deflectometer (FWD) and a visual condition assessment was carried out. The 168 individual reinstatements were re-visited on several occasions over a six-year period to assess their longer-term performance. Analysis of these sites indicated that the majority were in good general condition but during the six-year period of the study about one third of the sites were found to have surface defects which might lead to premature failure of the surfacing and hence, if left unchecked, cause damage of a more structural nature. As found in the review by Zohrabi and Burtwell, the pavement deflection data also indicated that the pavement within the zone of influence adjacent to a trench generally tended to be weaker than the original pavement remote from the trench.

Overall, the study reported that the 'service lives' of pavements and footways containing reinstatements had been reduced although the magnitude and severity of this reduction was not fully quantified. However, it has been possible to estimate the reduction in service life using the data reported by Steele *et al* (2003)[8] as described in Section 7 of this report.

It should be noted that the trenching and reinstatement works at the two major trial sites and the 168 individual reinstatements were observed by TRL supervisors (HAUC trained), and thus it is likely that the works were undertaken to a higher standard than most 'unobserved' reinstatements.

2.3 Visual disbenefits

The visual disbenefits of trenching were highlighted in a report by the House of Commons Transport Committee (2003)[9], which commented that:

> *"Several thousand street works are carried out in England every day, often at short notice. The patchwork surface repairs contribute significantly to the deteriorating appearance of the urban street scene."*

Commenting on the large number of excavations undertaken as a result of gas and water mains replacement programmes and the expansion of new telecommunications companies in the 1990s, the report stated that:

> *"The effect is an ugly patchwork quilt of different colour roads and paths. One does not have to walk far anywhere to see an example of where this has led to an uneven footpath with a loose surface or a road with a series of bumps or potholes."*

Similar sentiments were expressed in the Regulatory Impact Assessment associated with the Traffic Management Bill (2003)[2], which pointed out that:

> *"…over time a series of reinstatements on a particular street, which may have been carried out by several different undertakers, can have a negative effect, both visually and in terms of the strength and lifespan of the road……These trenches also impact upon the visual amenity of an area and can make our streets look ugly, creating an unattractive criss-cross pattern."*

A study by Alan Baxter and Associates (2002)[10] (on behalf of the Commission for Architecture and the Built Environment (CABE) and the Office of the Deputy Prime Minister (ODPM)) considered the reasons why there is a failure to create and maintain quality streetscapes. The Executive Summary included the following statement:

> *"One of the most commonly voiced complaints about street quality concerns the deleterious effect of utility works whereby* [improvement] *schemes are often undermined by subsequent poor quality interventions."*

With regard to the design and management of streetscapes, the report commented that:

> *"The most conspicuous problem arises from works by utilities, especially in streets where care has been taken to complete a coordinated, high quality [improvement] scheme. The disruption caused by utilities works is a common subject of public complaint: indeed there is probably no aspect of the public realm about which people feel so strongly. But apart from disruption, the visual aftermath of such works is often a permanent reminder of the casual way utilities treat our streets. The problem has become far worse in recent years with the proliferation of rival telecommunications companies, whose operations are subject to little overall supervision and effective enforcement of regulation.*

What matters here is the quality of the reinstatement after opening-up works in the street have been completed. All too often carefully laid finishes (granite setts or stone paving) are replaced by poorly backfilled trenches and crudely applied tarmac, leaving a scar across the original design."

The report pointed out that, in contrast to the English experience, the well cared for feel of streets in many European cities is partly the result of the more stringent control of utility street works, both in the planning of the works and in the supervision of reinstatements. One of the conclusions of the report was that, although efforts are being made throughout the country to improve our highways, the success of these efforts has been limited; one of the reasons given is the failure of the utilities to acknowledge their role in maintaining quality streetscapes.

The Transport Committee Inquiry into Local Roads and Pathways (2003)[9] also reported that:

"*many of our streets look more like patchwork quilts than roads*" and "*the fact that the road has been disturbed contributes to its decline.*"

Recommendation 20 of the report reads:

"*if the long term damage to roads is proven, local authorities should be able to reclaim these costs from Utility Companies. We expect the Department to bring forward powers through Section 78 of the New Roads and Street Works Act to enable this.*"

2.4 Examples of reinstatements in an urban environment

Examples of the impact of trenching on highways are shown in Figure 1 to Figure 12. Figure 1 shows three closely-spaced longitudinal reinstatements that occupy more than 40 per cent of one running lane and more than 20 per cent of the other. Figure 2 shows the same longitudinal reinstatements elsewhere along the carriageway where either the reinstatement is wider or there are additional reinstatements or patch repairs at ironwork, as well as several transverse reinstatements. The irregular edges of the longitudinal reinstatements are clearly seen, further detracting from the visual appearance of the carriageway. The surface is uneven along the whole length of the carriageway shown in Figure 1 and Figure 2. Figure 3 shows extensive cracking of the carriageway in the zone of influence of one of the longitudinal reinstatements that requires extensive repairs.

Figure 4 shows extensive patching at another longitudinal reinstatement, with a reinstatement through a patch repair, a patch repair through a reinstatement, one patch repair adjacent to another one, and another patch repair through both a reinstatement and a patch repair. A very short length of the longitudinal reinstatement is left between two of the patch repairs. Presumably, there has been insufficient funding to carry out half- or full-width resurfacing or any other repairs to prevent successive failures in the vicinity of the reinstatement.

Figure 5 and Figure 6 show reinstatements in a concrete pavement with an asphalt overlay. There has been significant settlement of the reinstatement, especially adjacent to the ironwork, such that the surface condition and ride quality are poor. Because it coincides with a wheel path, as shown in Figure 6, the unevenness in the surface compromises safety in wet conditions.

Figure 7 shows a pothole adjacent to ironwork where a patch repair has already been made, possibly caused by impact damage resulting from the surface irregularity at the pothole and/or ironwork.

Figure 8 shows reflection cracking coincident with an old reinstatement. The carriageway has been resurfaced without first repairing the deterioration of the lower layers of the reinstatement to prevent differential movement between the pavement and the reinstatement.

Figure 9 shows a longitudinal reinstatement in a carriageway and Figure 10 shows repairs being made to the highway as a result of the premature deterioration caused by the trenching. Repairs to the reinstatement itself can be seen, as well as an area around the reinstatement where damaged sections of the binder and surface courses have been planed out.

Figure 11 shows two longitudinal reinstatements in a footway, together with a number of transverse reinstatements and some ironwork. The patchwork quilt effect is evident.

Figure 12 shows reflection cracking of the surface treatment in a footway coincident with an old reinstatement where there has been differential movement between the reinstatement and the pavement after the treatment.

Figure 1 A heavily trenched carriageway

Figure 2 The carriageway shown in Figure 1 with intersecting longitudinal and transverse reinstatements

Figure 3 Cracking in the zone of influence adjacent to one of the longitudinal reinstatements shown in Figure 1

Figure 4 A reinstated carriageway with multiple repair patches

Figure 5 Surface deterioration at a reinstatement in a carriageway with a concrete pavement and an asphalt overlay

Figure 6 Surface deterioration at a reinstatement near ironwork in a carriageway with a concrete pavement and an asphalt overlay

Figure 7 Potholing in a carriageway adjacent to ironwork

Figure 8 Reflection cracking at an old reinstatement in a carriageway after resurfacing

Figure 9 A carriageway with a longitudinal reinstatement

Figure 10 Repairs being made to the reinstatement and the binder and surface courses in the carriageway shown in Figure 9 (viewed from the opposite end of the street)

Figure 11 A footway with multiple reinstatements

Figure 12 Reflection cracking at an old reinstatement in a footway after surface treatment

3 Research in North America

3.1 Pavement life reduction due to trenching

Perhaps the most significant body of research into the effects of utility works on pavement performance exists in North America where the impact of 'utility cuts', as they are known, has been examined in numerous municipal areas. Much of this is summarised in an AMEC report entitled 'Evaluation of pavement cut impacts' (AMEC, 2002)[11].

In common with the work undertaken in the UK, some of the studies used non-destructive testing techniques to collect deflection data for both reinstated sections of the pavement and control sections without utility cuts. Many of the studies also employed some form of visual assessment of the surface condition of the pavement.

Based on the studies reviewed, along with the collective experience of the authors and a panel of advisory consultants, the AMEC report concluded that utility cuts can have a negative impact on the performance of pavements, but the extent of the impact depends on the quality of the reinstatement and the age and condition of the existing pavement. It was stated that, where a utility cut is not properly restored, there is an adverse impact to the surrounding pavement that can extend up to 6 ft (1.8m) from the edge of the reinstatement (c.f. the zone of influence referred to in Section 2.2). However, it was also stated that where a utility cut is properly restored there would be little adverse impact on the surrounding pavement. (This conflicted with the results from some of the individual field studies, e.g. San Francisco, where it was concluded that the pavement was damaged no matter how good the reinstatement was.)

In nine of the 17 studies reviewed in the AMEC report, the data collected at the various sites were used to estimate the reduction in pavement life as a consequence of trenching. The results are summarised in Table 1, together with information on the method used to calculate the reduction. There was a large variation in the effect of utility cuts, with some pavement service lives being reduced by as little as two per cent and others by as much as 80 per cent. It can be seen that the *average* reduction in pavement life measured in the various studies ranged from 20 to 56 per cent. Taking all nine of the studies shown in Table 1, the overall average reduction in pavement life would appear to be just over 36 per cent.

The AMEC report pointed out that some of the bigger reductions in service life might well be due to freeze-thaw action and higher rainfall in some climates, and that the rates could be lower in warmer, drier climates. A reduction of 15 per cent was considered appropriate for metropolitan areas of Phoenix (Arizona), whereas a reduction of 20 per cent was deemed appropriate for Flagstaff, Prescott and other areas with a wetter, colder climate than Phoenix.

It should be noted that workmanship and construction practices in North America are different to those in the UK and so the results from one country are not directly applicable in another. Also, the level of trenching is generally lower in North America so the impact of closely-spaced trenches is likely to be less evident in North America than in the UK.

3.2 Utility cut, trench cut and pavement degradation fees

As a consequence of the premature deterioration highlighted in studies such as those mentioned above, a number of authorities in North America have developed and implemented a range of charges for excavating in the highway. The purpose of these 'utility cut fees', 'trench cut fees' or 'pavement degradation fees', as they are known, is to recoup some funding towards the additional maintenance costs incurred as a result of the premature deterioration of the highway (i.e. they are similar in principle to those considered in this report).

The fee paid by a utility for opening the highway can vary according to several factors such as the size and depth of the trench, and the age and condition of the existing highway etc.

The City of Vancouver introduced pavement degradation fees in 2005. They were reviewed in 2007 and it was estimated that those shown in Table 2 were required to cover the additional maintenance costs to repair the damage caused by utility openings (The City of Vancouver, 2007)[12]. The additional maintenance allowed for in the calculations included surface sealing, saw cut and seal, and planing out below the surface course when there has been settlement. Settlement was reported to be evident from 5 to 10 years after the cut was made. The cost of repairing potholes and the temporary patching of settled reinstatements was not included.

Table 1 Summary of pavement life reduction estimates (from AMEC[11])

City	Method used to estimate reduction in pavement life	Reduction in pavement life (%)		
		Minimum	Maximum	Average
Burlington, VT	Surface condition indicator	39	73	56
Phoenix, AZ	Surface condition indicator	-	-	23
Ottawa-Carleton, Canada	Surface condition indicator and Deflection	-	-	32
Cincinnati, OH	Deflection	47	60	54
Austin, TX	Surface condition indicator	3	50	26
Austin, TX	Surface condition indicator	2	66	20
Los Angeles, CA	Surface condition indicator and Deflection	17	34	26
San Francisco, CA	Surface condition indicator	20	80	53
San Francisco, CA	Surface condition indicator	29	50	40
			Mean	36

Table 2 Pavement degradation fees required to cover cost of additional maintenance because of damage caused by utility openings in 2007 (from The City of Vancouver)[12]

Pavement age when trenched (years)	Costs derived from linear distribution of calculated values	
	(Canadian $ / m^2)	(£ / m^2)*
Age ≤ 5	110	51.39
5 < Age ≤ 10	90	42.04
10 < Age ≤ 15	70	32.70
15 < Age ≤ 20	50	23.36
20 < Age	35	16.35

* Assuming exchange rate of 1 Canadian $ = £0.467 (the mean in 2007)

4 Stage 2: Development of charge structure

4.1 Form of charge structure

In Stage 2 of this three-stage study, a charge structure was developed to recover some of the additional maintenance costs incurred by highway authorities because of the premature deterioration in the *surface* condition of highways due to utility trenching. The development of this charge structure was reported by McMahon *et al* (2005) [3]. However, this section provides a detailed summary of how the structure was developed because this is relevant to the way the charges were revised in Stage 3 to include the deterioration in the structural and visual condition of highways due to trenching (see Sections 5 to 9).

The first step in Stage 2 was a detailed review of the various charge structures implemented in North America, and an assessment of their relevance to the UK. Some were found to be extremely simple; for example, based solely on the dimensions of the reinstatement, while others utilised a range of factors to calculate the utility cut fee. A list of factors, some or all of which were used in the various charge structures, is given below:

- Dimensions of reinstated area or 'patch' (based on surface area, length or both)
- Age of pavement at time of utility cut
- Pavement condition (usually assessed through a condition indicator ranging between 0 and 100)
- Depth of trench (utility cuts were categorised as 'deep' or 'shallow')
- Orientation of reinstatement (longitudinal or transverse)
- Location of reinstatement (carriageway or footway)
- Category of road ('Major' and 'Minor' routes).

Based on the review of the factors included in the charge structures used in North America, the charge structure which was deemed appropriate for application in the UK is shown in Table 3 and Table 4. It can be seen that the charge varies according to the age and condition of the highway, as well as the strategic importance of the route in question (the road category, i.e. Types 0, 1, 2, 3 or 4).

Table 3 Stage 2 proposed charge structure for carriageways

Condition	UKPMS Overall Condition Indicator	Charge (£ / m^2 of reinstatement)	
		New and Major carriageways*	All other carriageways**
Excellent	0 – 25	*X*	*y*
Good	26 – 50	½ *x*	½ *y*
Fair	51 – 75	¼ *x*	¼ *y*
Poor	76 – 100	⅛ *x*	⅛ *y*
		* New and Major carriageways	** All other carriageways
		Type 0 (all)	Type 3 (> 5 yrs old)
		Type 1 (all)	Type 4 (> 5 yrs old)
		Type 2 (all)	
		Type 3 (≤ 5 yrs old)	
		Type 4 (≤ 5 yrs old)	

Table 4 Stage 2 proposed charge structure for footways

Condition	UKPMS Overall Condition Indicator	Charge (£/m^2 of reinstatement)	
		New and High amenity footways*	All other footways**
Excellent	0 – 25	*a*	*B*
Good	26 – 50	½ *a*	½ *b*
Fair	51 – 75	¼ *a*	¼ *b*
Poor	76 – 100	⅛ *a*	⅛ *b*
		* New and High amenity footways	** All other footways
		Prestige walking routes	Secondary walking routes (> 5 yrs old)
		Primary walking routes	Link footways (> 5 yrs old)
		Secondary walking routes (≤ 5 yrs old)	Local access footways (> 5 yrs old)
		Link footways (≤ 5 yrs old)	
		Local access footways (≤ 5 yrs old)	

Having established the general approach to be taken, the next step was to calculate the range of charges to be levied. To ensure that these were fair and equitable, it was necessary to:

1. Determine the magnitude of the additional maintenance costs incurred over the service life of a highway due to the detrimental impact of trenching.
2. Devise a method of apportioning these costs fairly amongst all the individual reinstatement works which contribute to the premature deterioration of the highway.

The methods used to determine the additional maintenance costs are described in Section 4.2, while the principles used to apportion these costs are discussed in Section 4.3.

4.2 Additional maintenance costs

4.2.1 Whole-life costs approach

After considering various methods of cost calculation, it was decided that a whole-life cost approach was the most appropriate method to calculate the additional maintenance costs incurred by highway authorities. The principle of whole-life cost analysis is to calculate all the costs associated with a project (in this case highway maintenance) throughout its life to a common base so that comparisons can be made between options (Bull, 1993)[13]. Thus, in practice, the whole-life cost (WLC) represents the sum of money to be set aside today to meet all the eventual costs of a project, both present and future, after allowing for the accumulation of interest on that part of it intended for future commitments. The WLC is estimated by discounting all the anticipated maintenance costs, calculated at present day prices, by a factor which takes account of time from the start of the maintenance to when the expenditure would be incurred (see Appendix C.1). It is defined as follows:

$$\text{WLC} = \sum_{t=1}^{N} \frac{c_t}{(1 + r / 100)^t} \qquad (1)$$

where

N = the analysis period (years)

r = the discount rate

t = the year the cost is incurred

c_t = the cost (maintenance cost)

4.2.2 Maintenance treatments

Because the focus of Stage 2 was deterioration of the *surface* condition only, the maintenance treatments considered in the whole-life cost analyses were restricted to routine patching works, thin surfacing and surface dressings, and resurfacing of various depths up to a maximum of 100mm.

To determine the magnitude of the additional maintenance costs being met by authorities as a result of premature highway deterioration, two different maintenance scenarios were considered: these were called the 'Baseline' and the 'Required' maintenance scenarios.

The 'Baseline' scenario was defined as the level of maintenance that would be necessary for highways on which there were no trenching works. It represents the costs that would be incurred by highway authorities irrespective of any trenching activity, simply to ensure acceptable levels of safety and performance.

The 'Required' maintenance scenario was defined as the level of maintenance that is necessary for highways that are subject to trenching works and are therefore deteriorating more rapidly. It represents the level of maintenance which is currently required on highways subject to trenching in order to maintain the network in an acceptable and safe condition. Because of the detrimental effects of trenching on the performance of highways, the 'Required' level of maintenance is greater than the 'Baseline' level and is therefore more costly. The additional maintenance requirements are incurred as a result of:

- The shorter service lives of maintenance treatments such as inlays, thin surfacings and surface treatments.
- The increased levels of 'patching' works to repair cracks and potholes which develop as a result of the presence of reinstatements.

The difference in the costs of the 'Baseline' and 'Required' scenarios represent the *additional* maintenance costs being borne by authorities as a result of the premature deterioration caused by trenching.

Clearly, the performance requirements of a highway (and thus the level of maintenance carried out) vary depending on the strategic importance of the highway in question and the level of trafficking it receives. Therefore, separate 'Baseline' and 'Required' maintenance scenarios were determined for the Major and Minor categories of carriageway and footway defined in the charge structure. In Stage 2, Major carriageways were defined as road categories Types 0, 1 and 2, and Minor carriageways as road categories Types 3 and 4. The various maintenance scenarios were developed from consultation of the technical literature, along with information provided by highway engineers.

To undertake the whole-life cost analyses it was necessary to determine the unit costs for the various maintenance treatments and their anticipated service lives. To obtain this information, a brief review was undertaken of published information on typical maintenance activities in the UK, and this was supplemented by information obtained from the highway engineering departments of twelve authorities and TRL databases on carriageway and footway maintenance costs.

When discussing the likely maintenance scenarios with highway engineers, there was a clear perception amongst them that the presence of reinstatements in the highway results in the need for extra patching works, but it was not easy to quantify exactly the extent of these extra works. Because of the paucity of data on the amount of extra patching work undertaken annually, and the relatively small effect of patching works on the overall costs, it was decided that, for clarity, patching costs would not be included in the calculation of the additional maintenance costs. Therefore, it must be emphasised that the additional maintenance costs were purely the costs due to shortening the service lives of the maintenance treatments.

Given the range of maintenance treatments considered (and their potential service lives), an analysis period of 40 years was selected for all the whole-life cost analyses. However, the length of this period had little effect on the additional maintenance costs per year that were calculated because the residual life of maintenance treatments was taken into account at the end of the 40-year period.

4.2.3 Maintenance scenarios

For Major carriageways (i.e. Type 0, 1, and 2 roads), the 'Baseline' maintenance scenario used in the initial analyses was resurfacing every 20 years. A number of 'Required' maintenance scenarios were considered, dependent on the extent to which trenching was assumed to shorten the service life of the maintenance treatment under consideration. A few examples of possible scenarios are shown in Figure 13.

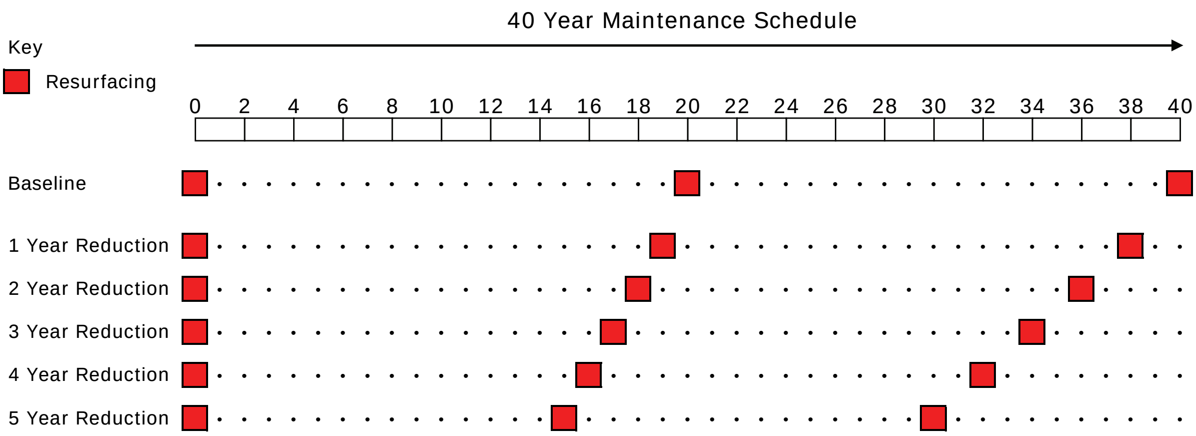

Figure 13 'Baseline' and 'Required' maintenance scenarios for Major carriageways

A similar approach was adopted for Minor carriageways (i.e. Type 3 and 4 roads) except that, for these carriageways, the service lives of the various maintenance treatments were assumed to be double those on Major carriageways.

To determine the additional maintenance costs for footways, it was assumed that the 'Baseline' scenario comprised resurfacing works every 20 years. These scenarios relate to flexible construction and were therefore likely to be more indicative of the Non-high amenity (Minor) footway classification, as defined in the charge structure shown above. There was relatively little data available on the frequency and costs of maintenance works on High amenity (Major) footways such as those comprising setts and block paviours. Thus, the additional maintenance costs calculated for footways were relevant to Minor footways, but the available data suggested that Minor footways make up the vast majority of the network.

4.2.4 Additional maintenance costs per km

Using whole-life cost analyses over a 40-year period, the costs (per km of highway) of the various 'Baseline' and 'Required' maintenance scenarios described above were calculated and the mid-range additional maintenance costs were chosen. These additional costs were then distributed uniformly over the 40-year analysis period in order to determine the amount of money that authorities would have to recoup annually, through the charge structure, to recover the costs.

Table 5 shows the additional maintenance cost per km per year when trenching is assumed to reduce the life of inlays on Major carriageways by 10 per cent (i.e. they last 18 years rather than 20 years), on Minor carriageways by 5 per cent (i.e. they last 38 years rather than 40 years), and on footways by 5 per cent (i.e. they last 19 years rather than 20 years). The assumed treatment costs and widths treated are also shown in the table. Appendix C.2 explains how the additional maintenance costs per km per year were calculated.

Table 5 Additional maintenance costs on trenched carriageways and footways (for 2005/2006)

Network	Treatment cost (£/m^2)	Width treated (m)	Untrenched service life (years)	Trenched service life (years)	Additional maintenance costs/km/year (£)
Major carriageways	17.00	7.3	20	18	716
Minor carriageways	17.00	7.3	40	38	169
Footways	10.80	1.8	20	19	54

4.2.5 Total additional maintenance costs

The total additional maintenance costs per year as a result of trenching were calculated by multiplying the additional maintenance costs per km per year in Table 5 by the length of the urban Major and Minor carriageway and Footway networks. The majority of street works are undertaken in urban areas, because that is where the bulk of underground utility services are situated. Therefore, for the purposes of the analyses, it was appropriate to assume that only urban highways deteriorate prematurely as a result of trenching activity. Clearly, some urban highways are not trenched but some rural carriageways are.

Appendix A gives details of the highway network in England. From Table A.1 it can be seen that in 2005 there was approximately 122,246 km of urban road in England, forming about 41 per cent of the overall network in terms of route-kilometres. Within the urban highway network, some 14,324 km were Major carriageways (as defined in the charge structure) and 107,922 km were Minor carriageways. In addition, information from the National Road Maintenance Condition Survey: 2004 (Department for Transport, 2005)[14] showed that there were some 215,000 km of urban footways in England in 2005.

The total annual additional maintenance costs in 2005/2006 calculated from the data in Table 5 and Table A.1 are shown in Table 6. The total estimated carriageway costs of nearly £28.5 million represented approximately 5 per cent of the money spent by local authorities in England on carriageway resurfacing works in the year 2003/2004.

Table 6 Total additional maintenance costs for the urban highway network in England (for 2005/2006)

Network	Additional maintenance costs/km/year (£)	Treated length (km)	Total additional maintenance costs (£m)
Major carriageways	716	14,324	10.25
Minor carriageways	169	107,922	18.23
Footways*	54	215,000	11.53

*(assuming Non-high amenity footway costs for all footways)

4.3 Apportioning the additional maintenance costs

4.3.1 The extent and location of reinstatements

Having determined the magnitude of the additional maintenance costs associated with trenching, and the form of the charge structure by which they were to be recovered, the next stage was to apportion these costs, in a fair and reasonable manner, over all the individual reinstatement works that contribute to the premature deterioration of the highway network. For this, it was necessary to estimate the amount of reinstatement work undertaken annually. This was done using data compiled by the consulting engineers Halcrow (2003)[15] during a project to assess the extent of street works in England and to monitor the effectiveness of section 74 of the New Roads and Street Works Act 1991[16] in reducing disruption from utilities' street works. Halcrow collected data from a representative sample of 25 highway authorities, out of a total of 150 authorities in England. Five authorities were 'inner' London boroughs, five were 'outer' London boroughs, five were county councils, five were metropolitan authorities, and five were unitary authorities.

From the sample data, Halcrow estimated the extent of trenching works in all authorities in England in the year 2002/03 (i.e. 1 April 2002 – 31 March 2003) by road category. These estimates are shown in Table 7.

Table 7 Area of excavation (in all Local Authorities in England) from 1 April 2002 – 31 March 2003 (Source: Halcrow[15])

Road Category	Area of excavation (m^2)	
	Carriageway	Footway
Type 0	0	0
Type 1	157,487	187,768
Type 2	339,445	305,092
Type 3	307,665	280,315
Type 4	1,394,451	1,698,352
TOTAL	2,199,048	2,471,527

It can be seen that the extent of utility trenching in England was estimated to be about 4.67 million square metres in 2002/2003, of which:

- 47 per cent occurred in carriageways, of which
    - 21 per cent was in Major carriageways (i.e. Types 0, 1 and 2)
    - 79 per cent was in Minor carriageways (i.e. Types 3 and 4)
- 53 per cent occurred in footways.

The total area of the reinstatements in Major carriageways in 2002/2003 was 496,932m^2, which was equivalent to approximately 14.7m^2 per lane per year (or 0.40 per cent of the surface area of Major carriageways per year), taking into account dual carriageways. The total area of the reinstatements in Minor carriageways was 1,702,116m^2, which was equivalent to approximately 7.9m^2 per lane per year (or 0.22 per cent of the surface area of Minor carriageways per year). The data show that the intensity of trenching on Major carriageways was almost twice that on Minor carriageways.

The total area of the reinstatements in footways was 2,471,527m^2, which was equivalent to about 11.5m^2 per km per year, i.e. somewhere in between the values for Major and Minor carriageways. However, because footways are narrower than carriageways (in the analyses they were taken to be 1.8m wide compared to the 3.65m width of a carriageway lane) this level of trenching activity represented about 0.6 per cent of the surface area of urban footways per year. On this basis, the intensity of trenching on footways was even higher than that on Major carriageways.

4.3.2 Apportionment process

Because the total additional maintenance costs in Table 6 represented the aggregate effect of all the reinstatements placed in highways, 'flat rate' charges per square metre of reinstatement could have been obtained by dividing the costs by the reinstated area as shown in Table 8. However, it was considered to be more equitable if the rates varied according to the condition and age of the highway being trenched.

Four condition categories were proposed - 'Excellent', 'Good', 'Fair', and 'Poor' - based on the value of the UKPMS Overall Condition Indicator for the stretch of highway on which the trench is situated. The categories are defined in Table 9. UKPMS data on the surface condition of the highway network were obtained from a number of local authorities for 2004/05, which is summarised in Table 10.

Table 8 Flat rate charges (based on costs in 2005/2006)

Network	Total additional maintenance costs (£m)	Area of network reinstated (m^2)	'Flat' rate charge (£/m^2)
Major carriageways	10.25	496,932	20.63
Minor carriageways	18.23	1,702,116	10.71
Footways*	11.53	2,471,527	4.67

*(assuming Non-high amenity footway costs for all footways)

Table 9 Condition categories

Condition	UKPMS Overall Condition Indicator
Excellent	0 – 25
Good	26 – 50
Fair	51 – 75
Poor	76 – 100

Table 10 Proportions of highway in each condition classification

Road Type	Condition category		Percentage of network in each condition category	
			Carriageway	Footway
Major (Types 0, 1 and 2)	Excellent	(0-25)	65	50
	Good	(26-50)	15	30
	Fair	(51-75)	10	10
	Poor	(76-100)	10	10
Minor (Types 3 and 4)	Excellent	(0-25)	40	50
	Good	(26-50)	30	30
	Fair	(51-75)	15	10
	Poor	(76-100)	15	10

Assuming that the data in Table 10 were representative of the highway network in England as a whole, the additional maintenance costs were apportioned among individual reinstatements according to the type of carriageway or footway on which they were located (from the Halcrow data) and the likely condition of the surface (from the UKPMS data). These variable charge rates were calculated to decrease by a factor of two for each decrease in condition. The rates are shown for carriageways and footways in Table 11 and Table 12, respectively.

It should be noted that the charge structure shown in Table 11 and Table 12 required trenches on 'new' highways (i.e. less than 5 years old) to be charged at the same rate as trenches on Major highways. In effect, this meant that trenches on newly resurfaced Minor highways were to be charged at the same rate as Major highways. However, because the authorities contacted did not hold information on the ages of highways in a readily available format, it was not possible to distinguish between 'new' and 'old' highways when deriving the charges.

As mentioned previously, all the cost calculations relating to Footways were based on Minor (i.e. Non-high amenity) footways of flexible construction. It was assumed that the maintenance costs for High amenity footways were double those for Non-high amenity footways.

The charge rates given in the tables were based on data applicable to utility trenching work undertaken in England, but it was thought that they would also be applicable to trenching in Wales.

Table 11 Stage 2 charge structure for carriageways (*surface* condition only, based on costs in 2005/2006)

Condition	UKPMS Overall Condition Indicator	Charge (£/m² of reinstatement)	
		New and Major carriageways*	All other carriageways**
Excellent	0 – 25	27.06	17.66
Good	26 – 50	13.53	8.83
Fair	51 – 75	6.76	4.42
Poor	76 – 100	3.38	2.21
		* New and Major carriageways	** All other carriageways
		Type 0 (all)	Type 3 (> 5 yrs old)
		Type 1 (all)	Type 4 (> 5 yrs old)
		Type 2 (all)	
		Type 3 (≤ 5 yrs old)	
		Type 4 (≤ 5 yrs old)	

Table 12 Stage 2 charge structure for footways (*surface* condition only, based on costs in 2005/2006)

Condition	UKPMS Overall Condition Indicator	Charge (£/m² of reinstatement)	
		New and High amenity footways*	All other footways**
Excellent	0 – 25	13.58	6.79
Good	26 – 50	6.79	3.39
Fair	51 – 75	3.39	1.70
Poor	76 – 100	1.70	0.85
		* New and High amenity footways	** All other footways
		Prestige walking routes	Secondary walking routes (> 5 yrs old)
		Primary walking routes	Link footways (> 5 yrs old)
		Secondary walking routes (≤ 5 yrs old)	Local access footways (> 5 yrs old)
		Link footways (≤ 5 yrs old)	
		Local access footways (≤ 5 yrs old)	

5 Stage 3: Overview of work carried out

As indicated above, the charges proposed in Stage 2 were to recover some of the additional maintenance costs due to the premature deterioration in the *surface* condition only of highways as a result of utility trenching. However, during the course of Stages 1 and 2, it was clear that trenching also affects the structural condition and appearance of highways, and that the charge structure should also recover the additional maintenance costs incurred because of these forms of premature deterioration. Therefore, Stage 3 was undertaken to extend the charge structure to recover these other costs and also to enable highway authorities to review the approach used in Stage 2. The work undertaken in Stage 3 can be summarised as follows:

- Consultation with highway authorities
- Review of the charge structures developed in Stage 2
- Calculation of the service life reduction of trenched highways from deflection data obtained in Stage 1
- Calculation of the additional maintenance costs due to the effects of utility trenching on the surface, structural and visual condition of highways
- Calculation of charges to recover the additional maintenance costs due to the effects of utility trenching on the surface, structural and visual condition of highways.

6 Stage 3: Consultation with highway authorities

6.1 Review of charge structures

A Workshop attended by highway engineers from over 30 highway authorities was held to review the charge structure proposed in Stage 2 and provide information on the maintenance treatments used to remedy the structural deterioration and visual disbenefits caused by trenching. The key information that was sought concerned:

- How much of the highway network is affected by trenching
  i.e. are some streets subjected to significant trenching whereas in others there are isolated trenches.
- The effect of trenching on treatment frequencies.
- The extent of maintenance treatments when a highway is affected by trenching
  e.g. small patches, large patches, resurfacing or surface treatment of a street or significant part thereof.
- The types of treatment when a highway is affected by trenching
  e.g. resurfacing rather than surface treatment, reconstruction rather than resurfacing.

The Workshop concluded that the approach and the basic structure of the economic model developed by TRL was appropriate, but some simplification was recommended. Furthermore, it was concluded that the cost of repairing all damage caused by trenching was higher than 5 per cent of the budget spent on carriageway resurfacing works (i.e. the amount that would be raised by the charges proposed in Stage 2).

Authorities were concerned about varying the charge with the age of the pavement because some authorities would not be able to distinguish between old and new surfaces, i.e. those laid in the last 5 years. Also, there would need to be clarification on whether a new surface that would attract a higher charge would be one that had been surface treated, inlaid or overlaid.

Varying the charges with condition was not recommended by most authorities. Comprehensive condition data are generally available for Type 0, 1, 2 and 3 roads, but data for Type 4 roads are less robust and, as shown in Table 6, these represent a large proportion of the network. It was thought that undertakers may challenge the accuracy of condition data and request reinspection with a view to reducing the condition score and, hence, the charge. Also, lower charges would be raised on highways in poor condition, which may be in that condition because of trenching, and this was thought by some to be inappropriate. However, the Steering Group considered that it was still appropriate to vary the charges according to the condition if age was ignored.

Workshop attendees reported that most Type 4 roads carry little traffic, whereas many urban Type 3 roads are now carrying traffic levels close to those on Type 2 roads. Therefore, it was recommended that Type 3 roads be grouped with Type 0, 1 and 2 roads as Major carriageways to leave only Type 4 roads as Minor carriageways.

The assumptions made in Stage 2 regarding the reduction in the service lives of maintenance treatments on carriageways due to trenching were thought by authorities to be underestimates, even though they were equivalent to, on average, a 10 per cent reduction in the service life of the whole of the major urban carriageway network (Type 0, 1, and 2 roads in Stage 2) and a 5 per cent reduction in the service life of the minor urban carriageway network (equivalent to Type 3 and 4 roads in Stage 2. Deterioration rates were said to be substantially higher for some parts of the network, with service lives as short as 5 years where levels of trenching are substantially higher than the average referred to in Stage 2. It was also reported that a lot of patching is due to utility trenching, but this is rarely recorded as such because the cause of the damage is often not known until work commences on site. Patching costs are often included in the average unit cost of a surface treatment or resurfacing rather than being itemised separately.

Engineers agreed that the service lives of Type 4 roads were longer than those of Type 0 to 3 roads, but not necessarily double as assumed in Stage 2.

6.2 Maintenance treatments

Highway authorities employ carriageway and footway maintenance treatments for three main reasons:

- Routine works to maintain safe operations
  - Patching
  - Filling potholes
  - Thin surfacing
  - Surface treatments
- Protective works to prevent the surface from becoming too damaged
  - Thin surfacing
  - Surface treatments
- Strengthening works when the pavement is no longer strong enough to withstand the design traffic loading
  - Overlay
  - Binder and surface course replacement
  - Full depth reconstruction

Routine works are often carried out in response to defects reported by highway inspectors or members of the public. Highway authorities were asked for details of how much is spent on patching and filling potholes at reinstatements, but it was not possible to use past records to attribute the reason for such treatments to deterioration caused by utility trenching. However, it was indicated that much patching is required at reinstatements.

Protective works are undertaken when the Detailed Visual Inspection (DVI) or Coarse Visual Inspection (CVI) scores for a length of road exceed a certain value, although authorities may also take into account the number of routine works and visual assessments.

Trenching can leave surfaces uneven and result in the deterioration of the surface condition. Surface dressing may help to seal the surface and prevent water ingress through cracks at reinstatements, but it cannot make all uneven surfaces even. DVI scores may not be significantly affected when a carriageway is patched or is surface dressed. Therefore, highway authorities often need to use an inlay to restore the surface profile of trenched areas and make a measurable difference to the surface condition whereas surface dressing may be satisfactory in untrenched areas. It should be noted that an inlay of thickness 40mm or less does not contribute structurally to Major carriageways and may offer minimal contribution to Minor carriageways.

Whereas full depth reconstruction to strengthen a carriageway is rarely undertaken by highway authorities, replacement of the binder and surface courses and some of the lower layers is required on some carriageways. Overlaying is not an option when kerb heights must be maintained, and this is normally the case as most trenching is in urban areas with kerbs.

Generally, footways are not subjected to the effects of traffic, although vehicle overrun is common on some footways, and footways are frequently crossed at entrances to properties and businesses. Some structural damage does result, therefore, which requires treatment every 40 years or so (20 years was assumed in Stage 2). Relatively little maintenance is carried out on footway surfacings to restore the visual condition, partly because of limited funding. Some authorities are replacing flags with bituminous surface courses to reduce the number of trip hazards. It is possible that trip hazards on flagged footways are more numerous because of trenching and reinstatement settlement, the trenching thereby being partly if not wholly responsible for the increased maintenance, but it was not possible to assign a fair cost to such maintenance. It was concluded, however, that footways suffer a slight decrease in their service life due to weakening of the structure and that surface treatments to restore the visual condition of some footways are appropriate.

Information on the unit costs of maintenance treatments was requested from Workshop attendees. Costs vary across the country and unit costs were sometimes difficult to determine because they are often dependent on the area treated and include the cost of a nominal treatment, such as a 40mm inlay, plus the cost of patching to repair local defects. However, those assumed in order to calculate the additional maintenance costs in Stage 3 are given in Table 13.

Table 13 Unit costs of carriageway and footway maintenance treatments (for 2007/2008)

Network	Treatment	Unit cost including traffic management (£/m^2)
Major carriageways	40mm surface course (inlay)	15
	Surface treatment	5
	60mm binder course (inlay)	18
	Replacement of lower layers at trench	5
Minor carriageways	40mm surface course (inlay)	12
	Surface treatment	5
	60mm binder course (inlay)	15
	Replacement of lower layers at trench	5
Footways	60mm surface and binder course (inlay)	16
	Surface treatment	4

7 Stage 3: Services lives of trenched areas tested in Stage 1

In Stage 1 of this study, Falling Weight Deflectometer (FWD) measurements were made at 168 individual reinstatement sites (Steele *et al*, 2003)[8]. Steele *et al* noted that for the 168 sites considered the central FWD deflections measured in the zone close to the reinstatements were on average approximately 10 per cent higher than those measured in the control sections well away from the reinstatements, as is illustrated in Figure 14.

It is generally assumed that the deflection of a pavement under a rolling wheel or FWD load represents a measure of the structural strength of the pavement and the higher the value the worse the condition. In fact, in the UK, there is a well established method of interpreting the deflection measurements under a rolling wheel load in order to estimate the structural residual life of a road pavement in terms of standard axles and the required strengthening to achieve a desired future life. This is explained more fully in Annex 4B of HD 29/08, Part 2 of Section 3, Volume 7, of the Design Manual for Roads and Bridges (The Highways Agency, 2008)[17]. However this method is designed for use with deflections measured with the UK Deflectograph and not with the FWD. Nevertheless in order to obtain some idea of the likely reduction in structural life caused by the presence of reinstatements at the trial sites, an approximate method has been derived of using the FWD measurements within the Highways Agency's Deflectograph interpretation method.

This method comprised a number of stages. Firstly, the central FWD measurements were converted to equivalent Deflectograph values using a relationship derived from over 250 separate measurements on a wide range of sites and in a wide range of conditions (Ferne, 1994)[18]. These Deflectograph values were then processed through the equivalent of the Highways Agency's deflection processing procedure to provide estimates of structural residual life. These residual lives were added to estimates of cumulative past traffic at the time of the measurement to provide an estimate of the likely total life of the pavement up to the point at which a detailed investigation of the pavement is needed and strengthening may need to be considered. In order to assess the effect of the presence of a reinstatement on the likely life of a section of pavement, the total likely life estimated from the deflections measured in the zone close to the reinstatement was divided by the life estimated for the control section well away from the reinstatement. This ratio was also expressed as a percentage reduction in the life of the pavement. Although the Highways Agency's method of estimating residual life is only intended for use with Deflectograph measurements, since the results are expressed in term of ratios of life estimates, rather than absolute values, any errors introduced by converting FWD values to Deflectograph values are minimised.

In order to carry out the life calculation, it was necessary to know the cumulative standard axles that had been carried by the road pavement up until the time of the deflection measurements. Unfortunately this level of detailed traffic information is not known for all the sites and, therefore, a range of assumptions was made for each of the sites. For Type 2 roads, it was assumed that the total intended 'design' traffic was 2.5, 5 and 10 msa (Specification for the Reinstatement of Openings in Highways, 2002)[7]. For Type 3 roads these design traffic levels were assumed to be 0.5, 1.0 and 2.5 msa, and for Type 4 roads, 0.1, 0.2 and 0.5 msa. It was then assumed for each of the three traffic design loads that, at the time of the deflection measurements, they had carried to date either 25, 50 or 75 per cent of the total design load. Thus nine different traffic scenarios were generated for each site and nine corresponding estimates of total life calculated from the deflections measured at each site leading to nine ratios of zone to control section life estimates.

Although there were 168 sites in the Stage 1 study reported by Steele *et al*, many of these sites were located on footways and it was not felt appropriate to apply the above described life calculations to such sites. This left 38 sites, 25 on Type 4 roads, 9 on Type 3 roads and 4 on Type 2 roads. With nine traffic scenarios applied to each site, a total of 342 results were generated.

These 342 results have been presented in the form of a histogram and a cumulative distribution graph in Figure 15. The latter illustrates that the median of these results is 0.83, i.e. the median reduction in the service life in the zones of influence compared to the control sections is estimated to be 17 per cent. In view of the wide range of the results in this analysis the median has been chosen rather than a mean because it is considered a useful measure of central tendency that is less affected by extreme values than the mean. It divides the histogram into two equal areas. In other words, at half of the sites it is estimated that the reinstatements caused less than a 17 per cent reduction in the total life, and at half of the sites the reduction is estimated to be greater than 17 per cent. The service life of a particular pavement is dependent on when it is trenched. Because of this, the 17 per cent reduction, and different percentage reductions that have been assumed in the analyses, are referred to as the ‘reference’ service life reduction of the binder course (see Section 8.3.2).

The 17 per cent ‘reference’ service life reduction is reasonably robust in terms of the calculation methodology. For example even the most extreme traffic scenarios did not alter the result by more than 5 percentage points. It should be noted that 38 sites is not a very large sample in terms of the size of the whole network and the number of reinstatements carried out each year. In addition it should be noted that they are not an entirely random sample, as was extensively discussed in Sections 6.6.4 and 7.2 of Steele *et al*[8].

Section 6.6.4 of Steele *et al* notes that FWD measurements were only made on sites of flexible construction that were undisturbed i.e. not resurfaced. “*Consequently, the sites for which the FWD data were obtained were those that were in ‘very good’ or ‘good’ condition throughout the study (otherwise they would probably have been resurfaced). Thus it should be appreciated that the FWD data comes from a ‘self-selected’ sample which represents the better examples of reinstatement practice.*”

Additionally the first paragraph of Section 7.2 states that “*it is important to remember that trained TRL supervisors monitored their excavation and reinstatement. Thus it is likely that these sites are representative of some of the better reinstatements undertaken in the highway network. Because of the limited number of sites it is difficult to extrapolate the results of the work to the highways network as a whole, other than to say that these ‘observed’ sites might be expected to perform better than typical ‘unobserved’ sites. However, if it is assumed that this particular group of reinstatements represent relatively higher standards of workmanship, the data could be used as a ‘benchmark’ against which the results of any future work could be compared.*”

Finally in Section 8, the Conclusions, Steele *et al* states that “*Sites for which the FWD data were obtained represent the better examples of reinstatement within the population.*” Thus caution should be taken if applying these results to derive conclusions that can be applied to the road network as a whole. The FWD measurements were made six years after the reinstatements had been completed, which represents a short time compared to their total life. The weakening of the pavements may have been more evident if the measurements had been made when the reinstatements were older. Also, the service life reductions measured are applicable to single reinstatements. When reinstatements are in close proximity such that their zones of influence overlap, higher reductions are likely.

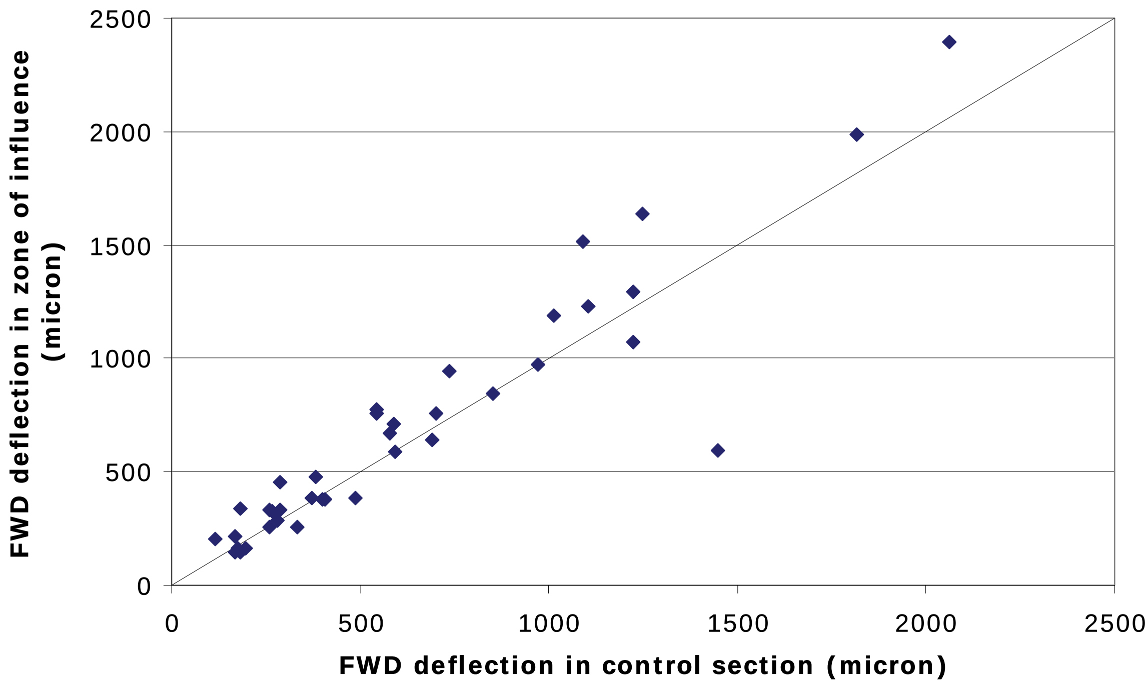

Figure 14 Comparison of central FWD deflections for zone and control areas of 38 carriageway sites

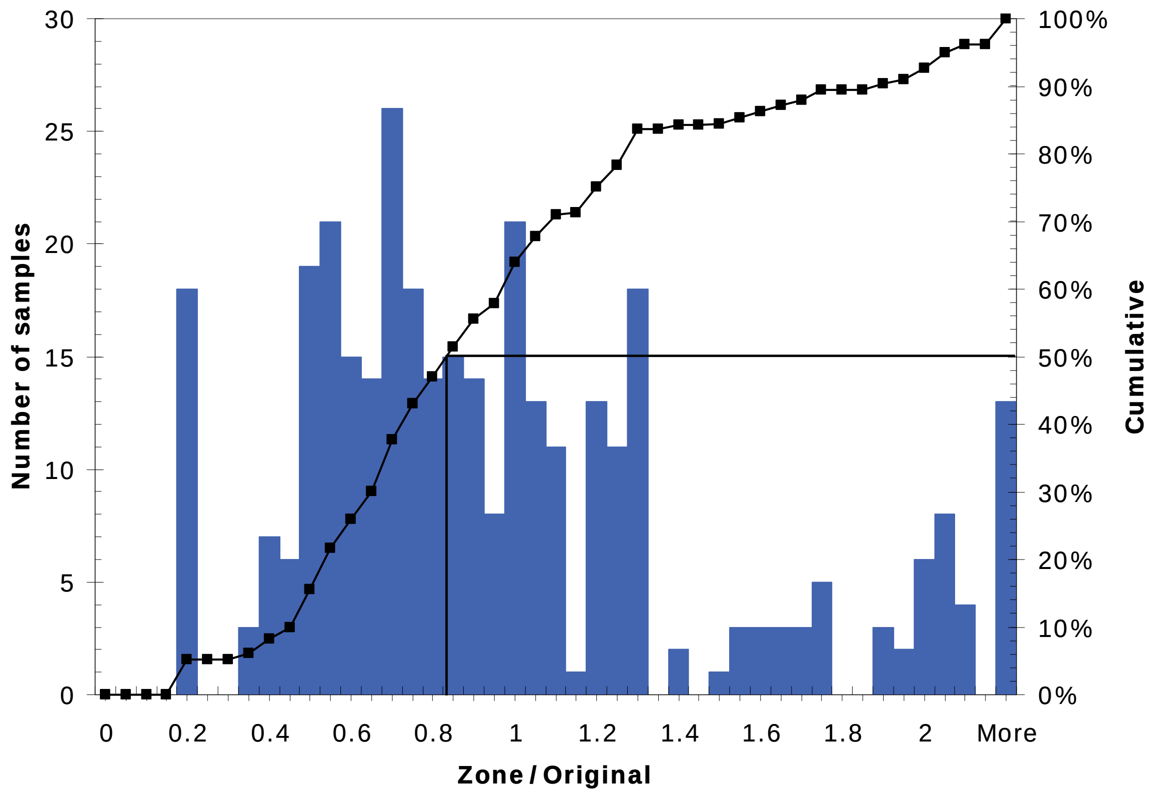

Figure 15 Histogram of zone to control area life ratios for all 38 carriageway sites and 9 traffic scenarios

8 Stage 3: Additional maintenance cost calculations

8.1 Sensitivity analyses

In Stage 2, in order to calculate the additional maintenance costs due to trenching, it was necessary to make assumptions about the extent of the highway network affected by trenching and the service life reduction. In Stage 3, it has been possible to base the additional maintenance costs on the area of reinstatement each year and the service life reduction described in Section 7. It has still been necessary to make some assumptions, but the effect of these has been assessed by conducting sensitivity analyses.

The factors included in the sensitivity analyses were as follows:

- 'Baseline' scenario maintenance treatments and treatment frequencies
- Effect of trenching on treatment frequencies
- Area around each reinstatement treated
- Area of the network treated

8.2 Extent of network affected by trenching

Using the data in Table 7, and including Type 3 roads in the Major carriageway category, the areas of Major and Minor carriageways and Footways that it was assumed are trenched each year are shown in Table 14.

Table 14 Assumed areas of network trenched each year

Network	Area of excavation per year (m^2)	Urban network length (m)	Urban network trenched per year (%)
Major carriageways	804,597	24,214	0.412
Minor carriageways	1,394,451	98,032	0.195
Footways	2,471,527	215,000	0.639

As explained above, the area of a highway that deteriorates prematurely due to trenching is not just the area of the trench itself but the zone of influence that extends a distance equal to the depth of the trench from its edges. Data on the dimensions of the trenches whose areas contributed to the totals in Table 14 are not available, so the area of their zones of influence is not known. However, the ratio of the area of the zone of influence of a trench relative to the surface area of the excavation has been calculated for trenches of different depth, length and width assuming the recommended minimum depths for apparatus in carriageways and footways that are listed in the NJUG guidelines on the positioning of underground utilities' apparatus (NJUG, 2007)[19], as shown in Appendix B. The ratio is greater than 3.0 for most of the trenches included in Table B 1. Furthermore, the ratio is 3.0 or greater for trenches of width equal to their depth, and of length not exceeding ten thousand times their width. On this basis, and for the purpose of this report, it has been assumed, conservatively, that the area of the zone of influence of all trenches is equal to three times their excavated area.

8.3 Trenching, service life reduction and treatment scenarios

Full reconstruction of an untrenched carriageway is rare and, generally, the binder and surface courses are replaced after 20 to 30 years on Major carriageways and after 30 to 40 years on Minor carriageways. In order to restore the surface condition, either surface treatment, resurfacing or overlaying is carried out between binder course replacements.

As shown in Section 7, the effect of trenching on carriageways is estimated to reduce the service life of the pavement within the zone of influence around the trench by 17 per cent. Therefore, the binder and surface course replacements must be brought forward to restore the condition of the carriageway. Furthermore, other bound and unbound layers below the binder course often need to be repaired or replaced to restore the structural condition of a trenched carriageway to that of an untrenched carriageway.

In order to calculate the additional maintenance costs due to trenching it has been assumed that a new carriageway, which is constructed in year 0, is trenched from year 1. When carrying out the analyses, different assumptions have been made concerning:

- Where and when the carriageway is trenched (Trenching scenarios).
- How trenching reduces the service life of the binder and surface courses and surface treatments (Service life reduction scenarios).
- How many zones of influences are treated when the surface course is replaced or surface treatments are made between binder course replacements (Treatment scenarios).

These assumptions (scenarios), which are summarised below, cover all the possible scenarios that could apply in practice. Full details of the assumptions made when calculating the additional maintenance costs are given in Appendix C.

8.3.1 'Different' and 'Same' trenching scenarios

The trenching scenarios that have been assumed in the analyses are referred to as the 'Different' and 'Same' scenarios. They are defined as follows:

- 'Different' – each trench formed over the analysis period of 40 years (see Section 4.2.4) is formed in a different area of carriageway. After the binder course has been replaced in a zone of influence, its service life becomes the same as that of an untrenched area.
- 'Same' – each trench formed over a specific number of years (either 13 or 19 years) is formed in a different area of carriageway. These areas are then trenched again in future years so the service life of each zone of influence is reduced even after the binder course has been replaced.

For example, consider an area of carriageway that is constructed in year 0 and is trenched in year 1, when trenching reduces the service life of the binder course by 15 per cent from 20 to 17 years. For the 'Different' scenario, it is assumed that the area is not trenched again, so the binder course laid in year 17 has a service life of 20 years, and subsequent binder courses have the same service life. For the 'Same' scenario, it is assumed that each area trenched over a period of 13 or 19 years is trenched again every 13 or 19 years. Therefore, each time the binder course is replaced (starting in year 17), the 'new' binder course has a service life of 17 years.

8.3.2 'Full reduction' and 'Partial reduction' service life reduction scenarios

The analyses described in Section 7 have estimated a median service life reduction of 17 per cent for carriageways when it was assumed that those tested were trenched when the age of their binder course corresponded to 25, 50 or 75 per cent of their untrenched service life. Therefore, it has been assumed that the service life of the binder course in an area of carriageway is reduced from, say, 20 to 16.6 years whether it is trenched in year 5, 10 or 15. Trafficking weakens a pavement over time, so the analyses indicate that the reduction in the service life of a binder course due to trenching is comparable for a 'new' carriageway before much weakening due to trafficking and for an 'old' carriageway that has been weakened by trafficking.

In order to calculate the additional maintenance costs due to trenching, it has been necessary to estimate the reduction in the service life of a binder course due to trenching whenever a carriageway is trenched, i.e. at all times up to the untrenched service life. As explained below, the service life reduction of areas first trenched when the age of the binder course is near to its untrenched service life cannot correspond to what was described as the 'reference' service life reduction referred to in Section 7. The service life reduction scenarios that have been assumed in the analyses that concern this are referred to as the 'Full reduction' and 'Partial reduction' scenarios. They are defined as follows:

- 'Full reduction' – trenching reduces the service life of the binder course whenever a carriageway is trenched
- 'Partial reduction' – trenching reduces the service life of the binder course only when its age when trenched does not exceed the untrenched service life multiplied by (1 – 'reference' service life reduction in per cent/100)

Table 15 shows the service lives of the binder course in trenched areas of Major carriageways with an untrenched service life of 20 years that were assumed in the analyses for the 'Full reduction' and 'Partial reduction' scenarios. The 'reference' service life reductions due to trenching are assumed to be 15 and 20 per cent.

A new carriageway should not be trenched in its first year (year 0) so there is no service life reduction for that year.

When the 'reference' service life reduction due to trenching is 15 per cent, it has been assumed that the service life of the binder course in areas trenched in years 1 to 16 is 17 years. Therefore, the service life of the binder course is not assumed to be greater in areas trenched in years 1, 2, 3 etc. than that in areas trenched in years 14, 15 and 16. Clearly, the service life of the binder course in areas trenched in years 18 and 19 must be greater than 17 years. Column 2 of Table 15 shows that it has been assumed that the service life of the binder course is 18, 19 and 20 years in areas trenched in years 17, 18 and 19 for the 'Full reduction' scenario. Column 3 of Table 15 shows that for the 'Partial reduction' scenario, no reduction in the service life of the binder course has been assumed when areas are trenched when the age of the binder course exceeds 17 years (= 20 years (the untrenched service life) x 0.85 (1 - 'reference' service life reduction (15%)/100).

Similar assumptions have been made when the 'reference' service life reduction due to trenching is 20 per cent, as shown in columns 4 and 5 of Table 15. For example, the service life of areas trenched in years 1 to 15 is assumed to be 16 years. For the 'Partial reduction' scenario, no reduction in service life is assumed when areas are trenched when the age of the binder course exceeds 16 years.

Table C 1 and Table C 2 show the service lives of the binder course in trenched areas of Major and Minor carriageways with untrenched service lives of 30 years and 40 years, respectively, for the 'Full reduction' and 'Partial reduction' scenarios.

Table 15 Assumed service lives of binder courses in trenched areas of Major carriageways – untrenched service life of binder course: 20 years

Year trenched	'Reference' service life reduction due to trenching: 15%		'Reference' service life reduction due to trenching: 20%	
	'Full reduction'	'Partial reduction'	'Full reduction'	'Partial reduction'
0	20	20	20	20
1	17	17	16	16
2	17	17	16	16
...	...	...	...	...
14	17	17	16	16
15	17	17	16	16
16	17	17	17	20
17	18	20	18	20
18	19	20	19	20
19	20	20	20	20

8.3.3 'Several zones' and 'One zone' treatment scenarios

The service lives given in Table 15 refer to the binder course. The surface course must, of course, be replaced at the same time as the binder course, but further surface course replacements and surface treatments are normally required between binder course replacements. In order to calculate the additional maintenance costs, it has been necessary to make assumptions about:

- When these intermediate maintenance treatments are made.
- Their extent relative to the zone of influence.

Two treatment scenarios have been considered, as follows:

- 'Several zones' - intermediate surface course replacements and surface treatments cover several zones of influence and their service lives are simply the service life of the binder course divided by one plus the number of intermediate maintenance treatments (rounding up to the nearest year).
- 'One zone' – surface course replacements are limited to only one zone of influence. If the untrenched service life of a surface course is X years, there is no service life reduction of the surface course in areas trenched in year X-2 or later. There is a service life reduction of one year in areas trenched in years X-4 and X-3, two years in areas trenched in years X-6 and X-5, etc. or until the service life reduction corresponds to the maximum possible for the 'Several zones' scenario.

In many pavements, there are trenches of different age in close proximity. A surface course replacement or a surface treatment is unlikely to cover just one zone of influence. It is more likely to cover the zones of influence of several trenches and, this being the case, their timing will be dependent on the condition of the oldest zone of influence. When it has been assumed that intermediate maintenance treatments cover several zones of influence of trenches of different age (the 'Several zones' scenario), it has been assumed that the service lives of the maintenance treatments are as explained above. For example, if the binder course is replaced in either year 16 or year 17, it has been assumed that a single intermediate surface course replacement or surface treatment is in year 8 or year 9 (8.5 rounded up to 9), respectively. Also, if the binder course is replaced in either year 24, year 25 or year 26, it has been assumed that two intermediate surface course replacements or surface treatments are in years 8 and 16, years 9 and 17 or years 9 and 18, respectively.

For most of the analyses it has been assumed that surface course replacements and surface treatments cover several zones of influence of trenches of different age (the 'Several zones' scenario) and are timed as described above. However, this implies that some zones of influence are treated even before they are trenched. This is best explained with reference to Table 15. For example, when the 'reference' service life reduction is 20 per cent, the binder course is replaced in year 16 in areas trenched in years 1 to 15. If a single intermediate treatment is assumed that covers several zones of influence, this will be in year 8. Therefore, areas trenched in years 9 and 10 will be treated before they are trenched, whereas the 'Baseline' scenario assumes an intermediate treatment in year 10 in those areas. In order to account for this slight anomaly, and to provide a lower bound, it has been assumed that some surface course replacements are limited to only one zone of influence (the 'One zone' scenario) and that the service lives of maintenance treatments are as explained above. For the example from Table 15 described above, the maximum reduction in service life is 2 years. Therefore, it has been assumed that the surface course is replaced in year 10 in areas trenched in years 8 to 19, in year 9 in areas trenched in years 6 and 7, and in year 8 in areas trenched in years 1 to 5.

Sections 8.4, 8.5 and 8.6 summarise the additional maintenance costs that have been calculated for Major carriageways, Minor carriageways and Footways, respectively, for different 'Baseline', trenching, service life reduction and treatment scenarios and different maintenance treatments.

8.4 Additional maintenance costs for Major carriageways

The following maintenance treatments have been assumed for the 'Baseline' scenarios for Major carriageways (items in parenthesis are used in the legends in Figure 16 to Figure 19):

- Binder course – year 0, 20, 40
  - Surface course – year 0, 10, 20, 30, 40 (SC 10y)
  - Surface course – year 0, 20, 40, and surface treatment – year 10, 30 (ST 10y)
  - Surface course – year 0, 20, 40, and surface treatment – year 7, 14, 27, 34 (ST 7y).
- Binder course – year 0, 30
  - Surface course – year 0, 15, 30 (SC 15y)
  - Surface course – year 0, 10, 20, 30, 40 (SC 10y)
  - Surface course – year 0, 15, 30, and surface treatment – year 8, 23, 38 (SC 15y + ST 8y)
  - Surface course – year 0, 30, and surface treatment – year 15 (ST 15y)
  - Surface course – year 0, 30, and surface treatment – year 10, 20, 40 (ST 10y).
- Binder course – year 0, 40
  - Surface course – year 0, 20, 40
  - Surface course – year 0, 14, 27, 40
  - Surface course – year 0, 10, 20, 30 and 40
  - Surface course – year 0, 20, 40, and surface treatment – year 10, 30
  - Surface course – year 0, 40, and surface treatment – year 20

- o Surface course – year 0, 40, and surface treatment – year 14, 27.

Table C 3, Table C 4 and Table C 5 show the additional maintenance costs for Major carriageways assuming untrenched service lives of 20, 30 and 40 years, respectively, for the binder course. The costs are given (i) for the binder course, (ii) for the surface course with surface treatments and (iii) totalled for the binder and surface courses and surface treatments. Because the 'Several zones' treatment scenario is assumed for most of the analyses, for clarity, only the cases when the 'One zone' treatment scenario is assumed are identified as such in the tables. The costs for 'reference' service life reductions from 10 to 30 per cent are given in Table C 3 and Table C 4, whereas those in Table C 5 are for 'reference' service life reductions of 15 and 20 per cent only.

It has been assumed that the zones of influence do not overlap and that the total area treated each year is three times the trenched area shown in Table 14 (Section 8.2).

For the 'Same' scenario, when the untrenched service life of the binder course is 20 years, it has been assumed that trenching in years 1 to 13 reduces the service life of the binder and surface courses and surface treatments in the same way as for the 'Different' scenario. However, it has been assumed that these areas are trenched again in years 14 to 26 and in years 27 to 39 etc. Similarly, when the untrenched service life of the binder course is 30 or 40 years, it has been assumed that trenching in years 1 to 19 reduces the service life in the same way as for the 'Different' scenario, and it has been assumed that these areas are trenched again in years 20 to 39 etc. For the 'Same' scenario, whenever the binder and surface courses are replaced at the same time, their service lives are the same as those laid from year 0 until the binder course is first replaced. Note that this assumes that some areas trenched in years 1 to 13 or in years 1 to 19 are trenched twice before the binder course is replaced.

The total additional maintenance costs (for the binder and surface courses with surface treatments) for the 'Full reduction' and 'Partial reduction' scenarios are shown in Figure 16 and Figure 17 and in Figure 18 and Figure 19, assuming that the untrenched service lives of the binder course are 20 and 30 years, respectively. It should be noted that the costs for the 'Same – Several zones' and 'Same – One zone' scenarios are identical for the 'Full reduction' and 'Partial reduction' scenarios.

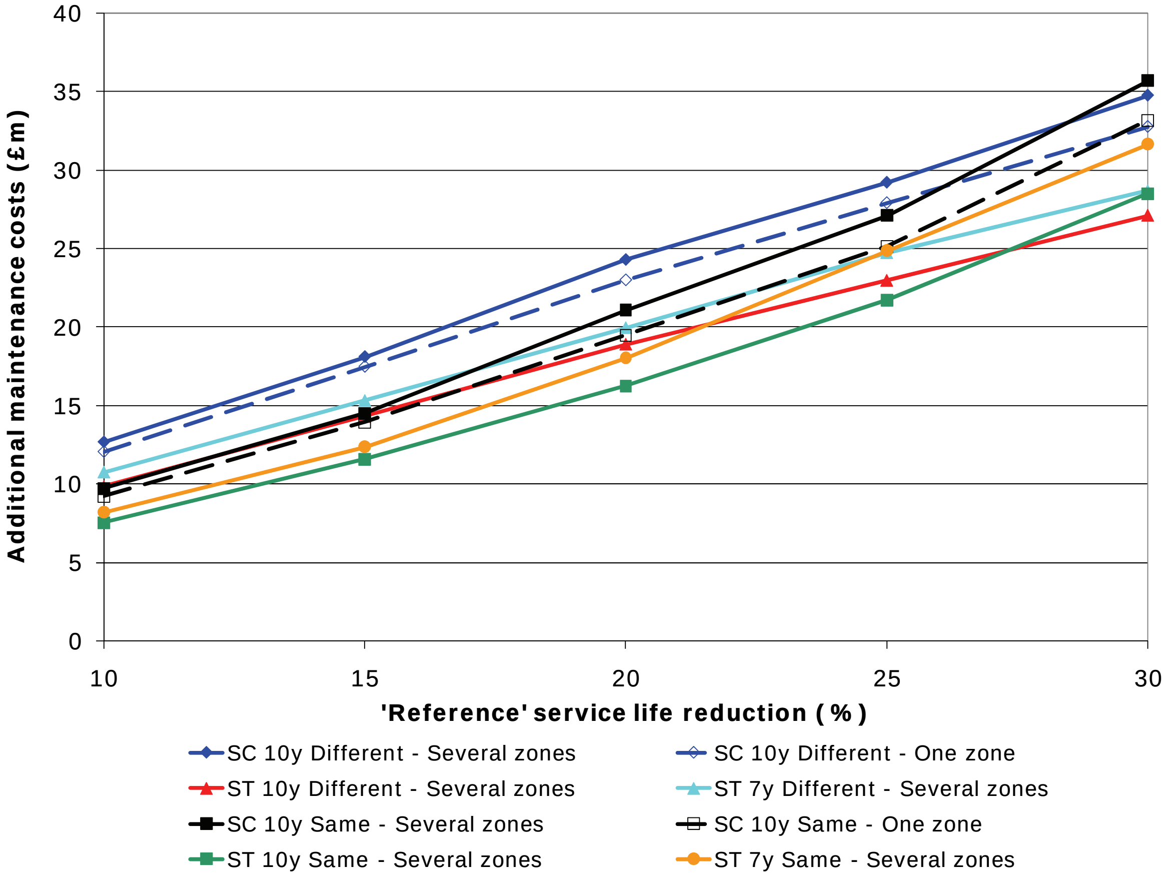

Figure 16 Additional maintenance costs for 2007/08 for Major carriageways (untrenched service life of binder course: 20 years) - 'Full reduction' scenario

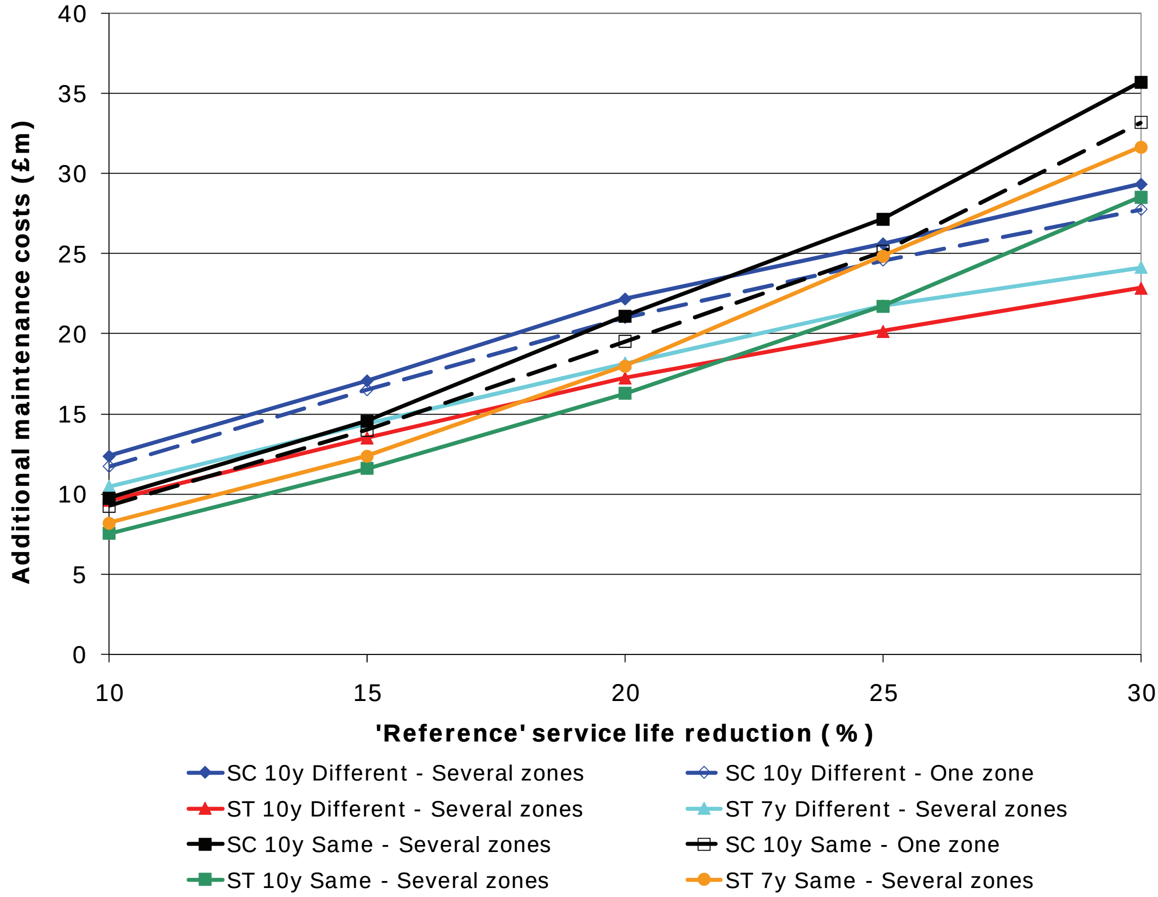

Figure 17 Additional maintenance costs for 2007/08 for Major carriageways (untrenched service life of binder course: 20 years) - 'Partial reduction' scenario

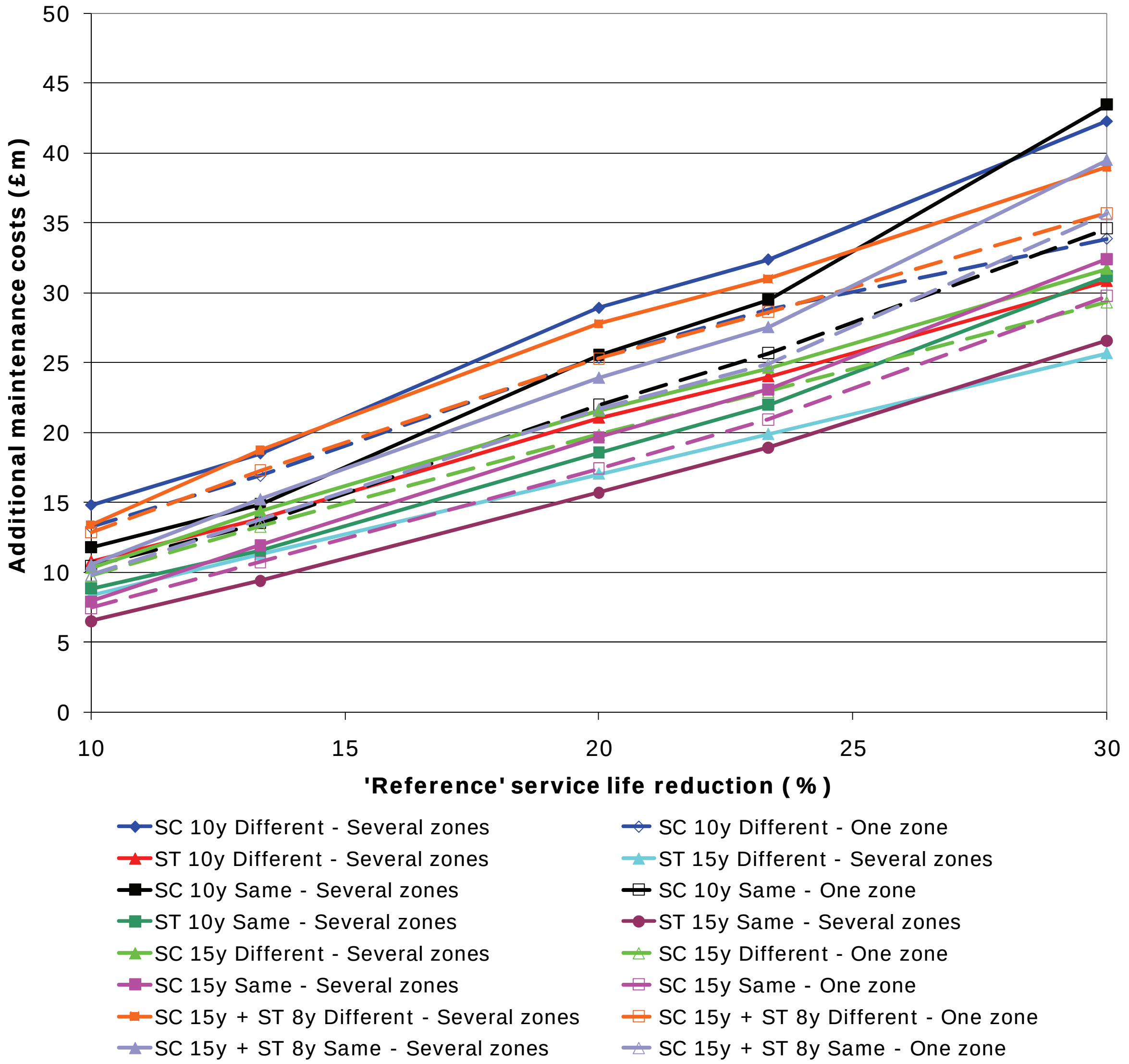

Figure 18 Additional maintenance costs for 2007/08 for Major carriageways (untrenched service life of binder course: 30 years) - 'Full reduction' scenario

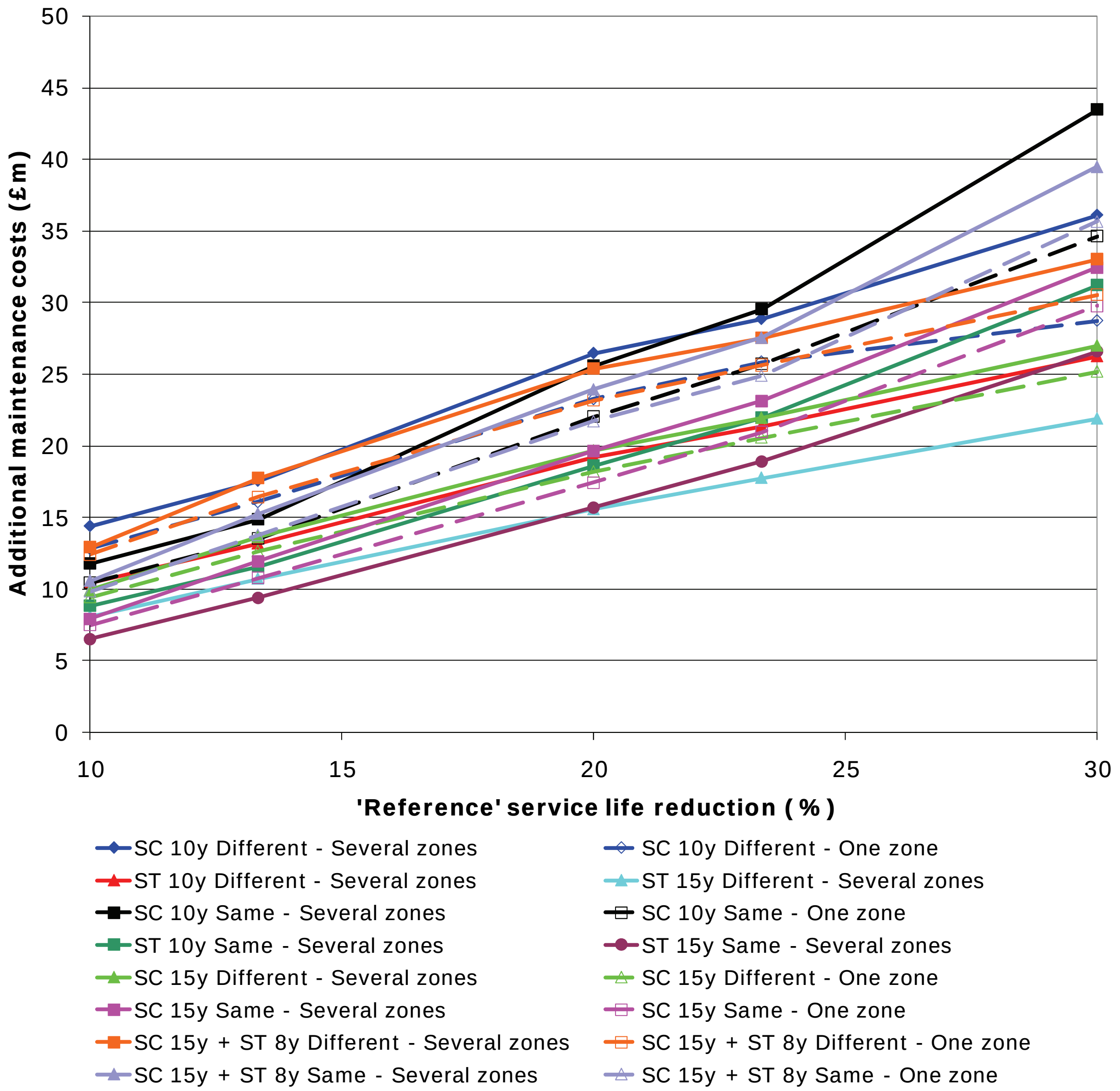

Figure 19 Additional maintenance costs for 2007/08 for Major carriageways (untrenched service life of binder course: 30 years) - 'Partial reduction' scenario

8.5 Additional maintenance costs for Minor carriageways

The following maintenance treatments have been assumed for the 'Baseline' scenarios for Minor carriageways (items in parenthesis are used in the legends in the figures):

- Binder course – year 0, 30
  - Surface course – year 0, 30 (SC 30y)
  - Surface course – year 15, 30 (SC 15y)
  - Surface course – year 0, 30, and surface treatment – year 15 (ST 15y)
  - Surface course – year 0, 30, and surface treatment – year 10, 20, 40 (ST 10y)
- Binder course – year 0, 40
  - Surface course – year 0, 40 (SC 40y)
  - Surface course – year 20, 40 (SC 20y)

- o Surface course – year 0, 40, and surface treatment – year 20 (ST 20y)
- o Surface course – year 0, 40, and surface treatment – year 14, 27 (ST 14y).

Table C 6 and Table C 7 show the additional maintenance costs for Minor carriageways assuming untrenched service lives of 30 and 40 years, respectively, for the binder course. The costs are given for 'reference' service life reductions from 10 to 30 per cent. As for Major carriageways, it has been assumed that the zones of influence do not overlap and that the total area treated each year is three times the trenched area shown in Table 14.

For the 'Same' scenario, it has been assumed that the areas trenched in years 1 to 19 are trenched again (c.f. Major carriageways when the untrenched service life of the binder course is 30 or 40 years). Also, whenever the binder and surface courses are replaced at the same time, it has been assumed that their service lives are the same as those laid from year 0 until the binder course is first replaced.

The total additional maintenance costs for the 'Full reduction' and 'Partial reduction' scenarios are shown in Figure 20 and Figure 21 and in Figure 22 and Figure 23. As above, it should be noted that the costs for the 'Same – Several zones' and 'Same – One zone' scenarios are identical for the 'Full reduction' and 'Partial reduction' scenarios.

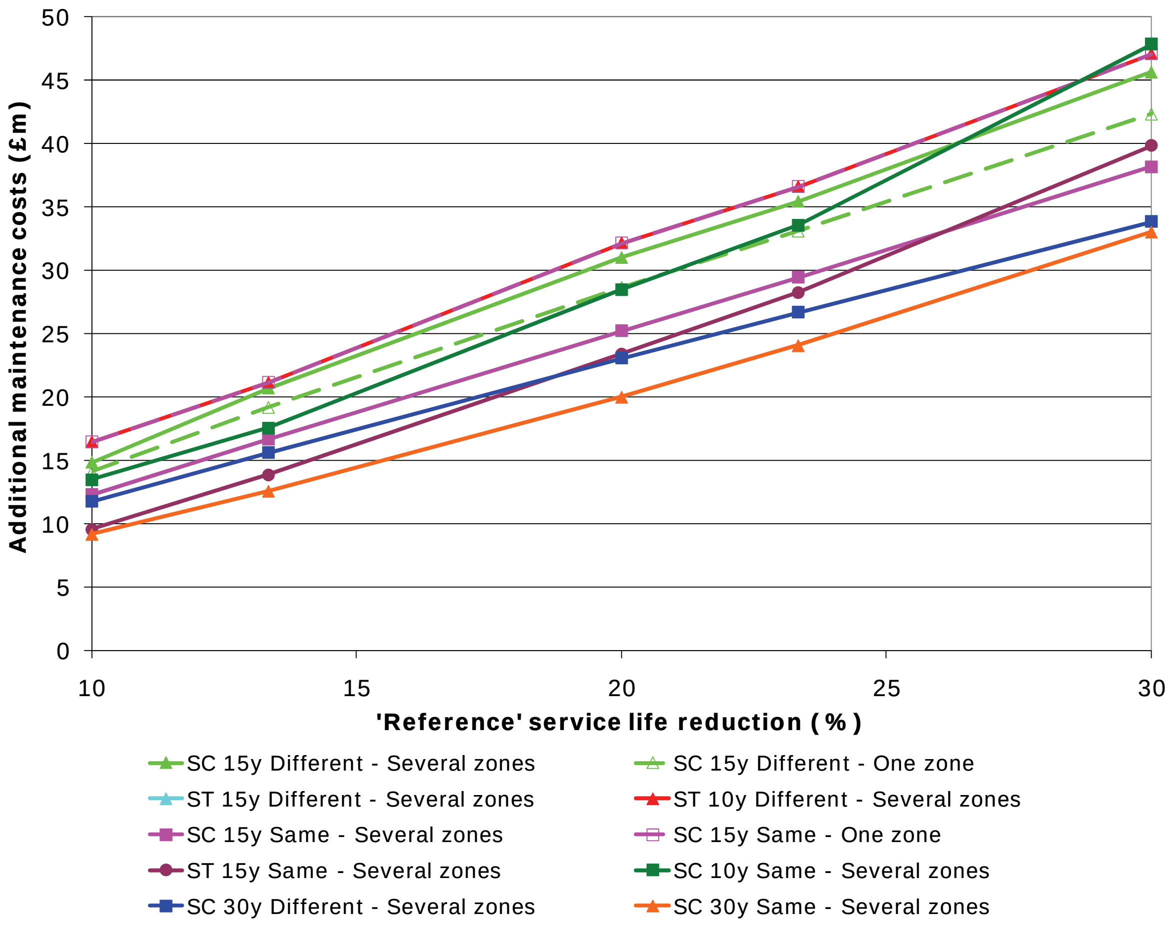

Figure 20 Additional maintenance costs for 2007/08 for Minor carriageways (untrenched service life of binder course: 30 years) - 'Full reduction' scenario

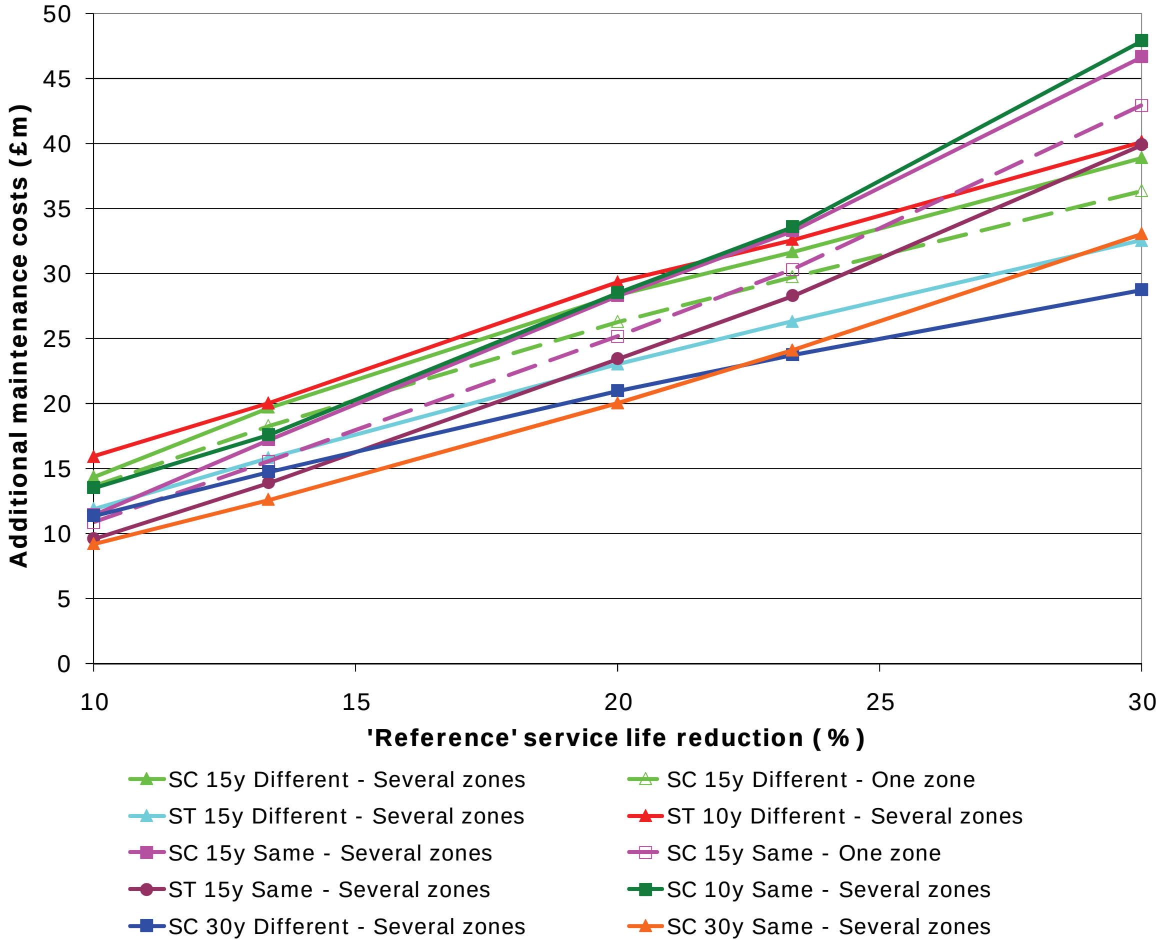

Figure 21 Additional maintenance costs for 2007/08 for Minor carriageways (untrenched service life of binder course: 30 years) - 'Partial reduction' scenario

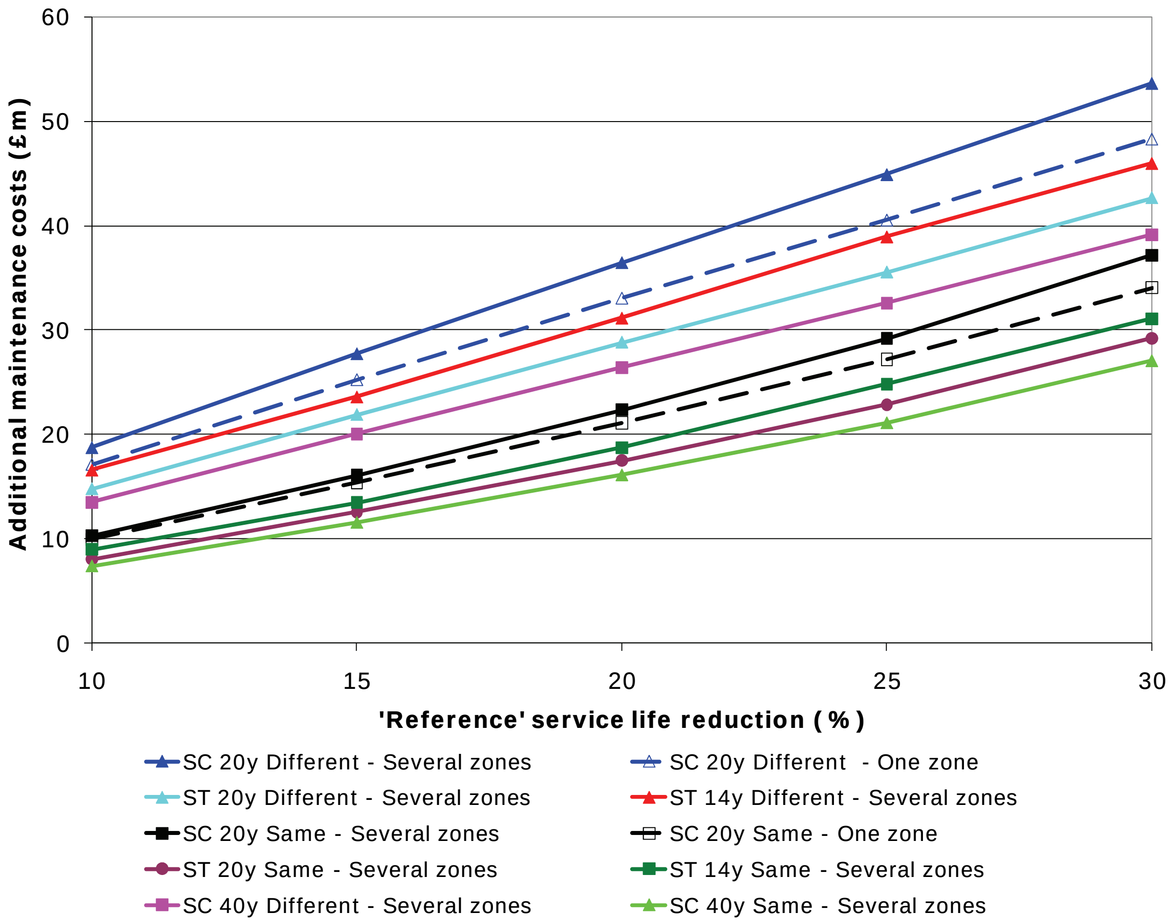

Figure 22 Additional maintenance costs for 2007/08 for Minor carriageways (untrenched service life of binder course: 40 years) - 'Full reduction' scenario

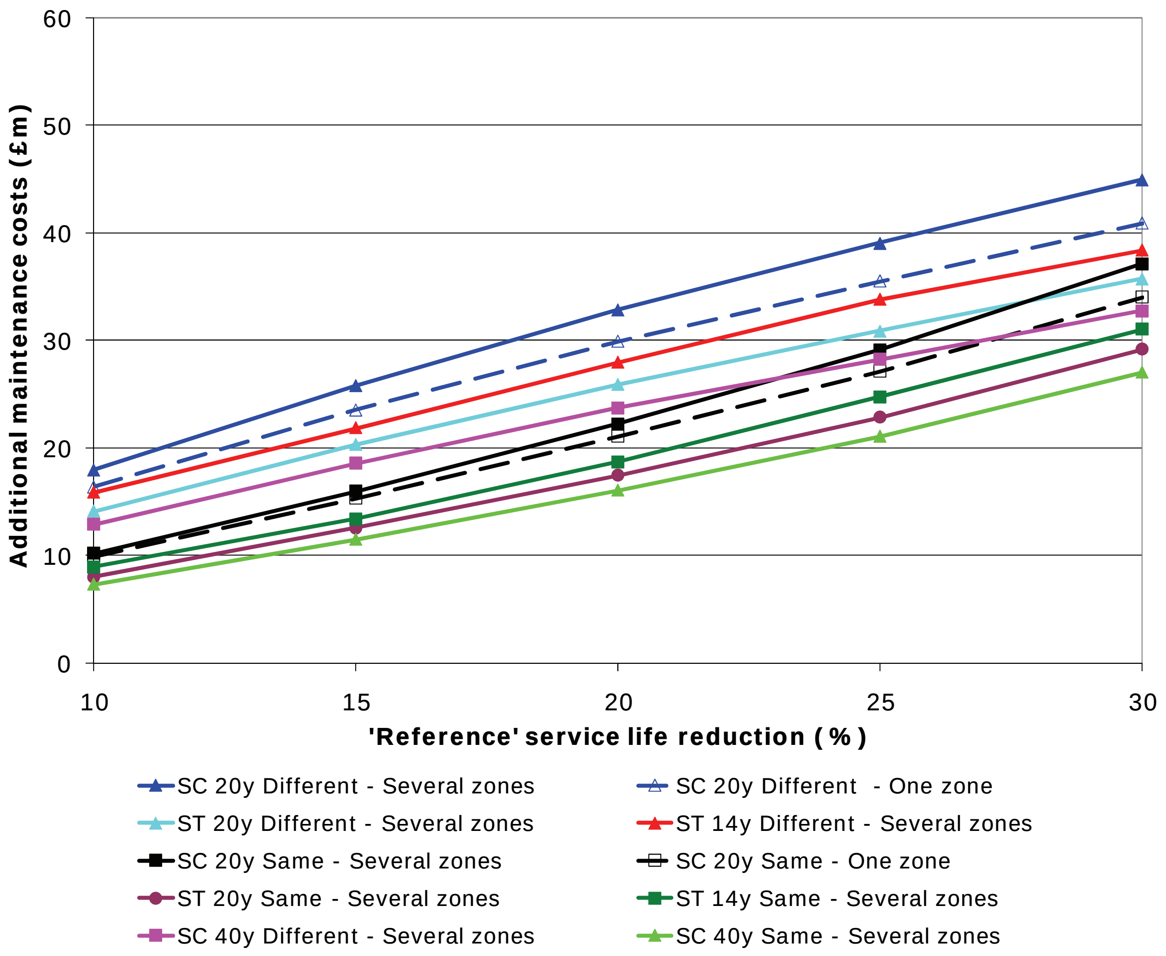

Figure 23 Additional maintenance costs for 2007/08 for Minor carriageways (untrenched service life of binder course: 40 years) - 'Partial reduction' scenario

8.6 Additional maintenance costs for Footways

The following maintenance treatments have been assumed for the 'Baseline' scenarios for Footways:

- Binder and surface courses – year 0, 30
    - Surface treatment – in year corresponding to half the service life of the trenched binder and surface courses.
- Binder and surface courses – year 0, 40
    - Surface treatment – in year corresponding to half the service life of the trenched binder and surface courses.

Table 16 and Table 17 show the additional maintenance costs for Footways for the 'Full reduction' trenching scenario, assuming untrenched service lives of 30 and 40 years, respectively, for the binder and surface courses. The costs are given for 'reference' service life reductions for both the binder and surface courses from 3.33 or 5 to 20 per cent. As for carriageways, it has been assumed that the zones of influence do not overlap and that the total area treated each year is three times the trenched area shown in Table 14.

Table 16 Additional maintenance costs for 2007/08 for Footways (untrenched service life of binder and surface courses: 30 years) – 'Full reduction' scenario

'Reference' service life reduction (%)	Years binder and surface courses are laid in untrenched areas	Year surface treatment is laid in trenched areas	Trenching scenario	Binder and surface course additional maintenance costs (£m)	Surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
3.33	0, 30	15	Different	3.5	11.8	15.3
3.33	0, 30	15	Same	2.6	10.6	13.2
10	0, 30	14	Different	10.4	11.3	21.7
10	0, 30	14	Same	8.1	11.0	19.2
13.33	0, 30	13	Different	13.8	11.3	25.1
13.33	0, 30	13	Same	11.2	11.9	23.1
20	0, 30	12	Different	20.4	12.1	32.6
20	0, 30	12	Same	17.7	14.0	31.7

Table 17 Additional maintenance costs for 2007/08 for Footways (untrenched service life of binder and surface courses: 40 years) – 'Full reduction' scenario

'Reference' service life reduction (%)	Years binder and surface courses are laid in untrenched areas	Year surface treatment is laid in trenched areas	Trenching scenario	Binder and surface course additional maintenance costs (£m)	Surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
5	0, 40	19	Different	6.0	12.8	18.9
5	0, 40	19	Same	3.1	9.3	12.4
10	0, 40	18	Different	12.0	12.6	24.5
10	0, 40	18	Same	6.5	9.6	16.1
15	0, 40	17	Different	17.7	12.2	30.0
15	0, 40	17	Same	10.2	9.9	20.2
20	0, 40	16	Different	23.4	11.9	35.2
20	0, 40	16	Same	14.3	10.3	24.6

An additional surface treatment has been assumed to remove the visual disbenefits of trenching. The timing of this treatment has been assumed to correspond to half the service life of the trenched binder and surface courses. For example, if the 'reference' service life reduction is 10 per cent, and the service life of the trenched binder and surface courses is 27 years, the surface treatment is in year 14 (27 x 0.5 = 13.5 rounded up to 14). However, it has been assumed that only the areas trenched up to half the trenched service life are surface treated because surface treatments are considered inappropriate in areas trenched later than this. Therefore, for the above example, it has been assumed that areas trenched in years 14 to 39 are not surface treated (see Table C 31 for the 'Different' scenario).

For the 'Same' scenario, it has been assumed that the areas trenched in years 1 to 19 are trenched again (c.f. Major carriageways when the untrenched service life of the binder course is 30 or 40 years). Also, whenever the binder and surface courses are replaced, it has been assumed that their service lives are the same as those laid from year 0 until the binder and surface courses are first replaced.

The additional maintenance costs for the 'Partial reduction' trenching scenario are shown in Table C 8 and Table C 9.

8.7 Areas treated because of deterioration caused by trenching

Table 18 shows what percentages of the Major and Minor carriageway and Footway networks are treated assuming the 'Different' and 'Same' trenching scenarios. The percentages for the 'Same' scenario are higher when the untrenched service life of the binder course is 30 or 40 years than when it is 20 years, because different areas are trenched in years 1 to 19 for the former and only in years 1 to 13 for the latter.

Table 18 Percentage of networks treated over 40 years

Network (ratio of treated area to trenched area)	Area trenched per year (m^2)	'Different' trenching scenario		'Same' trenching scenario (untrenched service life of binder course (years))	
		Urban network trenched per year (%)	Urban and rural network trenched per year (%)	Urban network trenched per year (%)	Urban and rural network trenched per year (%)
Major carriageways (3)	804,597	49.4	10.7	16.5 (20y) 24.7 (30 or 40y)	3.6 (20y) 5.4 (30 or 40y)
Major carriageways (5)	804,597	82.3	17.9	27.4 (20y) 41.2 (30 or 40y)	6.0 (20) 8.9 (30 or 40y)
Minor carriageways (3)	1,394,451	23.4	12.7	11.7	6.4
Footways (3)	2,471,527	76.6	-	38.3	-

As explained previously, the additional maintenance costs in Table C 3 to Table C 9 assume that the area covered by each treatment is equal to three times the total area trenched. For the 'Different' scenario, this represents 49, 23 and 77 per cent of the area of the urban Major and Minor carriageway and Footway networks, respectively. For the 'Same' scenario, the figures are 17, 12 and 38 per cent, respectively. The percentages for the urban and rural networks combined are approximately 80 and 50 per cent lower for Major and Minor carriageways, respectively. The case for Major carriageways when the treated area is five times the total area trenched is considered in Section 8.8.1.

8.8 Best estimates of additional maintenance costs

Having considered a range of maintenance treatment options for carriageways and footways in Sections 8.4 to 8.6, it is now possible to derive best estimates of the additional maintenance costs on which the new charge structures can be based.

As explained above, the 'Full reduction' and 'Partial reduction' scenarios are likely to represent the upper and lower bounds of the effect of trenching on the reduction in service life of the binder (and surface) course. Also, the cases in which the areas treated cover either several zones of influence (the ‘Several zones’ scenario) or one zone of influence (the ‘One zone’ scenario) represent upper and lower bounds for the extent and service life of surface course treatments. Therefore, the average of the costs estimated for the ‘Full reduction’ and ‘Partial reduction’ scenarios and the ‘Several zones’ and ‘One zone’ scenarios is considered to provide the best estimate for each maintenance treatment option considered for the ‘Different’ and ‘Same’ scenarios.

8.8.1 Major carriageways

Clearly different maintenance treatments would be used on different parts of the network and different parts of each network are likely to have different service lives. Table C 3 shows that when the ‘reference’ service life reduction is 20 per cent, the untrenched service life of the binder course is 20 years, and assuming the ‘Full reduction’ scenario, the additional maintenance costs range from £18.9m to £24.3m for the ‘Different’ scenario and from £16.3m to £21.1m for the ‘Same’ scenario.

Table C 4 shows that when the ‘reference’ service life reduction is 20 per cent, the untrenched service life of the binder course is 30 years, and assuming the ‘Full reduction’ scenario, the additional maintenance costs range from £17.1m to £28.9m for the ‘Different’ scenario and from £15.7m to £25.6m for the ‘Same’ scenario. Table C 5 shows that for the same ‘reference’ service life when the untrenched service life of the binder course is 40 years, and again assuming the ‘Full reduction’ scenario, the additional maintenance costs range from £19.5m to £38.9m for the ‘Different’ scenario and from £11.8m to £23.9m for the ‘Same’ scenario. The cost range is remarkably low when the untrenched service life of the binder course is 20 years, about £5m, but somewhat higher when the untrenched service life of the binder course is 30 or 40 years because the range of maintenance treatment options is greater, i.e. from two or three surface course replacements to one surface treatment between binder course replacements.

Table 19 shows the mean of the additional maintenance costs for both service life reduction and treatment scenarios considered in Section 8.4 for the ‘Different’ and ‘Same’ scenarios separately, and also for both trenching scenarios combined. However, rather than being based on the additional maintenance costs given in Table C 3 to Table C 5, they have been calculated assuming that the area treated is five times rather than three times the trenched area for surface course replacements or surface treatments. It is appropriate to use a factor of five rather than three because a significant area of Major carriageways would normally be treated covering many non-trenched areas; this is discussed further below. The mean additional maintenance costs for the ‘reference’ service life reduction of 17 per cent described in Section 7 have been calculated by linear interpolation from the data shown in the table.

Some of the maintenance treatments included in Table 19 are surface treatments with no surface course replacements between binder course replacements. Table 20 shows the mean of the additional maintenance costs for the maintenance treatment options excluding such surface treatments on the basis that they are unlikely to be effective on trenched Major carriageways; see Section 9.2.

It is apparent that the additional maintenance costs for the ‘Different’ and the ‘Same’ scenarios in Table 20 (and Table 19) differ by no more than 21 per cent when the untrenched service life of the binder course is 20 and 30 years. This is even though the areas of the network treated vary by a factor of three when the untrenched service life of the binder course is 20 years, and by a factor of two when the service life is 30 years (see Table 18). The additional maintenance costs for the two scenarios differ by up to 64 per cent when the untrenched service life of the binder course is 40 years, which is more in line with the ratio of the areas treated. In practice, some areas will be trenched in a way more closely resembling that assumed for the ‘Different’ scenario, and others in a way more closely resembling that assumed for the ‘Same’ scenario. However, without information on the proportion for each scenario, the mean of the additional maintenance costs for the two scenarios is considered to be the most appropriate. On this basis, the area treated over a period of 40 years when the untrenched service life of the binder course is 20 years is equivalent to 54.9 per cent (= (82.3 + 27.4)/2) of the area of urban Major carriageways or 11.9 per cent (= (17.9 + 6.0)/2) of the area of urban and rural Major carriageways combined. Similarly, the area treated over a period of 40 years is equivalent to 61.8 per cent of urban Major carriageways or 13.4 per cent of urban and rural Major carriageways when the untrenched service life of the binder course is 30 or 40 years. A ‘reference’ service life reduction of 17 per cent reduction in these areas compares with the 10 per cent reduction in the service life of the surface course over 100 per cent of the area of urban Major carriageways that was assumed in Stage 2.

Table 20 shows that the additional maintenance costs are slightly lower when the untrenched service life of the binder course is 20 years rather than 30 or 40 years. An untrenched service life of 40 years is considered to be too high for the binder course of most Major carriageways. The additional maintenance costs when the untrenched service life of the binder course is 20 years are considered to be most appropriate for Type 0, 1 and 2 roads, whereas those when the untrenched service life of the binder course is 30 years are considered to be most appropriate for Type 3 roads. Therefore, rather than simply averaging the additional maintenance costs for the two untrenched service lives, a weighted average has been calculated by scaling the costs according to the areas of each road category trenched in Table 7. The best estimate of the additional maintenance costs for 2007/08 for Major carriageways is the underlined figure in Table 20, i.e. £25.5m.

Table 19 Additional maintenance costs for 2007/08 for Major carriageways – All maintenance treatments

Untrenched service life of binder course (years)	‘Reference’ service life reduction (%)	Mean of total additional maintenance costs for ‘Different’ scenario (£m)	Mean of total additional maintenance costs for ‘Same’ scenario (£m)	Mean of total additional maintenance costs for all scenarios (£m)
20	15	21.1	17.4	19.2
20	20	27.5	25.0	26.2
20	**17**	**23.6**	**20.4**	**22.0**
30	13.33	21.1	17.6	19.3
30	20	31.2	28.8	30.0
30	**17**	**26.6**	**23.7**	**25.2**
40	15	27.6	16.9	22.2
40	20	35.8	23.7	29.7
40	**17**	**30.9**	**19.6**	**25.2**
20 and 30 Weighted	**17**	**24.8**	**21.7**	**23.2**

Table 20 Additional maintenance costs for 2007/08 for Major carriageways – All maintenance treatments except surface treatments only between binder course replacements

Untrenched service life of binder course (years)	'Reference' service life reduction (%)	Mean of total additional maintenance costs for 'Different' scenario (£m)	Mean of total additional maintenance costs for 'Same' scenario (£m)	Mean of total additional maintenance costs for all scenarios (£m)
20	15	23.5	19.3	21.4
20	20	30.9	27.6	29.2
20	**17**	**26.4**	**22.6**	**24.5**
30	13.33	22.6	18.8	20.7
30	20	33.5	30.7	32.1
30	**17**	**28.6**	**25.3**	**27.0**
40	15	29.7	18.2	24.0
40	20	38.5	25,6	32.0
40	**17**	**33.2**	**21.2**	**27.2**
20 and 30 Weighted	**17**	**27.3**	**23.6**	**25.5**

8.8.2 Minor carriageways

Table C 6 shows that when the 'reference' service life reduction is 20 per cent, the untrenched service life of the binder course is 30 years, and assuming the 'Full reduction' scenario, the additional maintenance costs range from £23.0m to £32.2m for the 'Different' scenario and from £20.0m to £28.5m for the 'Same' scenario. Table C 7 shows that when the 'reference' service life reduction is 20 per cent, the untrenched service life of the binder course is 40 years, and assuming the 'Full reduction' scenario, the additional maintenance costs range from £26.4m to £36.5m for the 'Different' scenario and from £16.1m to £22.3m for the 'Same' scenario.

Table 21 shows the mean of the additional maintenance costs for both service life reduction and treatment scenarios considered in Section 8.5 for the 'Different' and 'Same' scenarios separately, and also for both trenching scenarios combined. Because maintenance treatments are less extensive on Minor than on Major carriageways, the additional maintenance costs have been calculated assuming that the area treated is three times the trenched area for surface course replacements or surface treatments (c.f. five times for Major carriageways). The mean additional maintenance costs for a 'reference' service life reduction of 17 per cent have been calculated by linear interpolation from the data shown in the table. All of the treatment options have been included because all are possible on trenched Minor carriageways.

It is apparent that the additional maintenance costs for the 'Different' and the 'Same' scenarios in Table 21 are significantly different when the untrenched service life of the binder course is 40 years, but by a lower factor than the ratio of the areas of the network treated (i.e. a factor of two, see Table 18). However, they differ by no more than 18 per cent when the untrenched service life of the binder course is 30 years. Because trenches are likely to be more widely spaced on Minor carriageways than on Major carriageways, it is considered that Minor carriageways are trenched in a way more closely resembling that assumed for the 'Different' scenario. Therefore, the 'Different' scenario is considered to provide a more accurate estimate of the additional maintenance costs than the 'Same' scenario. On this basis, the area treated over a period of 40 years is equivalent to 23.4 per cent of the area of urban Minor carriageways and 12.7 per cent of the area of urban and rural Minor carriageways combined as shown in Table 18. A 'reference' service life reduction of 17 per cent in these areas compares with the 5 per cent reduction in the service life of the surface course over 100 per cent of urban Minor carriageways that was assumed in Stage 2.

Table 21 shows that the additional maintenance costs are slightly higher when the untrenched service life of the binder course is 40 years rather than 30 years for the 'Different' scenario. Both untrenched service lives are equally likely, so the mean of the additional maintenance costs for both untrenched service lives is considered to provide the best estimate. Therefore, the best estimate of the additional maintenance costs for 2007/08 for Minor carriageways is the underlined figure in Table 21, i.e. £24.3m.

Table 21 Additional maintenance costs for 2007/08 for Minor carriageways – All maintenance treatments

Untrenched service life of binder course (years)	'Reference' service life reduction (%)	Mean of total additional maintenance costs for 'Different' scenario (£m)	Mean of total additional maintenance costs for 'Same' scenario (£m)	Mean of total additional maintenance costs for all scenarios (£m)
30	13.33	18.2	15.4	16.8
30	20	26.8	25.1	25.9
30	**17**	**22.9**	**20.7**	**21.8**
40	15	22.9	13.8	18.3
40	20	29.6	19.2	24.4
40		**25.6**	**15.9**	**20.8**
30 and 40 Mean	**17**	**<u>24.3</u>**	**18.3**	**21.3**

8.8.3 Footways

Table 22 shows the mean of the additional maintenance costs for Footways when the 'reference' service life reduction for both the binder and surface courses is 10 per cent. The costs are for both service life reduction scenarios considered in Section 8.6 for the 'Different' and 'Same' scenarios separately, and also for both scenarios combined (see Table C 8 and Table C 9). They have been calculated assuming that the area treated is three times the trenched area for binder and surface course replacements. A 'reference' service life reduction of 10 per cent is assumed to be more appropriate for footways than the 17 per cent reduction assumed for carriageways. This is because footways are less affected by traffic, although they are subject to traffic at the entrances to properties and businesses, and by parked vehicles etc.

It is apparent that the additional maintenance costs for the 'Different' and 'Same' scenarios in Table 22 are significantly different when the untrenched service life of the binder and surface courses is 40 years, but by a lower factor than the ratio of the areas of the network treated (i.e. a factor of two, see Table 18). However, they differ by only 12 per cent when the untrenched service life of the binder and surface courses is 30 years. In practice, some areas will be treated in a way more closely resembling that assumed for the 'Different' scenario, and others in a way more closely resembling that assumed for the 'Same' scenario. However, without information on the proportion for each scenario, the mean of the costs for the two scenarios is considered to be the most appropriate. On this basis, the area of binder and surface courses treated over a period of 40 years is equivalent to 57.5 per cent (= (76.6 + 38.3)/2) of the area of urban footways, and the area surface treated over the same period is equivalent to 31.6 per cent of the area of urban footways. A 'reference' service life reduction of 10 per cent in these areas compares with the 5 per cent reduction in the service life of the binder and surface courses over 100 per cent of urban footways that was assumed in Stage 2.

Table 22 shows that when the untrenched service life of the binder and surface courses is 40 years rather than 30 years, the additional maintenance costs are slightly higher for the 'Different' scenario and slightly lower for the 'Same' scenario. However, the means for the two scenarios are almost identical for both untrenched service lives. Both untrenched service lives are equally likely, so the mean of the additional maintenance costs for both untrenched service lives is considered to provide the best estimate. Therefore, the best estimate of the additional maintenance costs for 2007/08 for Footways is the underlined figure in Table 22, £20.3m.

Table 22 Additional maintenance for 2007/08 costs for Footways – All maintenance treatments

Untrenched service life of binder and surface courses (years)	'Reference' service life reduction (%)	Mean of total additional maintenance costs for 'Different' scenario (£m)	Mean of total additional maintenance costs for 'Same' scenario (£m)	Mean of total additional maintenance costs for all scenarios (£m)
30	10	21.5	19.2	20.4
40	10	24.3	16.1	20.2
30 and 40 Mean	17	22.9	17.7	<u>20.3</u>

8.8.4 Comparison of additional maintenance costs and capital expenditure on carriageway and footway maintenance

The sum of the additional maintenance costs for Major and Minor carriageways and Footways that are described above is £70.1m. This total is estimated to be 7.7 per cent of the capital expenditure on carriageway and footway maintenance by English local highway authorities in 2007/08. The capital expenditure on carriageway and footway maintenance was £879.6m in 2006/07 (Department of Communities and Local Government, 2007)[20]. An annual increase in expenditure of 3.5 per cent has been assumed from 2006/07 to 2007/08.

9 Stage 3: New charge structure

9.1 Calculation of new charge rates

The best estimates of the additional maintenance costs discussed in Section 8.8 are summarised in Table 23. The total additional maintenance costs for carriageways are £49.8m compared to £28.5m estimated in Stage 2 for the deterioration in the surface condition (see Table 8). Note that costs in Table 23 and Table 8 for Major and Minor carriageways are not directly comparable because Type 3 roads have been moved from the Minor carriageway category in Stage 2 to the Major carriageway category in Stage 3.

Table 23 includes 'flat rate' charges per square metre of reinstatement that were obtained by dividing the costs by the reinstated areas shown in Table 8. However, the rates are to vary according to the condition of the highway being trenched. Assuming that the condition data in Table 10 are representative of the highway network in England variable charge rates have been calculated assuming that the charge decreases by a factor of two for each decrease in condition. The rates are shown for Major and Minor carriageways, and for Footways in Table 24 and Table 25, respectively.

Table 23 Additional maintenance costs and flat rate charges for 2007/08

Network	Total additional maintenance costs (£m)	Area of network reinstated (m^2)	'Flat' rate charge (£/m^2)
Major carriageways	25.5	804,597	31.69
Minor carriageways	24.3	1,394,451	17.43
Footways*	20.3	2,471,527	8.21

*(assuming Non-high amenity footway costs for all footways)

As in Stage 2, it is assumed that the additional maintenance costs for High amenity footways are double those for Non-high amenity footways. However, the effect of the higher charges for High amenity footways is not reflected in the total additional maintenance costs in Table 23. Notwithstanding this, it should be appreciated that the total sum raised by the charges levied would be in proportion to the amount of trenching each year. This is because the cost calculations have been based on the unit area trenched. Therefore, if there is more or less trenching than indicated in Table 23, the total sum raised by the charges will be correspondingly higher or lower.

The maximum charges derived in Stage 3 for the structural, surface and visual condition are 68, 63 and 76 per cent higher than those derived in Stage 2 for the *surface* condition only for Major carriageways, Minor carriageways and Footways, respectively. However, Type 3 roads have been moved from the Minor carriageway category in Stage 2 to the Major carriageway category in Stage 3 and the charges for the latter are 158 per cent higher than those for the former.

As for Stage 2, the charge rates given in the tables are based on data applicable to utility trenching work undertaken in England, but it is thought that they would also be applicable to trenching in Wales.

The charges should be increased annually in accordance with the Road Construction Tender Price Index from the base year of 2007/08.

Table 24 Finalised charge structure for carriageways for 2007/08

Condition	UKPMS Overall Condition Indicator	Charge (£/m² of reinstatement)	
		Major carriageways*	Minor carriageways**
Excellent	0 – 25	45.48	28.74
Good	26 – 50	22.72	14.37
Fair	51 – 75	11.37	7.19
Poor	76 – 100	5.68	3.59

* Major carriageways

Type 0, 1, 2 and 3 roads

** Minor carriageways

Type 4 roads

Table 25 Finalised charge structure for footways for 2007/08

Condition	UKPMS Overall Condition Indicator	Charge (£/m² of reinstatement)	
		High amenity footways*	All other footways**
Excellent	0 – 25	23.89	11.95
Good	26 – 50	11.95	5.97
Fair	51 – 75	5.97	2.99
Poor	76 – 100	2.99	1.49

* High amenity footways

Prestige walking routes

Primary walking routes

** All other footways

Secondary walking routes

Link footways

Local access footways

9.2 Factors not taken into account in the charge structure

The additional maintenance costs derived in Section 8 on which the charges are based are considered to be low estimates of the full impact of trenching on highways for the following reasons:

1. *Cost of patching*
No allowance was made when estimating the additional maintenance costs for the patching that is frequently required at reinstatements (see Figure 4, Figure 6 and Figure 7, for example).

2. *Greater 'reference' service life reduction*
The 'reference' service life reduction could be nearer to 30 per cent rather than the 17 per cent determined for trenches in 'very good' and 'good' condition. A higher 'reference' service life reduction may have been measured if the measurements had been after a period of more than six years.

3. *More costly maintenance treatments in trenched areas*
When the additional maintenance costs were calculated, it was assumed that the maintenance treatments in the trenched areas would be the same as those in untrenched areas. However, highway authorities reported that more costly maintenance treatments are often required where there are reinstatements than where there are none. Therefore, the effect of this on the additional maintenance

costs has been investigated by considering different maintenance treatments for the ‘Baseline’ (untrenched) scenarios and the ‘Required’ (trenched) scenarios (see Sections 4.2.2 and 4.2.3).

For each untrenched service life of the binder course assumed in Section 8, the maintenance treatments described in Section 8.4 for Major carriageways and in Section 8.5 for Minor carriageways were ranked in order of their unit cost. For example, the maintenance treatments assumed for Major carriageways when the untrenched service life of the binder course is 20 years were ranked as follows (Rank 1 is the lowest cost):

- Rank 1: Surface course – year 0, 20, 40
- Rank 2: Surface course – year 0, 20, 40, surface treatment – year 10, 30
- Rank 3: Surface course – year 0, 20, 40, surface treatment – year 7, 14, 27, 34
- Rank 4: Surface course – year 0, 10, 20, 30, 40

Table 26 shows the supplementary additional maintenance costs when the rank of the maintenance treatment for the ‘Required’ scenario is one rank higher than that for the ‘Baseline’ scenario. The supplementary additional maintenance costs exceed £10m in most cases, and £20m for Major carriageways for the ‘Different’ scenario. The mean of the supplementary additional maintenance costs for the ‘Different’ and ‘Same’ scenarios is £25.8m and £22.5m for Major carriageways when the untrenched service life of the binder course is 20 and 30 years, respectively. The weighted mean calculated by scaling the costs according to the areas of each road category (see Section 8.8.1) is £24.5m. The mean of the supplementary costs for Minor carriageways with untrenched service lives of 30 and 40 years is £17.9m for the ‘Different’ scenario. The rank of the maintenance treatments would not be increased in all trenched areas, nevertheless the supplementary additional maintenance costs are very high and comparable with the additional maintenance costs derived in Section 8.8. If half of the supplementary additional maintenance costs were included in the charges, the charges for Major and Minor carriageways would increase by 48 and 37 per cent, respectively.

4. *Closely spaced trenches*
   No allowance was made when calculating the additional maintenance costs for trenches that are in close proximity or cross each other, or that have overlapping zones of influence; the figures in Section 2.4 show that this is often the case. When trenches are near to each other, the area treated could be less than five times (Major carriageways) or three times (Minor carriageways) the area trenched. However, the ‘reference’ service life reduction is likely to be much higher than the 17 per cent reduction estimated for carriageways, so the net effect on the additional maintenance costs may be small.

5. *Trench orientation*
   No allowance was made for the different orientations of transverse and longitudinal trenches. Deterioration of the adjacent carriageway is generally greater for transverse than for longitudinal trenches.

6. *Area treated*
   For many trenches, the area of the surface course that is treated is likely to be greater than the five or three times the area trenched that was assumed for Major and Minor carriageways, respectively. Similarly, the area of the binder course that is treated is likely to exceed three times the area trenched, and the unit cost for the replacement of the lower layers is likely to be much more than the £5/m^2 assumed (see Table 13).

   For most trenches, the area treated was assumed to be less than the full or half width of the carriageway.

7. *Visual disbenefits on carriageways*
Finally, no allowance was made for maintenance treatments to remove the visual disbenefits and patchwork quilt effect caused by trenching on carriageways.

Table 26 Supplementary additional maintenance costs for 2007/08 when the 'Baseline' and 'Required' scenarios differ

Network (untrenched service life of binder course)	'Baseline' scenario	'Required' scenario (One rank higher than 'Baseline' scenario)	Supplementary additional maintenance costs (£m) Trenching scenario: Different	Same
Major carriageways (20 years) Costs for 5x trenched area	SC 0, 20, 40	SC 0, 20, 40 ST 10, 30	38.7	12.9
	SC 0, 20, 40 ST 10, 30	SC 0, 20, 40 ST 7, 14, 27, 34	38.1	12.7
	SC 0, 20, 40 ST 7, 14, 27, 34	SC 0, 10, 20, 30, 40	39.2	13.1
Major carriageways (30 years) Costs for 5x trenched area	SC 0, 30	SC 0, 30 ST 15	21.7	10.6
	SC 0, 30 ST 15	SC 0, 30 ST 10, 20, 40	22.3	10.9
	SC 0, 30 ST 10, 20, 40	SC 0, 15, 30	30.6	14.9
	SC 0, 15, 30	SC 0, 15, 30 ST 8, 23, 38	47.4	23.1
	SC 0, 15, 30 ST 8, 23, 38	SC 10, 20, 30, 40	29.2	14.2
Minor carriageways (30 years) Costs for 3x trenched area	SC 0, 30	SC 0, 30 ST 15	22.5	11.0
	SC 0, 30 ST 15	SC 0, 30 ST 10, 20, 40	23.2	11.3
	SC 0, 30 ST 10, 20, 40	SC 0, 15, 30	16.3	8.0
Minor carriageways (40 years) Costs for 3x trenched area	SC 0, 40	SC 0, 40 ST 20	19.0	9.2
	SC 0, 40 ST 20	SC 0, 40 ST 14, 27	19.3	9.4
	SC 0, 40 ST 14, 27	SC 0, 20, 40	7.3	3.6

10 Conclusions

UK Policy

1. Highway authorities have to undertake additional maintenance because of the premature deterioration of the highway due to utility trenching. Provision has been made in the Traffic Management Act 2004 to enable funding (contribution to costs of making good long-term damage) to be recovered from those responsible for the premature deterioration.
2. The Act includes options for half- or full-width resurfacing, but the use of charge rates to recover funding from all those opening the highway is considered by authorities to be more practical and equitable than a requirement for one particular undertaker to carry out half- or full-width resurfacing (with some of the cost then being recouped from other undertakers).

Deterioration caused by trenching

3. Research in the UK and North America has found that utility works have an adverse effect on the performance and appearance of highways.
4. The average reduction in the life of carriageways due to trenching that was measured in nine North American studies ranged from 20 to 56 per cent. Overall, the average reduction appeared to be just over 36 per cent.
5. In the UK, analysis of FWD data obtained from reinstatements in Type 2, 3 and 4 roads estimated that the median reduction in the service life of pavements in the zone adjacent to trenches is 17 per cent.

Charge structure and additional maintenance costs

6. A number of municipal authorities in North America have developed and implemented charge structures for trenching the highway. The charges levied vary according to a number of factors, such as the size, depth and orientation of the trench, and the age and condition of the highway.
7. A charge structure has been developed for the UK that enables charges to be levied against those opening the highway. The aim of the charge structure is to recover a contribution to the additional maintenance costs associated with the deterioration in the structural and surface condition of carriageways and the structural, surface and visual condition of footways due to utility trenching.
8. The additional maintenance costs have been calculated separately for Major carriageways (Type 0, 1, 2 and 3 roads), Minor carriageways (Type 4 roads) and Footways using a whole-life cost approach and assuming different trenching, service life reduction and treatment scenarios, and different maintenance treatments.
9. The additional maintenance costs for Major and Minor carriageways, assuming a ‘reference’ service life reduction of 17 per cent, were estimated to be £25.5m and £24.3m, respectively, for 2007/08.
10. The additional maintenance costs for Footways were estimated to be £20.3m, assuming a ‘reference’ service life reduction of 10 per cent for the binder and surface courses and additional surface treatments in areas trenched when their age is half or less than their service life.
11. The total additional maintenance costs for Major and Minor carriageways and Footways of £70.1m for 2007/08 represent 7.7 per cent of the capital expenditure on carriageway and footway maintenance by English local highway authorities in 2007/08.

Proposed charge rates

12. To derive the charge rates for trenching Major and Minor carriageways and Footways, the additional maintenance costs have been apportioned using data on the total area of reinstatements in 2002/03 and UKPMS Overall Condition Indicator data.

13. The proposed charge rates for 2007/08 for carriageways and footways are given Table 24 and Table 25, respectively. The charges are highest for trenching carriageways or footways where the UK Overall Condition Indicator score ranges from 0 to 25. The charges for trenching carriageways or footways where the UK Overall Condition Indicator score ranges from 26 to 50, from 51 to 75 and from 76 to 100 are, respectively, 50 per cent, 25 per cent and 12.5 per cent of the highest charges.
14. The highest charge for 2007/08 for Major carriageways is £45.48/m^2, and that for Minor carriageways is £28.74/m^2. The highest charge for High amenity footways is £23.89/m^2, and that for Non-high amenity footways is £11.95/m^2. The charges should be increased annually in accordance with the Road Construction Tender Price Index from the base year of 2007/08.
15. The additional maintenance costs given above are considered to be low estimates of the full impact of trenching on highways. No allowance was made for patching or the need to use more costly maintenance treatments in trenched than in untrenched areas. The ‘reference’ service life reductions and the areas treated that were assumed are considered to be low for most reinstatements.

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Appendix A Road categories and details of road lengths

The charge structure developed in Stage 2 divided the road hierarchy into Major and Minor carriageways, with a higher charge being specified for trenches excavated in carriageways of higher strategic importance. It was necessary to define the Major and Minor carriageway categories within the hierarchy of routes in the UK and one approach was to use the A, B, C and U road classifications used for the Transport Statistics of Great Britain for distinguishing between them in Stage 2 as follows:

Major carriageways: Motorways

All Purpose Trunk (A) Roads

Classified Principal (A) Roads

Classified Non-Principal (B) Roads

Minor carriageways: Classified Non-Principal (C) Roads

Unclassified (U) Roads

Details of the road hierarchy in England in 2005 that were used in Stage 2 are given in Table A 1. It can be seen that there are almost 300,000 km of road in England. Of this road network about 58 per cent (174,508 km) is located in rural areas and 41 per cent (122,246 km) is in urban areas (defined as the settlements with a population greater than 10,000). The majority of street works are likely to occur within urban areas. Of this urban network, approximately 88 per cent (107,922 km) is made up of C and U roads (i.e. Minor carriageways) while only 12 per cent (14,324 km) is Major carriageways. Non-Principal B Roads were included within the Major carriageways category because, in urban areas, these often form important local routes, such as high streets and connector routes.

Table A 1 also shows data for 2006, but these are similar to those for 2005. For this reason, the data for 2005 have been used to calculate the Stage 3 charge structure to simplify comparisons with the Stage 2 charge structure.

The drawback of basing the Major and Minor carriageway definitions on the traditional A, B, C and U road classification is that it differs from the terminology used with regard to street works in the Specification for the Reinstatement of Openings in Highways[7]. In the Specification, roads are categorised into five types, each with a limiting capacity expressed in millions of standard axles (msa) as shown in Table A 2. These road categories are based on the traffic expected to be carried over 20 years.

Each local authority has to categorise its road network on this basis, thus for continuity with current practice in street works and pavement condition assessment, it was decided that the definitions of Major and Minor carriageways would be based on the categories given in the Specification rather than the traditional A, B, C and U classification. However, as both are based on the level of traffic expected to use the road, there is a good deal of correlation between the two systems and it was deemed reasonable to replace one with the other. The final definitions of Major and Minor carriageways are therefore as follows:

Stage 2:

Major carriageways: Type 0, 1, and 2 roads (rather than A and B roads)

Minor carriageways: Type 3 and 4 roads (rather than C and U roads).

Stage 3:

Major carriageways: Type 0, 1, 2 and 3 roads (rather than A, B and C roads)

Minor carriageways: Type 4 roads (rather than U roads).

For footways, the categorization adopted in the structure was based on the hierarchy of footways defined in Well-maintained highways (Roads Liaison Group, 2004)[21].

Table A 1 Details of road lengths and types in England

Road type	Road length (km)							
	England in 2005				England in 2006			
	Urban		Rural		Urban		Rural	
	Single	Dual	Single	Dual	Single	Dual	Single	Dual
All Purpose Trunk (A)	158.4	261.7	2,010.4	2,555.1	114.1	196.4	1,633.4	2,405.7
Classified Principal (A)	6,949.3	2,298.8	16,502.6	1,428.5	7,022.3	2,369.5	16,891.1	1,616.7
Class. Non-Principal (B)	4,655.7		15,213.2		5,201.1		14,517.7	
Class. Non-Principal (C)	9,889.7		54,922.3		10,253.4		54,119.0	
Unclassified (U)	98,032.0		81,875.7		102,253.4		82,346.1	
Total	119,685.1	2,560.5	170,524.2	3,983.6	124,844.3	2,565.9	169,507.3	4,022.4
Motorway				2,948.6				3,007.1
All roads				299,698.1				298,628.0

Note: Urban roads are defined as those within an urban area with a population of 10,000 or more.

Table A 2 Road categories defined in the Specification for the Reinstatement of Openings in Highways[7]

Road Category	Traffic Capacity
Type 0	Roads carrying over 30 to 125 msa
Type 1	Roads carrying over 10 to 30 msa
Type 2	Roads carrying over 2.5 to 10 msa
Type 3	Roads carrying over 0.5 to 2.5 msa
Type 4	Roads carrying up to 0.5 msa

Appendix B How the zone of influence varies with the trench size

As explained in Section 2.2, the presence of a trench can have a weakening effect on an area of highway immediately adjacent to it called the 'zone of influence'. It has been assumed that the 'zone of influence' extends a distance equal to the depth of the trench from its edges. Information is available on the areas of carriageways and footways that are trenched (Halcrow, 2003), but data on the areas of the 'zones of influence' are required because these are the areas affected by trenching.

Figure B 1 shows the zone of influence of a trench of width 0.6m, length 1.2m and depth 0.9m. NJUG has produced guidelines on the positioning of underground utilities' apparatus (NJUG, 2007)[19]. The areas of the zone of influence, A_z, of trenches of different depth, length and width have been calculated using equation B.1 assuming the recommended minimum depths for apparatus in footways and carriageways that are given in Table 1 of the NJUG guidelines.

$$A_z = LW + 2DL + 2DW + 2D^2 \qquad \text{Equation B.1}$$

The ratio of the area of the zone of influence and the area of the trench for the trenches considered is shown in Table B 1. Although not shown in the table, when a trench increases in length from 15m to 150m, the ratio decreases by from 3 per cent for a 300mm deep trench to 10 per cent for a 1250mm deep trench.

The zone of influence of the longitudinal trench shown in Figure B 1 is 7.8 times the area of the trench. The ratio of the area of the zone of influence to the area of the trench is greater than 3.0 for most of the trenches included in Table B 1. The ratio is less than 3.0 only for trenches of length significantly greater than their depth, or for trenches, for example, of width more than twice their depth and of length more than three times their depth.

The ratio is 3.0 or greater for trenches of width equal to their depth and of length not exceeding ten thousand times their width. Furthermore, the ratio is 3.5 or greater for trenches of width equal to 80 per cent their depth and of length not exceeding ten thousand times their width. On this basis, and for the purpose of this report, it has been assumed, conservatively, that the area of the zone of influence of all trenches is equal to three times their area.

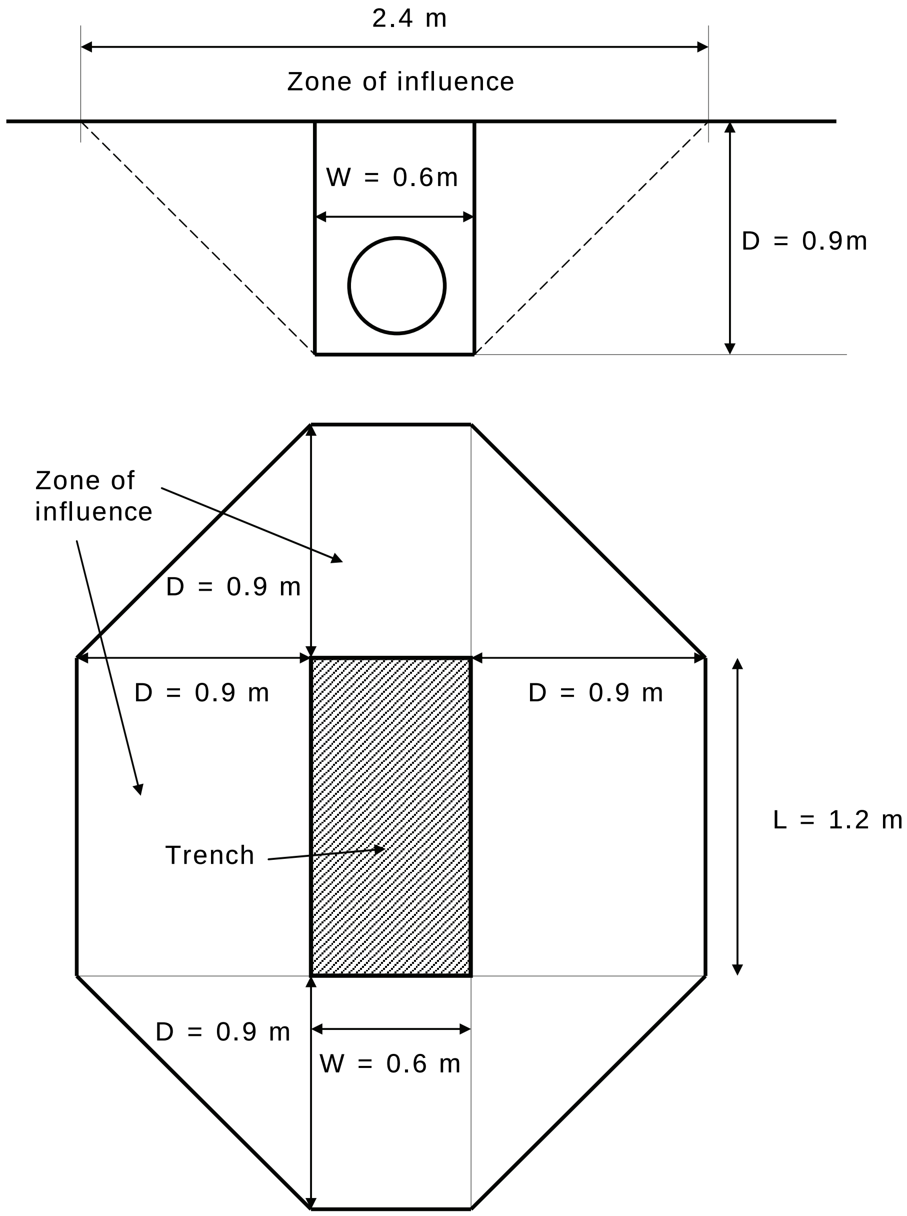

Figure B 1 Cross section and plan view of a trench and its zone of influence

Table B 1 Ratio of the area of the zone of influence and the area of trenches of different dimension

Type of apparatus	Recommended minimum depth of crown (mm)	Typical depth of trench, D (mm)	Width of trench, W (mm)	Length of trench, L (mm)	Area of zone of influence / Area of trench
Telecommunications in footway	250	300	300	300	7.0
	250	300	300	600	5.0
	250	300	300	15000	3.1
	250	300	600	600	3.5
	250	300	600	15000	2.1
Telecommunications in footway	350	400	300	300	9.9
	350	400	300	600	6.8
	350	400	300	15000	3.8
	350	400	600	600	4.6
	350	400	600	15000	2.4
Telecommunications in carriageway LV or HV Electricity in footway	450	500	300	300	13.2
	450	500	300	600	8.8
	450	500	300	15000	4.5
	450	500	600	600	5.7
	450	500	600	15000	2.8
	450	500	1000	1000	3.5
	450	500	1000	15000	2.1
Telecommunications in carriageway HV Electricity in footway LV Electricity in carriageway	600	650	300	300	19.1
	600	650	300	600	12.2
	600	650	300	15000	5.6
	600	650	600	600	7.7
	600	650	600	15000	3.3
	600	650	1000	1000	4.4
	600	650	1000	15000	2.4
Gas in footway	600	750	600	600	9.1
	600	750	600	1200	6.3
	600	750	600	15000	3.7
	600	750	1000	1000	5.1
	600	750	1000	15000	2.7
	600	750	2000	2000	2.8
	600	750	2000	15000	1.9

Type of apparatus	Recommended minimum depth of crown (mm)	Typical depth of trench, D (mm)	Width of trench, W (mm)	Length of trench, L (mm)	Area of zone <u>of influence</u> Area of trench
HV Electricity in carriageway EHV Electricity in footway	750	800	300	300	25.9
	750	800	300	600	16.1
	750	800	300	15000	6.7
	750	800	600	600	9.9
	750	800	600	15000	3.9
	750	800	1000	1000	5.5
	750	800	1000	15000	2.8
Gas in carriageway Water in footway or carriageway	750	900	600	600	11.5
	750	900	600	1200	7.8
	750	900	600	15000	4.3
	750	900	1000	1000	6.2
	750	900	1000	15000	3.0
	750	900	2000	2000	3.2
	750	900	2000	15000	2.1
Water in carriageway or footway EHV Electricity in carriageway or footwayc	900	1050	1000	1000	7.4
	900	1050	600	1200	9.3
	900	1050	600	15000	4.9
	900	1050	1000	1000	7.4
	900	1050	1000	15000	3.4
	900	1050	2000	2000	3.7
	900	1050	2000	15000	2.3
EHV Electricity in carriageway or footwayc	1200	1250	300	600	30.9
	1200	1250	300	15000	10.2
	1200	1250	600	600	18.0
	1200	1250	600	15000	5.7
	1200	1250	1000	1000	9.1
	1200	1250	1000	15000	3.9
	1200	1250	2000	2000	4.3

Appendix C Additional maintenance cost calculations

C.1 Whole-life costing

As mentioned in Section 4.2.1, the whole-life cost approach was considered to be the most appropriate method to calculate the additional maintenance costs due to trenching. Because whole-life costing considers different levels of expenditure at different times throughout the life of a project, it is necessary to make adjustments to account for changes in the value of money over time (Bull, 1993)[13]. There are various ways of explaining the time value of money but, in essence, it is more advantageous to pay costs later rather than earlier, because cash which does not have to be spent immediately can be invested and thereby increase in value by attracting interest. However, it also has to be remembered that whilst money that is invested will increase in value over time, the ‘purchasing power’ of that money will be offset to some extent by the effects of inflation.

In order to take account of these time dependent influences on the value of money, a notional interest rate, known as the discount rate, is used. This can be thought of as the *real* rate of increase in the value of money over time, i.e. the rate over and above the general inflation rate of the economy.

The discount rate, r, is calculated using the following equation:

$$r = \frac{1 + \text{interest rate}}{1 + \text{inflation rate}} - 1$$

If, for example, the interest received on an investment is 7% per annum while the rate of inflation is 3% per annum, then

$$r = \frac{1 + 0.07}{1 + 0.03} - 1 = 3.9\%$$

For transport infrastructure procurement, HM Treasury specifies that a discount rate of 3.5 per cent should be assumed for the first 30 years of any WLC assessment, reducing to 3.0 percent thereafter (HM Treasury, 2007)[22].

C.2 Whole-life costing example from Stage 2

Section 4.2.1 defines the whole-life cost of maintenance according to the following equation:

$$WLC = \sum_{t=1}^{N} \frac{c_t}{(1 + r / 100)^t} \qquad \text{(C.1)}$$

where

N = the analysis period (years)

r = the discount rate

t = the year the cost is incurred

c_t = the cost (maintenance cost)

Table 5 gives the additional maintenance costs on which the Stage 2 charge structures were based. The following explains how they were calculated.

C.2.1 Major carriageways

The cost of treating one kilometre of Major carriageway is the product of the treatment cost (£17.00/m^2), the carriageway width (7.3m) and its length (1000m). For the 'Baseline' scenario, it was assumed that carriageways are treated every 20 years, i.e. in years 0, 20 and 40. Year 40 is beyond the end of the accounting period, so the whole-life cost of the 'Baseline' scenario per km calculated from equation C.1 is:

$$WLC_{Baseline}(£) = 17.00 \text{ x } 7.3 \text{ x } 1000 \left[\frac{1}{(1.035)^0} + \frac{1}{(1.035)^{20}}\right] = 124{,}100 \text{ x } [1 + 0.503] = 186{,}468$$

It was assumed that trenching reduces the service life of maintenance treatments by 10 per cent. Therefore, it was assumed that trenched carriageways are treated every 18 years, i.e. in years 0, 18, 36 and 54. At end of the accounting period, the treatment laid in year 36 has a residual life of 14 years and, therefore, a residual value in year 40. The whole-life cost of the 'Trenched' scenario per km (equivalent to the 'Required' scenario in Sections 4.2.2 and 4.2.3) is given by the following equation:

$$WLC_{Trenched}(£) = 17.00 \text{ x } 7.3 \text{ x } 1000 \left[\frac{1}{(1.035)^0} + \frac{1}{(1.035)^{18}} + \frac{1}{(1.035)^{30}} \text{ x } \frac{1}{(1.03)^6} - \frac{1}{(1.035)^{30}} \text{ x } \frac{1}{(1.03)^{10}} \text{ x } \frac{14}{18}\right] = 124{,}100 \text{ x } \left[1 + 0.538 + 0.298 - 0.265 \text{ x } \frac{14}{18}\right] = 202{,}351$$

The last term in the square brackets is the product of the discount factor for year 40 and the residual life of the treatment laid in year 36 (14 years) at the start of year 40 expressed as a fraction of the service life of the treatment (18 years).

The additional maintenance costs per km due to trenching over the 40-year accounting period are calculated as follows:

$$WLC_{Trenched} - WLC_{Baseline}(£) = 202{,}351 - 186{,}468 = 15{,}882$$

To distribute these additional maintenance costs evenly over the accounting period, they are divided by the sum of the discount factors for years 1 to 39, i.e. 22.166. On this basis, the additional maintenance costs per km per year are estimated as follows:

$$\text{Additional maintenance costs/km/year } (£) = \frac{15{,}882}{22.166} = 716.5$$

C.2.2 Minor carriageways

The cost of treating one kilometre of Minor carriageway was assumed to be the same as that for treating one kilometre of Major carriageway. For the 'Baseline' scenario, it was assumed that Minor carriageways are treated every 40 years, i.e. in years 0 and 40. Year 40 is beyond the end of the accounting period, so the whole-life cost of the 'Baseline' scenario per km is:

$$WLC_{Baseline}(£) = 17.00 \text{ x } 7.3 \text{ x } 1000 \left[\frac{1}{(1.035)^0}\right] = 124{,}100$$

It was assumed that trenching reduces the service life of maintenance treatments by 5 per cent. Therefore, it was assumed that trenched carriageways are treated every 38 years, i.e. in years 0, 38 and 76. At end of the accounting period, the treatment laid in year 38 has a residual life of 36 years in year 40. The whole-life cost of the 'Trenched' scenario per km is given by the following equation:

$$WLC_{Trenched}(£) = 17.00 \times 7.3 \times 1000\ [\frac{1}{(1.035)^{0}} + \frac{1}{(1.035)^{30}} \times \frac{1}{(1.03)^{8}} - \frac{1}{(1.035)^{30}} \times \frac{1}{(1.03)^{10}} \times \frac{36}{38}] = 124{,}100 \times [1 + 0.281 - 0.265 \times \frac{36}{38}] = 127{,}835$$

The additional maintenance costs per km due to trenching over the 40-year accounting period are calculated as follows:

$$WLC_{Trenched} - WLC_{Baseline}(£) = 127{,}835 - 124{,}100 = 3{,}735$$

The additional maintenance costs per km per year are estimated as follows:

$$\text{Additional maintenance costs/km/year } (£) = \frac{3{,}735}{22.166} = 168.5$$

C.2.3 Footways

The cost of treating one kilometre of footway is the product of the treatment cost (£10.80/m^2), the footway width (1.8m) and its length (1000m). For the 'Baseline' scenario, it was assumed that footways are treated every 20 years, i.e. in years 0, 20 and 40. The whole-life cost of the 'Baseline' scenario per km is:

$$WLC_{Baseline}(£) = 10.80 \times 1.8 \times 1000\ [\frac{1}{(1.035)^{0}} + \frac{1}{(1.035)^{20}}] = 19{,}440 \times [1 + 0.503] = 29{,}210$$

It was assumed that trenching reduces the service life of maintenance treatments by 5 per cent. Therefore, it was assumed that footways are treated every 19 years, i.e. in years 0, 19, 38 and 57. At end of the accounting period, the treatment laid in year 38 has a residual life of 17 years in year 40. The whole-life cost of the 'Trenched' scenario per km is given by the following equation:

$$WLC_{Trenched}(£) = 10.80 \times 1.8 \times 1000\ [\frac{1}{(1.035)^{0}} + \frac{1}{(1.035)^{19}} + \frac{1}{(1.035)^{30}} \times \frac{1}{(1.03)^{8}} - \frac{1}{(1.035)^{30}} \times \frac{1}{(1.03)^{10}} \times \frac{17}{19}] = 19{,}440 \times [1 + 0.520 + 0.281 - 0.265 \times \frac{17}{19}] = 30{,}408$$

The additional maintenance costs per km due to trenching over the 40-year accounting period are calculated as follows:

$$WLC_{Trenched} - WLC_{Baseline}(£) = 30{,}408 - 29{,}210 = 1{,}198$$

The additional maintenance costs per km per year are estimated as follows:

$$\text{Additional maintenance costs/km/year } (£) = \frac{1{,}198}{22.166} = 54.1$$

C.3 Additional maintenance costs calculated in Stage 3

As explained in Section 8.3, in order to calculate the additional maintenance costs due to trenching it has been assumed that a new carriageway, which is constructed in year 0, is trenched from year 1. When carrying out the analyses, different scenarios have been considered concerning how the carriageway is trenched, how trenching reduces the service life of the carriageway, and how the carriageway is treated. These scenarios that are summarised below cover all the possible scenarios that apply in practice.

The trenching scenarios that have been assumed in the analyses that concern where and when a new carriageway is trenched are those referred to as the 'Different' and 'Same' trenching scenarios. They are defined as follows:

- 'Different' – each trench formed over the analysis period of 40 years is formed in a different area of carriageway. After the binder course has been replaced in a zone of influence, its service life becomes the same as that of an untrenched area
- 'Same' – each trench formed over a specific number of years is formed in a different area of carriageway. The areas are then trenched again in future years so the service life of each zone of influence is reduced even after the binder course has been replaced.

The scenarios that have been assumed in the analyses that concern the reduction in the service life of the binder course whenever a carriageway is trenched (at all times up to the untrenched service life) are referred to as the 'Full reduction' and 'Partial reduction' service life reduction scenarios. They are defined as follows:

- 'Full reduction' – trenching reduces the service life of the binder course whenever a carriageway is trenched
- 'Partial reduction' – trenching reduces the service life of the binder course only when its age when trenched does not exceed the untrenched service life multiplied by (1 – 'reference' service life reduction in per cent/100)

Table 15 shows the service lives of the binder course in trenched areas of Major carriageways with an untrenched service life of 20 years that were assumed in the analyses for the 'Full reduction' and 'Partial reduction' scenarios. The 'reference' service life reductions due to trenching are assumed to be 15 and 20 per cent. Table C 1 and Table C 2 show the same data for Major and Minor carriageways with untrenched service lives of 30 and 40 years, respectively.

The surface course must, of course, be replaced at the same time as the binder course, but further surface course replacements and surface treatments are normally required between binder course replacements. In order to calculate the additional maintenance costs, it has been necessary to make assumptions about:

- When these intermediate maintenance treatments are made
- Their extent relative to the zone of influence.

The treatment scenarios have been assumed that concern when surface course replacements and surface treatments are carried out and their extent are as follows:

- 'Several zones' - intermediate surface course replacements and surface treatments cover several zones of influence and their service lives are simply the service life of the binder course divided by one plus the number of intermediate maintenance treatments (rounding up to the nearest year)
- 'One zone' – surface course replacements are limited to only one zone of influence. If the untrenched service life of a surface course is X years, there is no service life reduction of the surface course in areas trenched in year X-2 or later. There is a service life reduction of one year in areas trenched in years X-4 and X-3, two years in areas trenched in years X-6 and X-5, etc. or until the service life reduction corresponds to the maximum for 'Several zones' scenario.

Note that the 'Several zones' treatment scenario is assumed for most of the analyses.

Table C 1 Service lives of binder course in trenched areas of Major and Minor carriageways – untrenched service life: 30 years

Year trenched	'Reference' service life reduction: 13.3%		'Reference' service life reduction: 20%	
	'Full reduction'	'Partial reduction'	'Full reduction'	'Partial reduction'
0	30	30	30	30
1	26	26	24	24
2	26	26	24	24
...	...	...	...	...
22	26	26	24	24
23	26	26	24	24
24	26	26	25	30
25	26	26	26	30
26	27	30	27	30
27	28	30	28	30
28	29	30	29	30
29	30	30	30	30

Table C 2 Service lives of the binder course in trenched areas of Major and Minor carriageways – untrenched service life: 40 years

Year trenched	'Reference' service life reduction: 15%		'Reference' service life reduction: 20%	
	'Full reduction'	'Partial reduction'	'Full reduction'	'Partial reduction'
0	40	40	40	40
1	34	34	32	32
2	34	34	32	32
...	...	...	...	...
30	34	34	32	32
31	34	34	32	32
32	34	34	33	40
33	34	34	34	40
34	35	40	35	40
35	36	40	36	40
36	37	40	37	40
37	38	40	38	40
38	39	40	39	40
39	40	40	40	40

Sections 8.4, 8.5 and 8.6 summarise the additional maintenance costs that have been calculated for Major and Minor carriageways and Footways, respectively, for different maintenance treatments and scenarios. The additional maintenance costs are given in Table C 3 to Table C 9 (i) for the binder course, (ii) for the surface course with surface treatments and (iii) totalled for the binder and surface courses and surface treatments. Because the 'Several zones' treatment scenario is assumed for most of the analyses, for clarity, only the cases when the 'One zone' treatment scenario is assumed are identified as such in the tables.

Section C.4 explains in detail how the additional maintenance costs were calculated.

C.4 Calculation tables

C.4.1 General

Table C 10 to Table C 33 represent Excel spreadsheets that have been used to calculate the additional maintenance costs for specific maintenance treatments and scenarios identified in Table C 3 to Table C 9.

The first column of each table is the discount rate for the year in which the highway is treated (see equation C.1). The year the highway is treated is given in column 2. As recommended for Treasury funded projects, a discount rate of 3.5 per cent has been assumed for years 1 to 30, and 3.0 per cent for the next 10 years (HM Treasury, 2007)[22].

The discount factors for each year that are shown in column 3 are the discount factor for the previous year divided by 1.0 plus the discount rate for the year. For example, the discount factor for year 2 is 0.93 (=1.000 / 1.035 / 1.035).

It has been assumed that a new section of highway is constructed in year 0. The 'Baseline' scenario is described in column 4, with 1 (in most cases) in a row indicating the year in which the highway is treated. Columns 5 to 44 correspond to the years in which areas of the highway are trenched.

The following describes the key assumptions made in Table C 10 to Table C 33.

C.4.2 Table C 10 (Rows 5 to 8 of Table C 3)

For the 'Baseline' scenario, the binder course is laid in years 0, 20 and 40. Year 40 is after the end of the accounting period so a binder course replacement in that year is not shown. Also, there is no residual life for the binder course laid in year 20 at the end of the period.

Because a new carriageway should not normally be trenched, the treatments in the first year, year 0, correspond to those for the 'Baseline' scenario.

The 'reference' service life reduction is 15 per cent. Therefore, the binder course laid in year 0 must be replaced in year 17 (c.f. year 20 for the 'Baseline' scenario) in areas trenched in year 1. It is assumed that a different area of the carriageway is trenched each year – the 'Different' scenario. Therefore, the area trenched in year 1 is not trenched again and it is assumed that the service life of the binder course laid in year 17 is the same as that for the 'Baseline' scenario, i.e. 20 years. The binder course laid in year 37 also has a service life of 20 years, so it has a residual life of 17 years at the end of the accounting period in year 40. The residual value of this treatment is represented by -0.85 (= -17/20) in the row corresponding to year 40.

As indicated in Table 15, areas trenched in years 2 to 16 have the same service life reduction as those trenched in year 1. Furthermore, for the 'Full reduction' scenario, it is assumed that the binder course is replaced in areas trenched in years 17 to 19 in years 18 to 20, respectively. For example, the binder course is replaced for the first time in year 19 in areas trenched in year 18. It is replaced for the second time in year 39, and the residual life of the binder course laid in year 39 at the end of the accounting period is 19 years and its residual value is represented by -0.95 (= -19/20).

It is assumed that no trenching is carried out in year 20 because of the resurfacing in that year, but that trenching continues from year 21 to year 39. The binder course is replaced for the first time in year 20 in areas trenched in years 21 to 39. The binder courses laid from year 20 in these areas have the same service lives as the binder courses laid from year 0 in areas trenched in years 1 to 19, respectively. Furthermore, the residual lives and residual values of the binder courses laid in years 37 to 39 in areas trenched in years 21 to 39 are the same as those of the binder courses laid at the same time in areas trenched in years 1 to 19.

The normalised net present values of the treatments described above, calculated according to equation C.1 and assuming a treatment cost of £1, are shown in the third last row of the table below the residual values. The penultimate row shows the normalised net present values for each area trenched area ('Trenched' scenario) minus those for untrenched areas ('Baseline' scenario). The sum of these additional net present values is the first figure in the last row of the table, i.e. 3.11.

The second and third figures in the last row of the table are the unit cost of the treatment and the area of Major carriageways that is trenched each year (from Table 13 and Table 14, respectively). The fourth figure in the last row is a scaling factor representing the area of the carriageway treated relative to the area trenched. A factor of 3 is assumed to take account of the zone of influence (see Appendix B), and an addition factor of 1.0526 is assumed to allow for the years in which no trenching is assumed (years 0 and 20). The product of these two factors, the scaling factor, is assumed to be 3.158 (= 3 x 40/38).

The net present value of the additional maintenance costs due to trenching over the accounting period of 40 years is the fifth figure in the final row of the table. It is the product of the first four figures in the final row. This total must be raised in equal amounts over a period of 40 years and is calculated by dividing the net present value by the sum of the discount factors for the 40 years (years 0 to 39) - the sixth figure in the final row. This gives the final figure in the final row which represents the amount that must be raised each year to cover the additional maintenance costs for the 'Different' and 'Full reduction' scenarios, i.e. £8.21m.

C.4.3 Table C 11 to Table C 13 (Rows 5 and 6 of Table C 3)

For the 'Baseline' scenario, the surface course is laid in years 0, 10, 20, 30 and 40. Year 40 is after the end of the accounting period so a surface course replacement in that year is not shown. Also, there is no residual life for the surface course laid in year 20 at the end of the period.

The 'reference' service life reduction is 15 per cent. As in Table C 10, since a new carriageway should not normally be trenched, the treatments in the first year, year 0, correspond to those for the 'Baseline' scenario. It is assumed that both the binder and surface courses must be replaced in year 17 (c.f. year 20 for the 'Baseline' scenario) in areas trenched in year 1. It is assumed that the deterioration in the surface condition due to trenching in year 1 also decreases the service life of the surface course by 15 per cent so the surface course must be replaced after 8.5 years, rounded up to year 9[1] (c.f. 10 years for the 'Baseline' scenario). It is assumed that surface course replacements between binder course replacements cover several zones of influence – the 'Several zones' scenario.

[1] For all calculations of the additional maintenance costs, whenever the 'reference' service life reduction requires a treatment after a number of years that is not an integer (e.g. 25 per cent of 30 years = 22.5 years), it has been assumed that the year in which the treatment is carried out is rounded up to the nearest integer (i.e. 23 years for the example shown).

It is assumed that a different area of the carriageway is trenched each year – the 'Different' scenario. Therefore, the area trenched in year 1 is not trenched again and it is assumed that the service life of the surface course laid in years 17, 27 and 37 is the same as that for the 'Baseline' scenario. The surface course laid in year 37 has a residual life of 7 years at the end of the accounting period in year 40, and its residual value is represented by -0.7 (= -7/10) in the row corresponding to year 40.

As assumed for Table C 10, the surface course in areas trenched in years 2 to 16 must be replaced in year 17. Similarly, for the 'Full reduction' scenario, the surface course must be replaced in areas trenched in years 17 to 19 in years 18 to 20, respectively. The area trenched in year 18, for example, must be treated in years 19 and 39. The residual life of the surface course laid in year 39 at the end of the accounting period is 9 years and its residual value is represented by -0.9 (= -9/10).

In Table C 11, it is assumed that the surface course is replaced in year 9 in areas trenched in years 2 to 17, and in year 10 in areas trenched in year 18 and 19, i.e. between binder course replacements.

It is assumed that no trenching is carried out in year 20 because of the resurfacing in that year, but that trenching continues from year 21 to year 39. The surface course is replaced in years 10 and 20 in the areas trenched in years 21 to 39. The surface courses laid from year 20 in these areas have the same service lives are those laid from year 0 in areas trenched in years 1 to 19, respectively. The residual lives and residual values of the surface courses laid in years 37 to 39 in areas trenched in years 21 to 39 are also the same as those of the surface courses laid at the same time in areas trenched in years 1 to 19. With these assumptions, the additional maintenance costs are estimated to be £9.90m for the 'Different', 'Full reduction' and 'Several zones' scenarios.

In Table C 12, it is assumed that surface course replacements are limited to the zone of influence of each trench (the 'One zone scenario) rather can covering several zones of influence (the 'Several zones' scenario) as assumed in Table C 11. In Table C 12, it is assumed that the surface course is replaced in year 9 in areas trenched in years 1 to 7, and in year 10 in areas trenched in years 8 to 19. Again, when similar assumptions are made for surface course replacements in areas trenched in years 21 to 39, the additional maintenance costs are estimated to be £9.26m for the 'Different', 'Full reduction' and 'One zone' scenarios, i.e. 6 per cent lower than those in Table C 11.

In Table C 10 to Table C 12, the reduction in the service life of the binder course corresponds to the 'Full reduction' scenario (c.f. column 2 of Table 15). In Table C 13, the 'Partial reduction' scenario is assumed (c.f. column 3 of Table 15). No service life reductions are assumed for areas trenched in years 17 to 19 and years 37 to 39. For the 'Different', 'Partial reduction' and 'One zone' scenarios, the additional maintenance costs are estimated to be £8.75m.

C.4.4 Table C 14 (Row 18 of Table C 3)

The 'Baseline' scenario is the same as that assumed for Table C 12 (and Table C 11). The 'reference' service life reduction is 30 per cent (c.f. 15 per cent in Table C 12) - the highest service life reduction considered in the analyses. As in Table C 12, the 'Full reduction' and 'One zone' scenarios are assumed.

Trenching in years 1 to 13 is assumed to reduce the service life of the binder course laid in year 0 to 14 years. Therefore, the binder course must be replaced for the first time and the surface course must be replaced for the second time in year 14. In the areas trenched in years 14, 15, 16, 17, 18 and 19, the binder and surface courses must be replaced in years 15, 16, 17, 18, 19 and 20, respectively.

For the 'One zone' scenario, it is assumed that the surface course is replaced for the first time in year 7 in areas trenched in years 1 to 3, in year 8 in areas trenched in years 4 to 5, in year 9 in areas trenched in years 6 to 7, and in year 10 in areas trenched in years 8 to 19 (see Section 8.3.3). Therefore, the surface course laid in year 10 in areas trenched in years 8 to 13 is replaced after only 4 years. Similarly, for example, the surface course laid in year 9 in areas trenched in years 6 and 7 is replaced after 5 years.

The surface course is replaced in years 10 and 20 in the areas trenched in years 21 to 39. The surface courses laid from year 20 in these areas have the same service lives as those laid from year 0 in areas trenched in years 1 to 19, respectively. The residual lives and residual values of the surface courses laid in years 37 to 39 in areas trenched in years 21 to 39 are also the same as those of the surface courses laid at the same time in areas trenched in years 1 to 19. With these assumptions, the additional maintenance costs for the 'Different', 'Full reduction' and 'One zone' scenarios are estimated to be £17.41m. Those for the case when the surface course replacements cover several zones of influence (the 'Several zones' scenario) are 11 per cent higher at £19.40m (see row 17 of Table C 3).

C.4.5 Table C 15 and Table C 16 (Row 7 and 8 of Table C 3)

The 'Baseline' scenario for the surface course is the same as that for Table C 11, except the surface course replacements in years 10 and 30 that are between binder course replacements (c.f. Table C 10) are replaced by one surface treatment in Table C 15 and by two surface treatments in Table C 16. Because, for Major carriageways, the cost of a surface treatment is £5 whereas a surface course replacement costs £15, the surface treatments are represented by 0.33 (= 5/15) rather than 1 in the tables. The surface course laid in year 20 and the surface treatment laid in year 30 have no residual life at year 40.

The surface course replacements in areas trenched in years 1 to 19 and 21 to 39 are identical to those in Table C 11 except, as for the 'Baseline' scenario, there are surface treatments instead of surface course replacements between binder course replacements. It is assumed that the surface course is replaced in years 17 and 37 in areas trenched in years 1 to 16, and that the residual value of the surface course laid in year 37 at the end of the accounting period is represented by -0.85 (= -17/20). It is assumed that the surface course is replaced in years 18 to 20 and years 38 to 40 in areas trenched in years 17 to 19, respectively. The residual value of the surface course laid in year 39, for example, is represented by -0.95 (=-19/20).

In Table C 15, it is assumed that in areas trenched in years 1 to 16 there is one surface treatment between surface course replacements in year 9 (8.5 rounded up to 9). Similarly, it is assumed that in areas trenched in years 17, 18 and 19 there is one surface treatment in years 9, 10 (9.5 rounded to 10) and 10, respectively.

In Table C 16, it is assumed that in areas trenched in years 1 to 16 there are surface treatments in years 6 (5.67 rounded up to 6) and 12 (11.33 rounded up to 12). In areas trenched in years 17, 18 and 19 there are surface treatments in years 6 and 12, in years 7 and 13, and in years 7 and 14, respectively.

In Table C 15 and Table C 16, as in Table C 11, it is assumed that surface treatments are not limited to the zone of influence. Rather, when there is surface deterioration, it is assumed that the area treated covers the zones of influence of areas trenched over several years (the 'Several zones' scenario), including areas trenched in years 1 to 9. All of the surface treatments are replaced before the end of the accounting period so they have no residual life or residual value at year 40.

The surface course is replaced in years 10 and 20 in the areas trenched in years 21 to 39. The surface courses and surface treatments laid from year 20 in these areas have the same service lives are those laid in year 0 in areas trenched in years 1 to 19, respectively. The residual lives and residual values of the surface courses laid in years 37 to 39 in areas trenched in years 21 to 39 are also the same as those of the surface courses laid at the same time in areas trenched in years 1 to 19. With these assumptions, the additional maintenance costs for the 'Different', 'Full reduction' and

'Several zones' scenarios are estimated to be £6.10m and £7.10m in Table C 15 and Table C 16, respectively.

C.4.6 Table C 17 (Row 25 to 28 of Table C 3)

The 'Baseline' scenario for Table C 17 is the same as that for Table C 10.

The 'reference' service life reduction is 15 per cent. Therefore, the binder course laid in year 0 is replaced in year 17 (c.f. year 20 for the 'Baseline' scenario) in areas trenched in years 1 to 13. However, it is assumed that no new areas are trenched after year 13 – the 'Same' scenario, but that the areas first trenched in years 1 to 13 are trenched again. Note that this assumes that some areas trenched in years 1 to 13 are trenched twice before the binder course is replaced in year 17 (i.e. in years 14 to 16).

It is assumed that the service life of the binder course laid in year 17 is also 17 years, i.e. the same as the binder course laid in year 0. This is because it is assumed that the areas trenched in years 1 to 13 (and in years 14 to 16) are trenched again in years 17 to 33 and in years 34 to 51. Similarly, it is assumed that the service life of the binder course laid in year 34 is 17 years because of the further trenching. Therefore, the binder course laid in year 34 has a residual life of 11 years at year 40 and its residual value is represented by -0.65 (= -11/17).

As in Table C 10, the second and third figures in the last row of Table C 17 are the unit cost of the treatment and the area of the carriageway that is trenched each year. The fourth figure in the last row is a scaling factor representing the area of the carriageway treated relative to the area trenched. A factor of 3 is assumed to take account of the zone of influence, and an addition factor of 1.0256 is assumed to allow for year 0 when there is no trenching (trenching is assumed in all other years). The product of these two factors, the scaling factor, is assumed to be 3.077 (= 3 x 40/39).

Although in Table C 17 it is assumed that the area of the carriageway affected by trenching is only one third of the area assumed in Table C 10, the additional maintenance costs for the 'Same' and 'Full reduction' scenarios are only 19 per cent lower than those for the 'Different' and 'Full reduction' scenarios, i.e. £6.67m compared to £8.21m.

C.4.7 Table C 18 (Row 26 of Table C 3)

The 'Baseline' scenario in Table C 18 is the same as that in Table C 11 to Table C 13.

The 'reference' service life reduction is 15 per cent. Therefore, the binder course laid in year 0 is replaced in year 17 (c.f. year 20 for the 'Baseline' scenario) in areas trenched in years 1 to 13. However, it is assumed that no new areas are trenched after year 13 – the 'Same' scenario, but that the areas trenched in years 1 to 13 (and in years 14 to 16) are trenched again in years 17 to 33 and in years 34 to 51, respectively.

Applying the principles explained in Section 8.3.3 for the 'One zone' scenario, it is assumed that the surface course is replaced in year 9 in areas trenched in years 1 to 7, and in year 10 in areas trenched in years 8 to 13. Similar assumptions are made when the areas trenched in years 1 to 13 (and in years 14 to 16) are trenched again in years 17 to 33 and in years 34 to 51. The service life of the surface course laid in year 34 in areas first trenched in years 1 to 7 is 9 years and its residual value is represented by -0.33 (= -3/9). The service life of the surface course laid in year 34 in areas first trenched in years 8 to 13 is 10 years and its residual value is represented by -0.40 (= -4/10).

Although in Table C 18 it is assumed that the area of the carriageway affected by trenching is only one third of the area assumed in Table C 12, the additional maintenance costs for the 'Same', 'Full reduction' and 'One zone' scenarios are only 21 per cent lower than those for the ‘’Different’, ‘Full reduction’ and ‘One zone’ scenarios, i.e. £7.28m compared to £9.26m.

C.4.8 Table C 19 (Rows 17 to 24 of Table C 4)

For the ‘Baseline’ scenario in Table C 19, it is assumed that the binder course is laid in years 0 and 30. The residual life of the binder course laid in year 30 at year 40 is 20 years and its residual value is represented by -0.67 (= -20/30). It is assumed that there is no trenching in year 0 or year 30.

The ‘reference’ service life reduction is 20 per cent. Therefore, the binder course laid in year 0 must be replaced in year 24 (= 0.8 x 30 = 24) in areas trenched in years 1 to 23. It is assumed that a different area of the carriageway is trenched each year – the ‘Different’ scenario. Therefore, the service life of the binder course laid in year 24 is the same as that for the ‘Baseline’ scenario and its residual value at year 40 is represented by -0.47(= -14/30).

The binder course is replaced in years 25 to 30 (and years 55 to 60) in areas trenched in years 24 to 29, respectively. For example, the binder course is replaced in year 28 in areas trenched in year 27 and its residual value is represented by -0.60 (= -18/30).

It is assumed that the binder course is replaced in years 30 and 54 in areas trenched in years 31 to 40. The residual value of the binder course laid in year 30 in those areas is, therefore, represented by -0.58 (= -14/24).

The area scaling factor is assumed to be 3.158 to take account of the zone of influence and the years in which no trenching is assumed (years 0 and 30); the same value as in Table C 10 to Table C 16. The additional maintenance costs for the ‘Different’ and ‘Full reduction’ scenarios are estimated to be £9.56m.

C.4.9 Table C 20 and Table C 21 (Rows 17 and 18 of Table C 4)

For the ‘Baseline’ scenario, it is assumed that the surface course is laid in years 0, 15 and 30. The residual life of the surface course laid in year 30 is 5 years and its residual value is represented by -0.33 (= -5/15). It is assumed that there is no trenching in years 0 and 30.

The ‘reference’ service life reduction is 20 per cent. As the binder course in Table C 19, the surface course laid in year 0 must be replaced in year 24 in areas trenched in years 1 to 23, and in years 25 to 30 in areas trenched in years 24 to 29, respectively.

In Table C 20, it is assumed that surface course replacements cover several zones of influence – the ‘Several zones’ scenario. Therefore, it is assumed that the surface course is replaced for the first time in year 12 in areas trenched in years 1 to 23, in year 13 in areas trenched in years 24 and 25, in year 14 in areas trenched in years 26 and 27, and in year 15 in areas trenched in years 28 and 29. It is assumed that the surface course is replaced for the third and fourth times in years 39 and 54 in areas trenched in years 1 to 23. The residual life of surface course laid in year 39 is represented by -0.93 (= -14/15). The surface course is replaced for the third time in years 40 to 45 in areas trenched in years 24 to 29, respectively. The residual values of the surface courses laid in years 25 to 30 in these areas are represented by values that range from 0 to -0.33 (= -5/15).

The surface course is replaced for the first and second times in years 15 and 30 in areas trenched in years 31 to 39. It is replaced for the third time in year 42 so the residual value of the surface course laid in year 30 is represented by -0.17 (= -2/12). The additional maintenance costs are estimated to be £12.00m for the ‘Different’, ‘Full reduction’ and ‘Several zones’ scenarios.

In Table C 21, it is assumed that surface course replacements are limited to the zone of influence only (the ‘One zone’ scenario), and the ‘Partial reduction’ scenario is assumed (see column 5 of Table C 1). The surface course is first replaced in year 12 in areas trenched in years 1 to 8, in year 13 in areas trenched in years 9 and 10, in year 14 in areas trenched in years 11 and 12, and in year 15 in areas trenched in years 13 to 29 (see Section 8.3.3). The surface course is replaced for the second and third times in areas trenched in years 1 to 23 as assumed in Table C 20. However, no service life reduction is assumed in areas trenched in years 24 to 29; the surface course replacements correspond to those for the 'Baseline' scenario.

The surface course is replaced for the first and second times in years 15 and 30 in area trenched in years 31 to 39. The surface course is replaced for the third time in year 42 in areas trenched in years 31 to 38, and in year 43 in areas trenched in year 39 (c.f. areas trenched in years 1 to 9). Therefore, the residual value of the surface course laid in year 30 in areas trenched in year 39 is represented by -0.23 (= -3/13), compared to -0.17 (= -2/12) in areas trenched in years 31 to 38. The additional maintenance costs are estimated to be £9.50m for the 'Different', 'Partial reduction' and 'One zone' scenarios, i.e. 21 per cent less than those estimated in Table C 20.

C.4.10 Table C 22 and Table C 23 (Rows 34 and 36 of Table C 4)

The 'Baseline' scenario in Table C 22 is the same as that in Table C 20. It is assumed that surface course replacements are limited to the zone of influence only (the 'One zone' scenario), and that the 'reference' service life reduction is 30 per cent.

Applying the principles explained in Section 8.3.3, it is assumed that the surface course is replaced for the first time in year 11 in areas trenched in years 1 to 6, in year 12 is areas trenched in years 7 and 8, in year 13 in areas trenched in years 9 and 10, in year 14 in areas trenched in years 11 and 12, and in year 15 in areas trenched in years 13 to 29. It is assumed that the surface course is replaced for the second time in year 21 (i.e. when the binder course is replaced) in areas trenched in years 1 to 20, and in years 22 to 30 in areas trenched in years 21 to 29. The surface course is replaced for the third and fourth times 15 and 30 years later in those areas. The residual values of the surface courses laid in years 36 to 39 in areas trenched in years 1 to 23 range from -0.73 (= -11/15) to -0.93 (= -14/15). The residual values of the surface courses laid in years 25 to 30 in areas trenched in years 24 to 29 range from 0 to -0.33 (= -5/15).

The surface course is replaced for the first and second times in years 15 and 30 in areas trenched in years 31 to 39. It is replaced for the third time in year 41 in areas trenched in years 31 to 36, in year 42 in areas trenched in years 37 and 38, and in year 43 in areas trenched in year 39. The residual values of the surface courses laid in year 30 in those areas are represented by -0.09 (= -1/11), -0.17 (= -2/12) and -0.23 (= -3/13), respectively. The additional maintenance costs are estimated to be £15.29m for the 'Different', 'Full reduction' and 'One zone' scenarios.

For the 'Baseline' scenario in Table C 23, it is assumed that the surface course is replaced every 10 years, i.e. twice between binder course replacements. It is assumed that surface course replacements are limited to the zone of influence only ('Zone Only' scenario) and that the 'reference' service life reduction is 30 per cent. Applying the principles explained in Section 8.3.3, it is assumed that the surface course is first replaced in year 7 in areas trenched in years 1 to 3, in year 8 in areas trenched in years 4 and 5, in year 9 in areas trenched in years 6 and 7, and in year 10 in areas trenched in years 8 to 29. The same principles are assumed when the surface course is replaced for a second time, but a further assumption is made that the surface course is not replaced sooner than mid way between the first replacement and the third replacement when the surface course is replaced at the same time as the binder course. On this basis, it is assumed that the surface course is replaced for the second time in year 14 in areas trenched in years 1 to 3, in year 15 in areas trenched in years 4 to 7, in year 16 in areas trenched in years 8 to 11, in year 17 in areas trenched in years 12 and 13, in year 18 in areas trenched in years 14 and 15 and in year 19 in areas trenched in years 16 and 17

It is assumed that the surface course is replaced in year 20 in areas trenched in years 21 to 29 and again when the binder course is replaced in years 22 to 30, respectively. However, this assumption and the assumptions made for areas trenched in years 12 to 17 imply that some surface course replacements are closely spaced. For this reason, it is assumed that the surface course is only replaced once before the binder course is replaced in areas trenched in years 18 to 20, i.e. in year 10. It should be noted that the close spacing of some surface course replacements is exaggerated when the 'reference' service life reduction is 30 per cent (the highest considered in Stage 3). It is considered more likely that surface course replacements cover several zones of influence - the 'Several zones' scenario, and that surface course replacements are mid way between binder course replacements.

The surface course is replaced for the fourth and fifth times 10 and 20 years after the binder course is replaced in areas trenched in years 1 to 29. The residual values of the surface courses laid in years 31 to 39 range from -0.10 (= -1/10) to -0.90 (= -9/10).

The surface course is replaced for the first, second and third times in years 10, 20 and 30 in areas trenched in years 31 to 39. It is replaced for the fourth time in year 37 in areas trenched in years 31 to 33, in year 38 in areas trenched in years 34 and 35, in year 39 in areas trenched in years 36 and 37, and in year 40 in areas trenched in years 38 and 39. The surface course is replaced for the fifth time in year 44 in areas trenched in years 31 to 33, in year 45 in areas trenched in years 34 to 37, and in year 46 in areas trenched in years 38 and 39. The residual values of the surface courses laid in years 37 to 39 are represented by -0.57 (= -4/7), -0.71 (= -5/7) and -0.83 (= -5/6). The additional maintenance costs are estimated to be £19.83m for the 'Different', 'Full reduction' and 'One zone' scenarios.

C.4.11 Table C 24 and Table C 25 (Rows 21 and 22 of Table C 4)

For the 'Baseline' scenario, it is assumed that the binder and surface courses are laid in years 0 and 30, the surface course is replaced between binder course replacements in year 15 (and year 45), and there are surface treatments between surface course replacements in years 8 (7.5 rounded up to 8), 23 (22.5 rounded up to 23) and 38 (37.5 rounded up to 38). The tables show the additional maintenance costs for both the surface courses and surface treatments. As in Table C 15 and Table C 16, the surface treatments are represented by 0.33. The residual life of the surface course laid in year 30 is 5 years at year 40. The residual life of the surface treatment in year 38 is 7 years at year 40. The residual value of both treatments is represented by -0.57 (= -5/15 + -5/7 x 1/3).

The 'reference' service life reduction is 20 per cent. In Table C 24, the 'Different' and 'Several zones' scenarios are assumed. The surface course replacements in areas trenched in years 1 to 29 and in years 31 to 39 are the same as those in Table C 20. The surface treatments are mid way between the surface course replacements in these areas. The residual value of the surface course laid in year 39 in areas trenched in years 1 to 23 is the same as that in Table C 20 – no surface treatments remain at year 40. The residual values of the surface courses and surface treatments in areas trenched in years 24 to 29 are calculated in the same way as explained previously and range from 0 to -0.57. For example, the residual value of the surface course laid in year 28 and the surface treatment in year 36 in areas trenched in year 27 that are replaced in year 43 is represented by -0.34 (= -3/15 + -3/7 x 1/3). Similarly, the residual value of the surface course laid in year 30 and the surface treatment in year 38 in areas trenched in years 31 to 39 that are replaced in year 42 is represented by -0.28 (= -2/12 + -2/6 x 1/3). The additional maintenance costs are estimated to be £18.23m for the 'Different', 'Full reduction' and 'Several zones' scenarios.

The assumptions made in Table C 25 are the same as those made in Table C 24, except that it is assumed that surface course replacements are in the zone of influence only ('One zone' scenario) as in Table C 21. It is assumed that surface treatments are mid way between surface course replacements. The residual values of the surface course and surface treatment in areas trenched in years 1 to 38 are the same as those in Table C 24. In Table C 25, the surface course is replaced for the third time in year 43 in areas trenched in year 39, therefore, the residual value of the surface course and surface treatment is represented by -0.40 (= -3/13 + -3/6 x 1/3). The additional maintenance costs are estimated to be £15.74m for the 'Different', 'Full reduction' and 'One zone' scenarios, i.e. 14 per cent less than those for the 'Different', 'Full reduction' and 'Several zones' scenarios.

C.4.12 Table C 26 and Table C 27 (Row 14 and 15 of Table C 6)

The 'Baseline' scenario for the surface course is the same as that for Table C 20, except that the surface course replacements at years 10 and 30 that are between binder course replacements (c.f. Table C 19) are replaced by one surface treatment in Table C 26 and two surface treatments in Table C 27. Both tables apply to Minor carriageways. For such carriageways, the cost of a surface treatment is £5 whereas a surface course replacement costs £12. Therefore, the surface treatments are represented by 0.42 (= 5/12). In both tables, the surface course laid in year 30 has a residual life of 20 years at year 40 and its residual value is represented by -0.67 (= -20/30). No surface treatments remain at year 40.

The 'reference' service life reduction is 20 per cent, and the 'Different' and 'Full reduction' scenarios are assumed. The surface course replacements in areas trenched in years 1 to 29 and 31 to 39 are identical to those in Table C 20 except, as for the 'Baseline' scenario, there are surface treatments instead of surface course replacements between binder course replacements. It is assumed that the surface course laid in year 24 in areas trenched in years 1 to 23 is replaced in year 54, and its residual value is represented by -0.47 (= -14/30). It is assumed that the surface course is replaced in years 25 to 30 and in years 55 to 60 in areas trenched in years 24 to 29. The residual values of the surface courses laid in years 25 to 30 range from -0.50 (= -15/30) to -0.67 (= -20/30). The surface course laid in year 30 in areas trenched in years 31 to 39 is replaced in year 54 and its residual value is represented by -0.58 (= -14/24).

In Table C 26, one surface treatment is assumed mid way between surface and binder course replacements. The second surface treatment is in year 39 in areas trenched in years 1 to 23, and its residual value is represented by -0.39 (= -14/15 x 5/12). The residual value of both the surface treatment and the surface course in areas trenched in years 1 to 23 is represented by -0.86 (= -0.47 + -0.39). There are no surface treatments at the end of the accounting period in other areas.

In Table C 27, two surface treatments are assumed between surface and binder course replacements. The third and fourth surface treatments are in years 34 and 44, respectively, in areas trenched in years 1 to 23. The residual value of the surface treatment in year 34 is represented by -0.17 (= -4/10 x 5/12). The residual value of both the surface treatment and the surface course in those areas is represented by -0.63 (= -0.47 + -0.17). The third and fourth surface treatments are from years 35 to 40 and from years 45 and 50, respectively, in areas trenched in years 24 to 29. The residual values of the third surface treatment in years 35 to 39 in areas trenched in years 24 to 28 range from -0.21(= - 5/10 x 5/12) to -0.38 (= -9/10 x 5/12). The residual values of both the surface course and surface treatments in those areas range from -0.71 (= -0.50 + -0.21) to -1.01 (= -0.63 + -0.38). No surface treatments remain at year 40 in areas trenched in year 29.

In Table C 27, the third and fourth surface treatments are in years 38 and 46, respectively, in areas trenched in years 31 to 39. The residual value of the surface treatment in year 38 is represented by -0.31 (= -6/8 x 5/12) and the residual value of both the surface treatment and surface course in those areas is represented by -0.90 (= -0.58 + -0.31).

Assuming £12 for the unit cost of the surface course (see Table 13) and that the area of Minor carriageways that is trenched each year is 1,394,451m^2 (see Table 14), the additional maintenance costs are estimated to be £10.84m and £17.77m in Table C 26 and Table C 27, respectively, for the ‘Different’, ‘Full reduction’ and ‘Several zones’ scenarios.

C.4.13 Table C 28 (Row 33 of Table C 6)

The ‘Baseline’ scenario is the same as that in Table C 20.

The ‘reference’ service life reduction is assumed to be 13.33 per cent so that the time between binder course replacements is a whole number of years in most areas (0.8667 x 30 = 26, c.f. 0.85 x 30 = 26.5). It is assumed that surface course replacements are limited to the zone of influence only (the ‘One zone’ scenario) and that no new areas are trenched in years 20 to 39 – the ‘Same’ scenario, but that the areas previously trenched in years 1 to 19 are trenched again.

It is assumed that the surface course is replaced for the second time in year 26 in areas trenched in years 1 to 19 at the same time as the binder course. Applying the principles explained in Section 8.3.3, it is assumed that the surface course is replaced for the first time in year 13 in areas first trenched in years 1 to 10, in year 14 in areas first trenched in years 11 and 12, and in year 15 in areas first trenched in years 13 to 19. Note that it is assumed that some areas trenched in years 1 to 19 are trenched twice before the binder course is replaced in year 26. For the ‘Same’ scenario, it is assumed that the surface course is replaced for a third time (after the surface and binder course have been replaced in year 26) in year 39 in areas first trenched in years 1 to 10, in year 40 in areas first trenched in years 11 and 12, and in year 41 in areas first trenched in years 13 to 19. The surface course is replaced for a fourth time in year 52 when the binder course is again also replaced.

The residual value of the surface course laid in year 39 in areas first trenched in years 1 to 10 is represented by -0.92 (= -12/13). The residual value of the surface course laid in year 26 in areas first trenched in years 13 to 19 is represented by -0.07 (= -1/15). The surface course laid in year 26 in areas trenched in years 11 and 12 has no residual value at year 40.

The area scaling factor is assumed to be 3.077 (= 3 x 40/39) because no trenching is assumed in year 0. The additional maintenance costs are estimated to be £7.68m for the ‘Same’, ‘Full reduction’ and ‘One zone’ scenarios.

C.4.14 Table C 29 (Row 23 of Table C 7)

For the ‘Baseline’ scenario, it is assumed that the binder and surface courses are laid in years 0 and 40 and that a surface course is also laid in year 20.

The ‘reference’ service life reduction is 30 per cent. Therefore, the surface and binder course are replaced in year 28 (= 0.7 x 40) in areas trenched in years 1 to 27, and in years 29 to 40 in areas trenched in years 28 to 39, respectively.

It is assumed that a different area of the carriageway is trenched each year – the ‘Different’ scenario, and that the surface course replacements are limited to the zone of influence - ‘One zone’ scenario. Therefore, applying the principles explained in Section 8.3.3, it is assumed that the surface course is replaced for the first time in year 14 in areas trenched in years 1 to 7, in year 15 in areas trenched in years 8 and 9, in year 16 in areas trenched in years 10 and 11, in year 17 in areas trenched in years 12 and 13, in year 18 in areas trenched in years 14 and 15, in year 19 in areas trenched in years 16 and 17, and in year 20 in areas trenched in years 18 to 39.

The surface course is replaced for the third time in year 48 in areas trenched in years 1 to 27 so the residual value of the surface course laid in year 28 in those areas is represented by -0.40 (= -8/20). The surface course is replaced for the third time in years 49 to 59 in areas trenched in years 28 to 38, respectively. The residual values of the surface courses laid in years 29 to 39 in those areas range from -0.45 (= -9/20) to -0.95 (= -19/20). The surface course laid in year 20 in areas trenched in year 39 has no residual value.

The area scaling factor is assumed to be 3.077 (= 3 x 40/39) because no trenching is assumed in year 0. The additional maintenance costs are estimated to be £23.83m for the ‘Different’, ‘Full reduction’ and ‘One zone’ scenarios.

C.4.15 Table C 30 (Row 14 of Table C 7)

For the ‘Baseline’ scenario, it is assumed that the binder and surface courses are laid in years 0 and 40 and that there is a surface treatment in year 20 represented by 0.42.

The ‘reference’ service life reduction is 20 per cent. Therefore, the binder and surface courses are replaced in year 32 (= 0.8 x 40) in areas trenched in years 1 to 31, and in years 33 to 40 in areas trenched in years 32 to 39, respectively. The residual value of the binder and surface courses laid in year 32 is represented by -0.80 (= -32/40), and the residual values of those laid in years 33 to 39 range from -0.83 (= -33/40) to -0.98 (= -39/40). The binder and surface courses laid in year 0 in areas trenched in year 39 have no residual life or residual value.

One surface treatment is assumed mid way between binder and surface course replacements, e.g. in year 16 in areas trenched in years 1 to 31. No surface treatments remain at year 40 so none have a residual value.

The area scaling factor is assumed to be 3.077 (= 3 x 40/39) because no trenching is assumed in year 0. The additional maintenance costs are estimated to be £12.32m for the ‘Different’, ‘Full reduction’ and ‘Several zones’ scenarios.

C.4.16 Table C 31 (Row 3 of Table C 8)

For the ‘Baseline’ scenario, it is assumed that the binder and surface courses are laid in years 0 and 30. The residual value of the binder and surface courses laid in year 30 is represented by –0.67 (= -20/30).

The ‘reference’ service life reduction for both the binder and surface courses is 10 per cent. Therefore, for the ‘Different’ trenching scenario, it is assumed that the binder and surface courses are replaced in year 27 (= 0.9 x 30) in areas trenched in years 1 to 26, and in years 28 to 30 in areas trenched in years 27 to 29, respectively. The residual value of the binder and surface courses laid in year 27 is represented by -0.57 (= -17/30). The residual values of those laid in years 28 to 30 range from -0.60 (= -18/30) to -0.67 (= -20/30).

In areas trenched in years 31 to 39, the binder and surface course are replaced in years 30 and 57. The residual value of the binder and surface courses laid in year 30 in these areas is represented by -0.63 (= -17/27).

It is assumed that there is a surface treatment between binder and surface course replacements in year 14 in areas trenched in years 1 to 13 in order to reduce the visual disbenefits in those areas. No surface treatments are assumed in areas trenched in years 14 to 29 because they are considered inappropriate when they are carried out when the age of the binder and surface courses is more than half their service life, i.e. 14 years or more. Because, for footways, the cost of a surface treatment is £4 whereas a binder and surface course replacement costs £16, the surface treatment in year 14 is represented by 0.25 (= 4/16) in the tables.

It is assumed that there are similar surface treatments in year 44 in areas trenched in years 31 to 39, but these are outside the accounting period.

The area scaling factor is assumed to be 3.158 (= 3 x 40/38) because no trenching is assumed in years 0 and 30. Assuming £16 for the unit cost of the surface and binder courses (see Table 13) and that the area of footways that is trenched each year is 2,471,527m^2 (see Table 14), the additional maintenance costs are estimated to be £21.73m for the 'Different', 'Full reduction' and 'Several zones' scenarios.

C.4.17 Table C 32 (Row 4 of Table C 8)

The 'Baseline' scenario and the 'reference' service life reduction in Table C 32 are the same as those in Table C 31, but the 'Same' trenching scenario is assumed.

It is assumed that the binder and surface courses are replaced in year 27 in areas trenched in years 1 to 19. It is assumed that no new areas are trenched in years 20 to 39 but that the areas trenched in years 1 to 19 are trenched again. The service life of the binder and surface courses laid in year 27 is, therefore, 27 years and their residual value is represented by -0.52 (= -14/27). Note that this assumes that some areas trenched in years 1 to 19 are trenched twice before the binder and surface courses are replaced in year 27 (i.e. in years 20 to 26).

As in Table C 31, it is assumed that there is a surface treatment in year 14 between binder and surface course replacements in areas trenched in years 1 to 13 in order to reduce the visual disbenefits in those areas. Also, as in Table C 31, no surface treatments are assumed in areas trenched in years 14 to 19 because they are considered inappropriate when they are carried out when the age of the binder and surface courses is more than half their service life, i.e. 14 years or more.

The area scaling factor is assumed to be 3.077 (= 3 x 40/39) because no trenching is assumed in year 0. The additional maintenance costs are estimated to be £19.16m for the 'Same', 'Full reduction' and 'Several zones' scenarios.

C.4.18 Table C 33 (Row 3 of Table C 9)

For the 'Baseline' scenario, it is assumed that the binder and surface courses are laid in years 0 and 40.

The 'reference' service life reduction for the binder and surface courses is 10 per cent. Therefore, for the 'Different' trenching scenario, it is assumed that the binder and surface courses are replaced in year 36 (= 0.9 x 40) in areas trenched in years 1 to 35, and in years 37 to 40 in areas trenched in years 36 to 39, respectively. The residual value of the binder and surface courses laid in year 36 is represented by -0.90 (= -36/40). The residual values of those laid in years 37 to 39 range from -0.93 (= -37/40) to -0.98 (= -39/40). The binder and surface courses laid in year 0 in areas trenched in year 39 have no residual life or residual value.

It is assumed that there is a surface treatment in year 18 between binder and surface course replacements in areas trenched in years 1 to 17. No surface treatments are assumed in areas trenched in years 18 to 39 because they are considered inappropriate when they are carried out when the age of the binder and surface courses is more than half their service life, i.e. 18 years or more.

The area scaling factor is assumed to be 3.077 (= 3 x 40/39) because no trenching is assumed in year 0. The additional maintenance costs are estimated to be £24.53m for the 'Different', 'Full reduction' and 'Several zones' scenarios.

Table C 3 Additional maintenance costs for Major carriageways (untrenched service life of binder course: 20 years)

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance	Total additional maintenance costs (£m)
1	10	0, 20, 40	0, 10, 20, 30, 40	Different	5.6	7.1	12.7	5.4	6.9	12.3
2	10	0, 20, 40	0, 10, 20, 30, 40	Different (One zone)	5.6	6.5	12.0	5.4	6.3	11.7
3	10	0, 20, 40	SC 0, 20, 40 ST 10, 30	Different	5.6	4.3	9.8	5.4	4.1	9.6
4	10	0, 20, 40	SC 0, 20, 40 ST 7, 14, 27, 34	Different	5.6	5.2	10.7	5.4	5.0	10.4
5	15	0, 20, 40	0, 10, 20, 30, 40	Different	8.2	9.9	18.1	7.7	9.3	17.1
6	15	0, 20, 40	0, 10, 20, 30, 40	Different (One zone)	8.2	9.3	17.5	7.7	8.7	16.5
7	15	0, 20, 40	SC 0, 20, 40 ST 10, 30	Different	8.2	6.1	14.3	7.7	5.7	13.5
8	15	0, 20, 40	SC 0, 20, 40 ST 7, 14, 27, 34	Different	8.2	7.1	15.3	7.7	6.7	14.4
9	20	0, 20, 40	0, 10, 20, 30, 40	Different	10.7	13.6	24.3	9.8	12.4	22.2
10	20	0, 20, 40	0, 10, 20, 30, 40	Different (One zone)	10.7	12.3	23.0	9.8	11.2	21.0
11	20	0, 20, 40	SC 0, 20, 40 ST 10, 30	Different	10.7	8.2	18.9	9.8	7.5	17.2
12	20	0, 20, 40	SC 0, 20, 40 ST 7, 14, 27, 34	Different	10.7	9.2	20.0	9.8	8.4	18.1
13	25	0, 20, 40	0, 10, 20, 30, 40	Different	13.1	16.1	29.2	11.5	14.1	25.6
14	25	0, 20, 40	0, 10, 20, 30, 40	Different (One zone)	13.1	14.8	27.9	11.5	13.1	24.6.
15	25	0, 20, 40	SC 0, 20, 40 ST 10, 30	Different	13.1	9.8	23.0	11.5	8.6	20.1
16	25	0, 20, 40	SC 0, 20, 40 ST 7, 14, 27, 34	Different	13.1	11.6	24.7	11.5	10.2	21.7

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance	Total additional maintenance costs (£m)
17	30	0, 20, 40	0, 10, 20, 30, 40	Different	15.4	19.4	34.8	12.9	16.4	29.3
18	30	0, 20, 40	0, 10, 20, 30, 40	Different (One zone)	15.4	17.4	32.8	12.9	14.8	27.7
19	30	0, 20, 40	SC 0, 20, 40 ST 10, 30	Different	15.4	11.7	27.1	12.9	9.9	22.8
20	30	0, 20, 40	SC 0, 20, 40 ST 7, 14, 27, 34	Different	15.4	13.3	28.7	12.9	11.2	24.1
21	10	0, 20, 40	0, 10, 20, 30, 40	Same	4.3	5.5	9.7	4.3	5.5	9.7
22	10	0, 20, 40	0, 10, 20, 30, 40	Same (One zone)	4.3	5.0	9.2	4.3	5.0	9.2
23	10	0, 20, 40	SC 0, 20, 40 ST 10, 30	Same	4.3	3.2	7.5	4.3	3.2	7.5
24	10	0, 20, 40	SC 0, 20, 40 ST 7, 14, 27, 34	Same	4.3	3.9	8.2	4.3	3.9	8.2
25	15	0, 20, 40	0, 10, 20, 30, 40	Same	6.7	7.8	14.5	6.7	7.8	14.5
26	15	0, 20, 40	0, 10, 20, 30, 40	Same (One zone)	6.7	7.3	13.9	6.7	7.3	13.9
27	15	0, 20, 40	SC 0, 20, 40 ST 10, 30	Same	6.7	4.9	11.6	6.7	4.9	11.6
28	15	0, 20, 40	SC 0, 20, 40 ST 7, 14, 27, 34	Same	6.7	5.7	12.3	6.7	5.7	12.3
29	20	0, 20, 40	0, 10, 20, 30, 40	Same	9.3	11.8	21.1	9.3	11.8	21.1
30	20	0, 20, 40	0, 10, 20, 30, 40	Same (One zone)	9.3	10.2	19.5	9.3	10.2	19.5
31	20	0, 20, 40	SC 0, 20, 40 ST 10, 30	Same	9.3	7.0	16.3	9.3	7.0	16.3
32	20	0, 20, 40	SC 0, 20, 40 ST 7, 14, 27, 34	Same	9.3	8.7	18.0	9.3	8.7	18.0

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance	Total additional maintenance costs (£m)
33	25	0, 20, 40	0, 10, 20, 30, 40	Same	12.1	15.0	27.1	12.1	15.0	27.1
34	25	0, 20, 40	0, 10, 20, 30, 40	Same (One zone)	12.1	13.0	25.1	12.1	13.0	25.1
35	25	0, 20, 40	SC 0, 20, 40 ST 10, 30	Same	12.1	9.6	21.7	12.1	9.6	21.7
36	25	0, 20, 40	SC 0, 20, 40 ST 7, 14, 27, 34	Same	12.1	12.8	24.8	12.1	12.8	24.8
37	30	0, 20, 40	0, 10, 20, 30, 40	Same	15.3	20.4	35.7	15.3	20.4	35.7
38	30	0, 20, 40	0, 10, 20, 30, 40	Same (One zone)	15.3	17.8	33.2	15.3	17.8	33.2
39	30	0, 20, 40	SC 0, 20, 40 ST 10, 30	Same	15.3	13.2	28.5	15.3	13.2	28.5
40	30	0, 20, 40	SC 0, 20, 40 ST 7, 14, 27, 34	Same	15.3	16.3	31.6	15.3	16.3	31.6

Table C 4 Additional maintenance costs for Major carriageways (untrenched service life of binder course: 30 years)

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
1	10	0, 30	0, 15, 30	Different	4.9	5.4	10.3	4.7	5.2	9.9
2	10	0, 30	0, 15, 30	Different (One zone)	4.9	4.9	9.8	4.7	4.7	9.4
3	10	0, 30	0, 10, 20, 30, 40	Different	4.9	9.9	14.8	4.7	9.7	14.4
4	10	0, 30	0, 10, 20, 30, 40	Different (One zone)	4.9	8.4	13.2	4.7	8.1	12.8
5	10	0, 30	SC 0, 15, 30 ST 8, 23, 38	Different	4.9	8.5	13.4	4.7	8.2	12.9
6	10	0, 30	SC 0, 15, 30 ST 8, 23, 38	Different (One zone)	4.9	8.0	12.9	4.7	7.7	12.4
7	10	0, 30	SC 0, 30 ST 15	Different	4.9	3.5	8.4	4.7	3.4	8.1
8	10	0, 30	SC 0, 30 ST 10, 20, 40	Different	4.9	5.9	10.8	4.7	5.7	10.4
9	13.33	0, 30	0, 15, 30	Different	6.5	7.9	14.4	6.1	7.5	13.7
10	13.33	0, 30	0, 15, 30	Different (One zone)	6.5	6.8	13.3	6.1	6.5	12.6
11	13.33	0, 30	0, 10, 20, 30, 40	Different	6.5	12.1	18.5	6.1	11.4	17.5
12	13.33	0, 30	0, 10, 20, 30, 40	Different (One zone)	6.5	10.5	16.9	6.1	10.0	16.1
13	13.33	0, 30	SC 0, 15, 30 ST 8, 23, 38	Different	6.5	12.3	18.7	6.1	11.6	17.8
14	13.33	0, 30	SC 0, 15, 30 ST 8, 23, 38	Different (One zone)	6.5	10.8	17.3	6.1	10.3	16.4
15	13.33	0, 30	SC 0, 30 ST 15	Different	6.5	4.8	11.3	6.1	4.6	10.7
16	13.33	0, 30	SC 0, 30 ST 10, 20, 40	Different	6.5	7.4	13.9	6.1	7.0	13.2

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
17	20	0, 30	0, 15, 30	Different	9.6	12.0	21.6	8.7	11.0	19.7
18	20	0, 30	0, 15, 30	Different (One zone)	9.6	10.3	19.0	8.7	9.5	18.2
19	20	0, 30	0, 10, 20, 30, 40	Different	9.6	19.4	28.9	8.7	17.7	26.5
20	20	0, 30	0, 10, 20, 30, 40	Different (One zone)	9.6	15.8	25.4	8.7	14.6	23.3
21	20	0, 30	SC 0, 15, 30 ST 8, 23, 38	Different	9.6	18.2	27.8	8.7	16.6	25.3
22	20	0, 30	SC 0, 15, 30 ST 8, 23, 38	Different (One zone)	9.6	15.7	25.3	8.7	14.5	23.2
23	20	0, 30	SC 0, 30 ST 15	Different	9.6	7.5	17.1	8.7	6.9	15.6
24	20	0, 30	SC 0, 30 ST 10, 20, 40	Different	9.6	11.5	21.1	8.7	10.5	19.2
25	23.33	0, 30	0, 15, 30	Different	11.1	13.6	24.6	9.9	12.1	22.0
26	23.33	0, 30	0, 15, 30	Different (One zone)	11.1	11.9	22.9	9.9	10.7	20.6
27	23.33	0, 30	0, 10, 20, 30, 40	Different	11.1	21.3	32.4	9.9	19.0	28.8
28	23.33	0, 30	0, 10, 20, 30, 40	Different (One zone)	11.1	17.8	28.8	9.9	16.0	25.9
29	23.33	0, 30	SC 0, 15, 30 ST 8, 23, 38	Different	11.1	19.9	31.0	9.9	17.7	27.5
30	23.33	0, 30	SC 0, 15, 30 ST 8, 23, 38	Different (One zone)	11.1	17.5	28.6	9.9	15.8	25.6
31	23.33	0, 30	SC 0, 30 ST 15	Different	11.1	8.8	19.9	9.9	7.9	17.7
32	23.33	0, 30	SC 0, 30 ST 10, 20, 40	Different	11.1	12.9	24.0	9.8	11.5	21.4

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
33	30	0, 30	0, 15, 30	Different	14.0	17.7	31.7	11.9	15.1	27.0
34	30	0, 30	0, 15, 30	Different (One zone)	14.0	15.3	29.3	11.9	13.3	25.2
35	30	0, 30	0, 10, 20, 30, 40	Different	14.0	28.2	42.3	11.9	24.2	36.1
36	30	0, 30	0, 10, 20, 30, 40	Different (One zone)	14.0	19.8	33.9	11.9	16.8	28.7
37	30	0, 30	SC 0, 15, 30 ST 8, 23, 38	Different	14.0	25.0	39.0	11.9	21.1	33.0
38	30	0, 30	SC 0, 15, 30 ST 8, 23, 38	Different (One zone)	14.0	21.7	35.7	11.9	18.6	30.5
39	30	0, 30	SC 0, 30 ST 15	Different	14.0	11.6	25.7	11.9	10.0	21.9
40	30	0, 30	SC 0, 30 ST 10, 20, 40	Different	14.0	16.8	30.8	11.9	14.3	26.3
41	10	0, 30	0, 15, 30	Same	3.8	4.1	7.9	3.8	4.1	7.9
42	10	0, 30	0, 15, 30	Same (One zone)	3.8	3.7	7.5	3.8	3.7	7.5
43	10	0, 30	0, 10, 20, 30, 40	Same	3.8	8.0	11.8	3.8	8.0	11.8
44	10	0, 30	0, 10, 20, 30, 40	Same (One zone)	3.8	6.6	10.5	3.8	6.6	10.5
45	10	0, 30	SC 0, 15, 30 ST 8, 23, 38	Same	3.8	6.8	10.6	3.8	6.8	10.6
46	10	0, 30	SC 0, 15, 30 ST 8, 23, 38	Same (One zone)	3.8	6.0	9.8	3.8	6.0	9.8
47	10	0, 30	SC 0, 30 ST 15	Same	3.8	2.7	6.5	3.8	2.7	6.5
48	10	0, 30	SC 0, 30 ST 10, 20, 40	Same	3.8	5.0	8.8	3.8	5.0	8.8

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
49	13.33	0, 30	0, 15, 30	Same	5.2	6.7	12.0	5.2	6.7	12.0
50	13.33	0, 30	0, 15, 30	Same (One zone)	5.2	5.5	10.8	5.2	5.5	10.8
51	13.33	0, 30	0, 10, 20, 30, 40	Same	5.2	9.6	14.9	5.2	9.6	14.9
52	13.33	0, 30	0, 10, 20, 30, 40	Same (One zone)	5.2	8.3	13.6	5.2	8.3	13.6
53	13.33	0, 30	SC 0, 15, 30 ST 8, 23, 38	Same	5.2	10.0	15.3	5.2	10.0	15.3
54	13.33	0, 30	SC 0, 15, 30 ST 8, 23, 38	Same (One zone)	5.2	8.5	13.8	5.2	8.5	13.8
55	13.33	0, 30	SC 0, 30 ST 15	Same	5.2	4.2	9.4	5.2	4.2	9.4
56	13.33	0, 30	SC 0, 30 ST 10, 20, 40	Same	5.2	6.4	11.6	5.2	6.4	11.6
57	20	0, 30	0, 15, 30	Same	8.3	11.4	19.6	8.3	11.4	19.6
58	20	0, 30	0, 15, 30	Same (One zone)	8.3	9.1	17.4	8.3	9.1	17.4
59	20	0, 30	0, 10, 20, 30, 40	Same	8.3	17.3	25.6	8.3	17.3	25.6
60	20	0, 30	0, 10, 20, 30, 40	Same (One zone)	8.3	13.7	22.0	8.3	13.7	22.0
61	20	0, 30	SC 0, 15, 30 ST 8, 23, 38	Same	8.3	15.6	23.9	8.3	15.6	23.9
62	20	0, 30	SC 0, 15, 30 ST 8, 23, 38	Same (One zone)	8.3	13.4	21.7	8.3	13.4	21.7
63	20	0, 30	SC 0, 30 ST 15	Same	8.3	7.4	15.7	8.3	7.4	15.7
64	20	0, 30	SC 0, 30 ST 10, 20, 40	Same	8.3	10.3	18.6	8.3	10.3	18.6

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
65	23.33	0, 30	0, 15, 30	Same	10.0	13.1	23.1	10.0	13.1	23.1
66	23.33	0, 30	0, 15, 30	Same (One zone)	10.0	11.0	21.0	10.0	11.0	21.0
67	23.33	0, 30	0, 10, 20, 30, 40	Same	10.0	19.5	29.5	10.0	19.5	29.5
68	23.33	0, 30	0, 10, 20, 30, 40	Same (One zone)	10.0	15.7	25.7	10.0	15.7	25.7
69	23.33	0, 30	SC 0, 15, 30 ST 8, 23, 38	Same	10.0	17.6	27.5	10.0	17.6	27.5
70	23.33	0, 30	SC 0, 15, 30 ST 8, 23, 38	Same (One zone)	10.0	14.9	24.9	10.0	14.9	24.9
71	23.33	0, 30	SC 0, 30 ST 15	Same	10.0	8.9	18.9	10.0	8.9	18.9
72	23.33	0, 30	SC 0, 30 ST 10, 20, 40	Same	10.0	12.0	22.0	10.0	12.0	22.0
73	30	0, 30	0, 15, 30	Same	13.7	18.7	32.4	13.7	18.7	32.4
74	30	0, 30	0, 15, 30	Same (One zone)	13.7	16.1	29.8	13.7	16.1	29.8
75	30	0, 30	0, 10, 20, 30, 40	Same	13.7	29.8	43.5	13.7	29.8	43.5
76	30	0, 30	0, 10, 20, 30, 40	Same (One zone)	13.7	20.9	34.6	13.7	20.9	34.6
77	30	0, 30	SC 0, 15, 30 ST 8, 23, 38	Same	13.7	25.8	39.5	13.7	25.8	39.5
78	30	0, 30	SC 0, 15, 30 ST 8, 23, 38	Same (One zone)	13.7	21.9	35.7	13.7	21.9	35.7
79	30	0, 30	SC 0, 30 ST 15	Same	13.7	12.9	26.6	13.7	12.9	26.6
80	30	0, 30	SC 0, 30 ST 10, 20, 40	Same	13.7	17.5	31.2	13.7	17.5	31.2

Table C 5 Additional maintenance costs for Major carriageways (untrenched service life of binder course: 40 years)

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
1	15	0, 40	0, 20, 40	Different	8.3	11.0	19.3	7.7	10.3	18.0
2	15	0, 40	0, 20, 40	Different (One zone)	8.3	9.2	17.5	7.7	8.6	16.3
3	15	0, 40	0, 14, 27, 40	Different	8.3	16.0	24.3	7.7	14.8	22.5
4	15	0, 40	0, 14, 27, 40	Different (One zone)	8.3	12.4	20.7	7.7	11.7	19.4
5	15	0, 40	0, 10, 20, 30, 40	Different	8.3	20.3	28.6	7.7	18.9	26.7
6	15	0, 40	0, 10, 20, 30, 40	Different (One zone)	8.3	15.9	24.3	7.7	15.1	22.8
7	15	0, 40	SC 0, 20, 40 ST 10, 30	Different	8.3	12.5	20.8	7.7	11.7	19.4
8	15	0, 40	SC 0, 20, 40 ST 10, 30	Different (One zone)	8.3	10.2	18.5	7.7	9.6	17.4
9	15	0, 40	SC 0, 40 ST 20	Different	8.3	6.5	14.8	7.7	6.0	13.8
10	15	0, 40	SC 0, 40 ST 14, 27	Different	8.3	7.5	15.8	7.7	6.9	14.7
11	20	0, 40	0, 20, 40	Different	10.9	14.4	25.3	9.8	13.0	22.9
12	20	0, 40	0, 20, 40	Different (One zone)	10.9	11.9	22.9	9.8	10.9	20.8
13	20	0, 40	0, 14, 27, 40	Different	10.9	21.1	32.0	9.8	18.9	28.7
14	20	0, 40	0, 14, 27, 40	Different (One zone)	10.9	16.1	27.1	9.8	14.8	24.7
15	20	0, 40	0, 10, 20, 30, 40	Different	10.9	28.0	38.9	9.8	25.4	35.3
16	20	0, 40	0, 10, 20, 30, 40	Different (One zone)	10.9	19.0	29.9	9.8	17.9	27.8

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
17	20	0, 40	SC 0, 20, 40 ST 10, 30	Different	10.9	16.9	27.8	9.8	15.3	25.2
18	20	0, 40	SC 0, 20, 40 ST 10, 30	Different (One zone)	10.9	13.5	24.4	9.8	12.4	22.3
19	20	0, 40	SC 0, 40 ST 20	Different	10.9	8.5	19.5	9.8	7.7	17.6
20	20	0, 40	SC 0, 40 ST 14, 27	Different (One zone)	10.9	9.9	20.8	9.8	8.9	18.7
21	15	0, 40	0, 20, 40	Same	4.8	6.4	11.1	4.8	6.4	11.1
22	15	0, 40	0, 20, 40	Same (One zone)	4.8	5.9	10.7	4.8	5.9	10.7
23	15	0, 40	0, 14, 27, 40	Same	4.8	9.1	13.9	4.8	9.1	13.9
24	15	0, 40	0, 14, 27, 40	Same (One zone)	4.8	7.9	12.7	4.8	7.9	12.7
25	15	0, 40	0, 10, 20, 30, 40	Same	4.8	11.5	16.3	4.8	11.5	16.3
26	15	0, 40	0, 10, 20, 30, 40	Same (One zone)	4.8	10.0	14.8	4.8	10.0	14.8
27	15	0, 40	SC 0, 20, 40 ST 10, 30	Same	4.8	7.2	12.0	4.8	7.2	12.0
28	15	0, 40	SC 0, 20, 40 ST 10, 30	Same (One zone)	4.8	6.6	11.4	4.8	6.6	11.4
29	15	0, 40	SC 0, 40 ST 20	Same	4.8	3.7	8.5	4.8	3.7	8.5
30	15	0, 40	SC 0, 40 ST 14, 27	Same	4.8	4.2	9.0	4.8	4.2	9.0

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
31	20	0, 40	0, 20, 40	Same	6.7	8.8	15.5	6.7	8.8	15.5
32	20	0, 40	0, 20, 40	Same (One zone)	6.7	8.0	14.7	6.7	8.0	14.7
33	20	0, 40	0, 14, 27, 40	Same	6.7	12.9	19.6	6.7	12.9	19.6
34	20	0, 40	0, 14, 27, 40	Same (One zone)	6.7	10.8	17.4	6.7	10.8	17.4
35	20	0, 40	0, 10, 20, 30, 40	Same	6.7	17.3	23.9	6.7	17.3	23.9
36	20	0, 40	0, 10, 20, 30, 40	Same (One zone)	6.7	13.5	20.2	6.7	13.5	20.2
37	20	0, 40	SC 0, 20, 40 ST 10, 30	Same	6.7	10.2	16.9	6.7	10.2	16.9
38	20	0, 40	SC 0, 20, 40 ST 10, 30	Same (One zone)	6.7	9.3	16.0	6.7	9.3	16.0
39	20	0, 40	SC 0, 40 ST 20	Same	6.7	5.1	11.8	6.7	5.1	11.8
40	20	0, 40	SC 0, 40 ST 14, 27	Same	6.7	5.9	12.5	6.7	5.9	12.5

Table C 6 Additional maintenance costs for Minor carriageways (untrenched service life of binder course: 30 years)

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
1	10	0, 30	0, 30	Different	7.3	4.4	11.8	7.1	4.3	11.3
2	10	0, 30	0, 15, 30	Different	7.3	7.5	14.9	7.1	7.3	14.3
3	10	0, 30	0, 15, 30	Different (One zone)	7.3	6.8	14.1	7.1	6.6	13.6
4	10	0, 30	SC 0, 30 ST 15	Different	7.3	5.0	12.3	7.1	4.8	11.9
5	10	0, 30	SC 0, 30 ST 10, 20, 40	Different	7.3	9.1	16.5	7.1	8.8	15.9
6	13.33	0, 30	0, 30	Different	9.7	5.8	15.6	9.2	5.5	14.7
7	13.33	0, 30	0, 15, 30	Different	9.7	11.0	20.7	9.2	10.5	19.7
8	13.33	0, 30	0, 15, 30	Different (One zone)	9.7	9.5	19.2	9.2	9.0	18.3
9	13.33	0, 30	SC 0, 30 ST 15	Different	9.7	6.9	16.7	9.2	6.6	15.8
10	13.33	0, 30	SC 0, 30 ST 10, 20, 40	Different	9.7	11.4	21.2	9.2	10.8	20.0
11	20	0, 30	0, 30	Different	14.4	8.6	23.0	13.1	7.9	21.0
12	20	0, 30	0, 15, 30	Different	14.4	16.6	31.0	13.1	15.2	28.3
13	20	0, 30	0, 15, 30	Different (One zone)	14.4	14.3	28.7	13.1	13.2	26.3
14	20	0, 30	SC 0, 30 ST 15	Different	14.4	10.8	25.2	13.1	9.9	23.0
15	20	0, 30	SC 0, 30 ST 10, 20, 40	Different	14.4	17.8	32.2	13.1	16.3	29.4

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
16	23.33	0, 30	0, 30	Different	16.7	10.0	26.7	14.8	8.9	23.8
17	23.33	0, 30	0, 15, 30	Different	16.7	18.8	35.5	14.8	16.8	31.6
18	23.33	0, 30	0, 15, 30	Different (One zone)	16.7	16.4	33.1	14.8	14.9	29.7
19	23.33	0, 30	SC 0, 30 ST 15	Different	16.7	12.8	29.5	14.8	11.5	26.3
20	23.33	0, 30	SC 0, 30 ST 10, 20, 40	Different	16.7	19.9	36.6	14.8	17.8	32.6
21	30	0, 30	0, 30	Different	21.1	12.7	33.8	17.9	10.8	28.7
22	30	0, 30	0, 15, 30	Different	21.1	24.5	45.7	17.9	20.9	38.9
23	30	0, 30	0, 15, 30	Different (One zone)	21.1	21.2	42.3	17.9	18.4	36.3
24	30	0, 30	SC 0, 30 ST 15	Different	21.1	17.0	38.2	17.9	14.6	32.5
25	30	0, 30	SC 0, 30 ST 10, 20, 40	Different	21.1	26.0	47.1	17.9	22.2	40.1
26	10	0, 30	0, 30	Same	5.7	3.4	9.2	5.7	3.4	9.2
27	10	0, 30	0, 15, 30	Same	5.7	5.7	11.4	5.7	5.7	11.4
28	10	0, 30	0, 15, 30	Same (One zone)	5.7	5.1	10.8	5.7	5.1	10.8
29	10	0, 30	SC 0, 30 ST 15	Same	5.7	3.8	9.6	5.7	3.8	9.6
30	10	0, 30	SC 0, 30 ST 10, 20, 40	Same	5.7	7.7	13.5	5.7	7.7	13.5

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
31	13.33	0, 30	0, 30	Same	7.9	4.7	12.6	7.9	4.7	12.6
32	13.33	0, 30	0, 15, 30	Same	7.9	9.3	17.2	7.9	9.3	17.2
33	13.33	0, 30	0, 15, 30	Same (One zone)	7.9	7.7	15.5	7.9	7.7	15.5
34	13.33	0, 30	SC 0, 30 ST 15	Same	7.9	6.0	13.9	7.9	6.0	13.9
35	13.33	0, 30	SC 0, 30 ST 10, 20, 40	Same	7.9	9.7	17.6	7.9	9.7	17.6
36	20	0, 30	0, 30	Same	12.5	7.5	20.0	12.5	7.5	20.0
37	20	0, 30	0, 15, 30	Same	12.5	15.7	28.2	12.5	15.7	28.2
38	20	0, 30	0, 15, 30	Same (One zone)	12.5	12.6	25.2	12.5	12.6	25.3
39	20	0, 30	SC 0, 30 ST 15	Same	12.5	10.9	23.4	12.5	10.9	23.4
40	20	0, 30	SC 0, 30 ST 10, 20, 40	Same	12.5	16.0	28.5	12.5	16.0	28.5
41	23.33	0, 30	0, 30	Same	15.0	9.0	24.1	15.0	9.0	24.1
42	23.33	0, 30	0, 15, 30	Same	15.0	18.2	33.3	15.0	18.2	33.3
43	23.33	0, 30	0, 15, 30	Same (One zone)	15.0	15.2	30.3	15.0	15.2	30.3
44	23.33	0, 30	SC 0, 30 ST 15	Same	15.0	13.2	28.3	15.0	13.2	28.3
45	23.33	0, 30	SC 0, 30 ST 10, 20, 40	Same	15.0	18.5	33.6	15.0	18.5	33.6

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
46	30	0, 30	0, 30	Same	20.7	12.4	33.0	20.7	12.4	33.0
47	30	0, 30	0, 15, 30	Same	20.7	26.0	46.6	20.7	26.0	46.6
48	30	0, 30	0, 15, 30	Same (One zone)	20.7	22.3	42.9	20.7	22.2	42.9
49	30	0, 30	SC 0, 30 ST 15	Same	20.7	19.2	39.9	20.7	19.2	39.9
50	30	0, 30	SC 0, 30 ST 10, 20, 40	Same	20.7	27.2	47.9	20.7	27.2	47.9

Table C 7 Additional maintenance costs for Minor carriageways (untrenched service life of binder course: 40 years)

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
1	10	0, 40	0, 40	Different	8.4	5.1	13.5	8.1	4.9	13.0
2	10	0, 40	0, 20, 40	Different	8.4	10.3	18.7	8.1	9.9	18.0
3	10	0, 40	0, 20, 40	Different (One zone)	8.4	8.6	17.1	8.1	8.3	16.4
4	10	0, 40	SC 0, 40 ST 20	Different	8.4	6.3	14.7	8.1	6.1	14.2
5	10	0, 40	SC 0, 40 ST 14, 27	Different	8.4	8.1	16.6	8.1	7.8	15.9
6	15	0, 40	0, 40	Different	12.5	7.5	20.0	11.7	7.0	18.6
7	15	0, 40	0, 20, 40	Different	12.5	15.2	27.7	11.7	14.2	25.9
8	15	0, 40	0, 20, 40	Different (One zone)	12.5	12.7	25.2	11.7	11.9	23.6
9	15	0, 40	SC 0, 40 ST 20	Different	12.5	9.4	21.9	11.7	8.7	20.4
10	15	0, 40	SC 0, 40 ST 14, 27	Different	12.5	11.1	23.6	11.7	10.3	21.9
11	20	0, 40	0, 40	Different	16.5	9.9	26.4	14.9	8.9	23.8
12	20	0, 40	0, 20, 40	Different	16.5	20.0	36.5	14.9	18.1	32.9
13	20	0, 40	0, 20, 40	Different (One zone)	16.5	16.5	33.0	14.9	15.1	30.0
14	20	0, 40	SC 0, 40 ST 20	Different	16.5	12.3	28.8	14.9	11.1	26.0
15	20	0, 40	SC 0, 40 ST 14, 27	Different	16.5	14.7	31.1	14.9	13.1	28.0
16	25	0, 40	0, 40	Different	20.3	12.2	32.5	17.7	10.6	28.3

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
17	25	0, 40	0, 20, 40	Different	20.3	24.6	44.9	17.7	21.4	39.1
18	25	0, 40	0, 20, 40	Different (One zone)	20.3	20.2	40.5	17.7	17.9	35.6
19	25	0, 40	SC 0, 40 ST 20	Different	20.3	15.2	35.5	17.7	13.3	30.9
20	25	0, 40	SC 0, 40 ST 14, 27	Different	20.3	18.6	38.9	17.7	16.2	33.9
21	30	0, 40	0, 40	Different	24.4	14.7	39.1	20.5	12.3	32.8
22	30	0, 40	0, 20, 40	Different	24.4	29.2	53.6	20.5	24.5	45.0
23	30	0, 40	0, 20, 40	Different (One zone)	24.4	23.8	48.3	20.5	20.4	40.9
24	30	0, 40	SC 0, 40 ST 20	Different	24.4	18.2	42.7	20.5	15.3	35.8
25	30	0, 40	SC 0, 40 ST 14, 27	Different	24.4	21.5	46.0	20.5	17.9	38.4
26	10	0, 40	0, 40	Same	4.6	2.8	7.4	4.6	2.8	7.4
27	10	0, 40	0, 20, 40	Same	4.6	5.6	10.3	4.6	5.6	10.3
28	10	0, 40	0, 20, 40	Same (One zone)	4.6	5.4	10.0	4.6	5.4	10.0
29	10	0, 40	SC 0, 40 ST 20	Same	4.6	3.4	8.0	4.6	3.4	8.0
30	10	0, 40	SC 0, 40 ST 14, 27	Same	4.6	4.4	9.0	4.6	4.4	9.0

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
31	15	0, 40	0, 40	Same	7.2	4.3	11.6	7.2	4.3	11.6
32	15	0, 40	0, 20, 40	Same	7.2	8.8	16.0	7.2	8.8	16.0
33	15	0, 40	0, 20, 40	Same (One zone)	7.2	8.2	15.4	7.2	8.2	15.4
34	15	0, 40	SC 0, 40 ST 20	Same	7.2	5.3	12.6	7.2	5.3	12.6
35	15	0, 40	SC 0, 40 ST 14, 27	Same	7.2	6.2	13.4	7.2	6.2	13.4
36	20	0, 40	0, 40	Same	10.1	6.0	16.1	10.1	6.0	16.1
37	20	0, 40	0, 20, 40	Same	10.1	12.2	22.3	10.1	12.2	22.3
38	20	0, 40	0, 20, 40	Same (One zone)	10.1	11.0	21.1	10.1	11.0	21.1
39	20	0, 40	SC 0, 40 ST 20	Same	10.1	7.4	17.5	10.1	7.4	17.5
40	20	0, 40	SC 0, 40 ST 14, 27	Same	10.1	8.6	18.7	10.1	8.6	18.7
41	25	0, 40	0, 40	Same	13.2	7.9	21.1	13.2	7.9	21.1
42	25	0, 40	0, 20, 40	Same	13.2	16.0	29.2	13.2	16.0	29.2
43	25	0, 40	0, 20, 40	Same (One zone)	13.2	14.0	27.2	13.2	14.0	27.2
44	25	0, 40	SC 0, 40 ST 20	Same	13.2	9.7	22.9	13.2	9.7	22.9
45	25	0, 40	SC 0, 40 ST 14, 27	Same	13.2	11.6	24.8	13.2	11.6	24.8

Row No.	'Reference' service life reduction (%)	Years binder course is laid in untrenched areas	Years surface course or surface treatment are laid in untrenched areas	Trenching scenario (Treatment scenario)	'Full reduction' in service life			'Partial reduction' in service life		
					Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance	Total additional maintenance costs (£m)	Binder course additional maintenance costs (£m)	Surface course and surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
46	30	0, 40	0, 40	Same	16.9	10.2	27.1	16.9	10.2	27.1
47	30	0, 40	0, 20, 40	Same	16.9	20.3	37.2	16.9	20.3	37.2
48	30	0, 40	0, 20, 40	Same (One zone)	16.9	17.1	34.0	16.9	17.1	34.0
49	30	0, 40	SC 0, 40 ST 20	Same	16.9	12.3	29.2	16.9	12.3	29.2
50	30	0, 40	SC 0, 40 ST 14, 27	Same	16.9	14.1	31.1	16.9	14.1	31.1

Table C 8 Additional maintenance costs for Footways (untrenched service life of binder and surface courses: 30 years)

Row No.	'Reference' service life reduction (%)	Years binder and surface courses are laid in untrenched areas	Year surface treatment is laid in trenched areas	Trenching scenario	'Full reduction' in service life			'Partial reduction' in service life		
					Binder and surface course additional maintenance costs (£m)	Surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)	Binder and surface course additional maintenance costs (£m)	Surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
1	3.33	0, 30	15	Different	3.5	11.8	15.3	3.5	11.8	15.3
2	3.33	0, 30	15	Same	2.6	10.6	13.2	2.6	10.6	13.2
3	10	0, 30	14	Different	10.4	11.3	21.7	10.1	11.3	21.4
4	10	0, 30	14	Same	8.1	11.0	19.2	8.1	11.0	19.2
5	13.33	0, 30	13	Different	13.8	11.3	25.1	13.1	11.3	24.4
6	13.33	0, 30	13	Same	11.2	11.9	23.1	11.2	11.9	23.1
7	20	0, 30	12	Different	20.4	12.1	32.6	18.6	12.1	30.7
8	20	0, 30	12	Same	17.7	14.0	31.7	17.7	14.0	31.7

Table C 9 Additional maintenance costs for Footways (untrenched service life of binder and surface courses: 40 years)

Row No.	'Reference' service life reduction (%)	Years binder and surface courses are laid in untrenched areas	Year surface treatment is laid in trenched areas	Trenching scenario	'Full reduction' in service life			'Partial reduction' in service life		
					Binder and surface course additional maintenance costs (£m)	Surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)	Binder and surface course additional maintenance costs (£m)	Surface treatment additional maintenance costs (£m)	Total additional maintenance costs (£m)
1	5	0, 40	19	Different	6.0	12.8	18.9	6.0	12.8	18.8
2	5	0, 40	19	Same	3.1	9.3	12.4	3.1	9.3	12.4
3	10	0, 40	18	Different	12.0	12.6	24.5	11.5	12.6	24.0
4	10	0, 40	18	Same	6.5	9.6	16.1	6.5	9.6	16.1
5	15	0, 40	17	Different	17.7	12.2	30.0	16.5	12.2	28.8
6	15	0, 40	17	Same	10.2	9.9	20.2	10.2	9.9	20.2
7	20	0, 40	16	Different	23.4	11.9	35.2	21.1	11.9	32.9
8	20	0, 40	16	Same	14.3	10.3	24.6	14.3	10.3	24.6

Table C 10 Additional maintenance costs: Major carriageways – binder course untrenched service life: 20 years, 'reference' service life reduction: 15% - 'Full reduction', 'Different' areas trenched each year

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73																																									
3.5%	10	0.71																																									
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64																																									
3.5%	14	0.62																																									
3.5%	15	0.60																																									
3.5%	16	0.58																																									
3.5%	17	0.56			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																							
3.5%	18	0.54																			1																						
3.5%	19	0.52																				1																					
3.5%	20	0.50	1	1																			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44																																									
3.5%	25	0.42																																									
3.5%	26	0.41																																									
3.5%	27	0.40																																									
3.5%	28	0.38																																									
3.5%	29	0.37																																									
3.5%	30	0.36																																									
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32																																									
3.0%	35	0.31																																									
3.0%	36	0.30																																									
3.0%	37	0.29			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
3.0%	38	0.28																			1																					1		
3.0%	39	0.27																				1																					1	
3.0%	40	0.27	R.V.		-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.90	-0.95			-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.90	-0.95	
NPV if tr'tm'nt cost=1			1.50	1.50	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.58	1.54	1.50	1.50	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.57	1.55	1.52	1.50
Trenched minus baseline				0.00	0.00	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.08	0.04	0.00	0.00	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.04	0.02
Tr'ch'd minus b'line over 40y				3.11		Unit cost (£/area)				23		Trenched area per year					804597			Area scaling factor					3.158		NPV (£m)			182.01		Sum of discount factors				22.17		Annual cost (£m)			8.21		

Table C 11 Additional maintenance costs: Major carriageways - surface course untrenched service life: 10 years, 'reference' service life reduction: 15% - 'Full reduction', 'Different' areas trenched each year, 'Several zones' treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																						
3.5%	10	0.71	1	1																		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64																																									
3.5%	14	0.62																																									
3.5%	15	0.60																																									
3.5%	16	0.58																																									
3.5%	17	0.56			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																							
3.5%	18	0.54																				1																					
3.5%	19	0.52																					1																				
3.5%	20	0.50	1	1																			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44																																									
3.5%	25	0.42																																									
3.5%	26	0.41																																									
3.5%	27	0.40			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																							
3.5%	28	0.38																				1																					
3.5%	29	0.37																					1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
3.5%	30	0.36	1	1																			1	1																		1	1
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32																																									
3.0%	35	0.31																																									
3.0%	36	0.30																																									
3.0%	37	0.29			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
3.0%	38	0.28																				1																				1		
3.0%	39	0.27																					1																				1	
3.0%	40	0.27	R.V.		-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.80	-0.90			-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.80	-0.90	
NPV if tr'tmnt cost=1			2.57	2.57	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.72	2.63	2.57	2.57	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.65	2.60	2.57
Trenched minus baseline				0.00	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.15	0.06	0.00	0.00	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.08	0.03	0.00
Tr'ch'd minus b'line over 40y				5.76	Unit cost (£/area)	15	Trenched area per year	804597	Area scaling factor	3.158	NPV (£m)	219.45	Sum of discount factors	22.17	Annual cost (£m)	9.90																											

Table C 12 Additional maintenance costs: Major carriageways - surface course untrenched service life: 10 years, 'reference' service life reduction: 15% - 'Full reduction', 'Different' areas trenched each year, 'One zone' treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73			1	1	1	1	1	1	1																																
3.5%	10	0.71	1	1								1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64																																									
3.5%	14	0.62																																									
3.5%	15	0.60																																									
3.5%	16	0.58																																									
3.5%	17	0.56			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																							
3.5%	18	0.54																			1																						
3.5%	19	0.52																				1																					
3.5%	20	0.50	1	1																			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44																																									
3.5%	25	0.42																																									
3.5%	26	0.41																																									
3.5%	27	0.40			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																							
3.5%	28	0.38																			1																						
3.5%	29	0.37																				1			1	1	1	1	1	1	1												
3.5%	30	0.36	1	1																			1	1								1	1	1	1	1	1	1	1	1	1	1	1
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32																																									
3.0%	35	0.31																																									
3.0%	36	0.30																																									
3.0%	37	0.29			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
3.0%	38	0.28																			1																					1		
3.0%	39	0.27																				1																					1	
3.0%	40	0.27	R.V.		-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.80	-0.90			-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.80	-0.90	
NPV if tr'tm'nt cost=1			2.57	2.57	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.70	2.63	2.57	2.57	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.64	2.60	2.57
Trenched minus baseline				0.00	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.13	0.06	0.00	0.00	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.07	0.03	0.00
Tr'ch'd minus b'line over 40y				5.39	Unit cost (£/area)	15	Trenched area per year	804597	Area scaling factor	3.158	NPV (£m)	205.24	Sum of discount factors	22.17	Annual cost (£m)	9.26																											

Table C 13 Additional maintenance costs: Major carriageways - surface course untrenched service life: 10 years, 'reference' service life reduction: 15% - 'Partial reduction', 'Different' areas trenched each year, 'One zone' treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73			1	1	1	1	1	1	1																																
3.5%	10	0.71	1	1								1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64																																									
3.5%	14	0.62																																									
3.5%	15	0.60																																									
3.5%	16	0.58																																									
3.5%	17	0.56			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																							
3.5%	18	0.54																																									
3.5%	19	0.52																																									
3.5%	20	0.50	1	1																	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44																																									
3.5%	25	0.42																																									
3.5%	26	0.41																																									
3.5%	27	0.40			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																							
3.5%	28	0.38																																									
3.5%	29	0.37																									1	1	1	1	1	1	1												
3.5%	30	0.36	1	1																	1	1	1	1								1	1	1	1	1	1	1	1	1	1	1	1
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32																																									
3.0%	35	0.31																																									
3.0%	36	0.30																																									
3.0%	37	0.29			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
3.0%	38	0.28																																									
3.0%	39	0.27																																									
3.0%	40	0.27	R.V.		-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70					-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70	-0.70			
NPV if tr'tm'nt cost=1			2.57	2.57	2.79	2.79	2.79	2.79	2.79	2.79	2.79	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.77	2.57	2.57	2.57	2.57	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.67	2.57	2.57	2.57
Trenched minus baseline				0.00	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.00	0.00	0.00	0.00	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.00	0.00	0.00

Tr'ch'd minus b'line over 40y	5.09	Unit cost (£/area)	15	Trenched area per year	804597	Area scaling factor	3.158	NPV (£m)	193.86	Sum of discount factors	22.17	Annual cost (£m)	8.75

Table C 14 Additional maintenance costs: Major carriageways - surface course untrenched service life: 10 years, ‘reference’ service life reduction: 30% - ‘Full reduction’, ‘Different’ areas trenched each year, ‘One zone’ treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79			1	1	1																																				
3.5%	8	0.76						1	1																																		
3.5%	9	0.73								1	1																																
3.5%	10	0.71	1	1								1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64																																									
3.5%	14	0.62			1	1	1	1	1	1	1	1	1	1	1	1	1																										
3.5%	15	0.60																1																									
3.5%	16	0.58																	1																								
3.5%	17	0.56																		1																							
3.5%	18	0.54																			1																						
3.5%	19	0.52																				1																					
3.5%	20	0.50	1	1																			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44			1	1	1	1	1	1	1	1	1	1	1	1	1																										
3.5%	25	0.42																1																									
3.5%	26	0.41																	1																								
3.5%	27	0.40																		1					1	1	1																
3.5%	28	0.38																			1							1	1														
3.5%	29	0.37																				1								1	1												
3.5%	30	0.36	1	1																			1	1								1	1	1	1	1	1	1	1	1	1	1	1
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32			1	1	1	1	1	1	1	1	1	1	1	1	1								1	1	1	1	1	1	1	1	1	1	1	1	1						
3.0%	35	0.31																1																				1					
3.0%	36	0.30																	1																				1				
3.0%	37	0.29																		1																				1			
3.0%	38	0.28																			1																				1		
3.0%	39	0.27																				1																				1	
3.0%	40	0.27	R.V.		-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.50	-0.60	-0.70	-0.80	-0.90			-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.50	-0.60	-0.70	-0.80	-0.90	
NPV if tr'tm'nt cost=1			2.57	2.57	3.05	3.05	3.05	3.03	3.03	3.00	3.00	2.98	2.98	2.98	2.98	2.98	2.98	2.90	2.83	2.77	2.70	2.63	2.57	2.57	2.82	2.82	2.82	2.80	2.80	2.79	2.79	2.78	2.78	2.78	2.78	2.78	2.78	2.75	2.71	2.67	2.64	2.60	2.57
Trenched minus baseline				0.00	0.48	0.48	0.48	0.46	0.46	0.43	0.43	0.41	0.41	0.41	0.41	0.41	0.41	0.34	0.26	0.20	0.13	0.06	0.00	0.00	0.25	0.25	0.25	0.24	0.24	0.22	0.22	0.21	0.21	0.21	0.21	0.21	0.21	0.18	0.14	0.10	0.07	0.03	0.00
Tr'ch'd minus b'line over 40y				10.12	Unit cost (£/area)	15	Trenched area per year	804597	Area scaling factor	3.158	NPV (£m)	385.80	Sum of discount factors	22.17	Annual cost (£m)	17.41																											

Table C 15 Additional maintenance costs: Major carriageways – surface course / surface treatment untrenched service lives: 20 / 10 years, 'reference' service life reduction: 15 % - 'Full reduction', 'Different' areas trenched each year, 'Several zones' treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73			0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33																						
3.5%	10	0.71	0.33	0.33																		0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64																																									
3.5%	14	0.62																																									
3.5%	15	0.60																																									
3.5%	16	0.58																																									
3.5%	17	0.56			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																							
3.5%	18	0.54																			1																						
3.5%	19	0.52																				1																					
3.5%	20	0.50	1	1																			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44																																									
3.5%	25	0.42																																									
3.5%	26	0.41																																									
3.5%	27	0.40			0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33																							
3.5%	28	0.38																			0.33																						
3.5%	29	0.37																				0.33			0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33		
3.5%	30	0.36	0.33	0.33																			0.33	0.33																		0.33	0.33
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32																																									
3.0%	35	0.31																																									
3.0%	36	0.30																																									
3.0%	37	0.29			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
3.0%	38	0.28																			1																					1		
3.0%	39	0.27																				1																					1	
3.0%	40	0.27	R.V.		-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.90	-0.95			-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.90	-0.95	
NPV if tr'tm'nt cost=1			1.86	1.86	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.95	1.90	1.86	1.86	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.90	1.88	1.86
Trenched minus baseline				0.00	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.09	0.04	0.00	0.00	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.05	0.02	0.00
Tr'ch'd minus b'line over 40y				3.54	Unit cost (£/area)	15	Trenched area per year	804597	Area scaling factor	3.158	NPV (£m)	135.11	Sum of discount factors	22.17	Annual cost (£m)	6.10																											

Table C 16 Additional maintenance costs: Major carriageways – surface course / surface treatment untrenched service lives: 20 / 6.67 years, trenched service life reduction: 15% - 'Full reduction', 'Different', 'Several zones'

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81			0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33																						
3.5%	7	0.79	0.33	0.33																		0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
3.5%	8	0.76																																									
3.5%	9	0.73																																									
3.5%	10	0.71																																									
3.5%	11	0.68																																									
3.5%	12	0.66			0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33																						
3.5%	13	0.64																				0.33																					
3.5%	14	0.62	0.33	0.33																			0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
3.5%	15	0.60																																									
3.5%	16	0.58																																									
3.5%	17	0.56			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																							
3.5%	18	0.54																			1																						
3.5%	19	0.52																				1																					
3.5%	20	0.50	1	1																			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44			0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33																							
3.5%	25	0.42																			0.33																						
3.5%	26	0.41																				0.33			0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33		
3.5%	27	0.40	0.33	0.33																			0.33	0.33																		0.33	0.33
3.5%	28	0.38																																									
3.5%	29	0.37																																									
3.5%	30	0.36																																									
3.0%	31	0.35			0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33																							
3.0%	32	0.34																			0.33				0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33		
3.0%	33	0.33																				0.33																				0.33	
3.0%	34	0.32	0.33	0.33																			0.33	0.33																			0.33
3.0%	35	0.31																																									
3.0%	36	0.30																																									
3.0%	37	0.29			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
3.0%	38	0.28																			1																					1		
3.0%	39	0.27																				1																				1	
3.0%	40	0.27	R.V.		-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.90	-0.95			-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.85	-0.90	-0.95	
NPV if tr'tm'nt cost=1			2.21	2.21	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.33	2.26	2.21	2.21	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.28	2.26	2.23	2.21
Trenched minus baseline				0.00	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.12	0.05	0.00	0.00	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.05	0.02	0.00

Tr'ch'd minus b'line over 40y	4.13	Unit cost (£/area)	15	Trenched area per year	804597	Area scaling factor	3.158	NPV (£m)	157.29	Sum of discount factors	22.17	Annual cost (£m)	7.10

Table C 17 Additional maintenance costs: Major carriageways - binder course untrenched service life: 20 years, 'reference' service life reduction: 15% - 'Full reduction', 'Same' areas trenched each year

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73																																									
3.5%	10	0.71																																									
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64																																									
3.5%	14	0.62																																									
3.5%	15	0.60																																									
3.5%	16	0.58																																									
3.5%	17	0.56			1	1	1	1	1	1	1	1	1	1	1	1	1																										
3.5%	18	0.54																																									
3.5%	19	0.52																																									
3.5%	20	0.50	1	1														1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44																																									
3.5%	25	0.42																																									
3.5%	26	0.41																																									
3.5%	27	0.40																																									
3.5%	28	0.38																																									
3.5%	29	0.37																																									
3.5%	30	0.36																																									
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32			1	1	1	1	1	1	1	1	1	1	1	1	1																										
3.0%	35	0.31																																									
3.0%	36	0.30																																									
3.0%	37	0.29																																									
3.0%	38	0.28																																									
3.0%	39	0.27																																									
3.0%	40	0.27	R.V.		-0.65	-0.65	-0.65	-0.65	-0.65	-0.65	-0.65	-0.65	-0.65	-0.65	-0.65	-0.65	-0.65																										
NPV if tr'tm'nt cost=1			1.50	1.50	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Trenched minus baseline				0.00	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tr'ch'd minus b'line over 40y				2.60	Unit cost (£/area)	23	Trenched area per year	804597	Area scaling factor	3.077	NPV (£m)	147.79	Sum of discount factors	22.17	Annual cost (£m)	6.67																											

Table C 18 Additional maintenance costs: Major carriageways - surface course untrenched service life: 10 years, 'reference' service life reduction: 15% - 'Full reduction', 'Same' areas trenched each year, 'One zone' treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73			1	1	1	1	1	1	1																																
3.5%	10	0.71	1	1								1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64																																									
3.5%	14	0.62																																									
3.5%	15	0.60																																									
3.5%	16	0.58																																									
3.5%	17	0.56			1	1	1	1	1	1	1	1	1	1	1	1	1																										
3.5%	18	0.54																																									
3.5%	19	0.52																																									
3.5%	20	0.50	1	1														1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44																																									
3.5%	25	0.42																																									
3.5%	26	0.41			1	1	1	1	1	1	1																																
3.5%	27	0.40										1	1	1	1	1	1																										
3.5%	28	0.38																																									
3.5%	29	0.37																																									
3.5%	30	0.36	1	1														1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32			1	1	1	1	1	1	1	1	1	1	1	1	1																										
3.0%	35	0.31																																									
3.0%	36	0.30																																									
3.0%	37	0.29																																									
3.0%	38	0.28																																									
3.0%	39	0.27																																									
3.0%	40	0.27	R.V.		-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40																										
NPV if tr'tm'nt cost=1			2.57	2.57	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.87	2.87	2.87	2.87	2.87	2.87	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57	2.57
Trenched minus baseline				0.00	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.30	0.30	0.30	0.30	0.30	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tr'ch'd minus b'line over 40y				4.34	Unit cost (£/area)				15		Trenched area per year					804597		Area scaling factor					3.077		NPV (£m)			161.34		Sum of discount factors					22.17		Annual cost (£m)					7.28	

Table C 19 Additional maintenance costs: Major carriageways - binder course untrenched service life: 30 years, 'reference' service life reduction: 20% - 'Full reduction', 'Different' areas trenched each year

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73																																									
3.5%	10	0.71	1																																								
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64																																									
3.5%	14	0.62																																									
3.5%	15	0.60																																									
3.5%	16	0.58																																									
3.5%	17	0.56																																									
3.5%	18	0.54																																									
3.5%	19	0.52																																									
3.5%	20	0.50	1																																								
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																
3.5%	25	0.42																												1															
3.5%	26	0.41																													1														
3.5%	27	0.40																														1													
3.5%	28	0.38																															1												
3.5%	29	0.37																																1											
3.5%	30	0.36	1	1																															1	1	1	1	1	1	1	1	1	1	1
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32																																									
3.0%	35	0.31																																									
3.0%	36	0.30																																									
3.0%	37	0.29																																									
3.0%	38	0.28																																									
3.0%	39	0.27																																									
3.0%	40	0.27	-0.67	-0.67	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.47	-0.50	-0.53	-0.57	-0.60	-0.63	-0.67	-0.67	-0.58	-0.58	-0.58	-0.58	-0.58	-0.58	-0.58	-0.58	-0.58
NPV if tr'tm'nt cost=1			1.18	1.18	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.29	1.27	1.24	1.22	1.20	1.18	1.18	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Trenched minus baseline				0.00	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.11	0.09	0.06	0.04	0.02	0.00	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Tr'ch'd minus b'line over 40y				3.63	Unit cost (£/area)	23	Trenched area per year	804597	Area scaling factor	3.158	NPV (£m)	211.87	Sum of discount factors	22.17	Annual cost (£m)	9.56																											

Table C 20 Additional maintenance costs: Major carriageways - surface course untrenched service life: 15 years, 'reference' service life reduction: 20% - 'Full reduction', 'Different' areas trenched each year, 'Several zones' treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																					
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73																																									
3.5%	10	0.71																																									
3.5%	11	0.68																																									
3.5%	12	0.66			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																
3.5%	13	0.64																											1	1													
3.5%	14	0.62																													1	1											
3.5%	15	0.60	1	1																													1	1	1	1	1	1	1	1	1	1	1	1
3.5%	16	0.58																																									
3.5%	17	0.56																																									
3.5%	18	0.54																																									
3.5%	19	0.52																																									
3.5%	20	0.50																																									
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																
3.5%	25	0.42																											1															
3.5%	26	0.41																												1														
3.5%	27	0.40																													1													
3.5%	28	0.38																														1												
3.5%	29	0.37																															1											
3.5%	30	0.36	1	1																														1	1	1	1	1	1	1	1	1	1	1
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32																																									
3.0%	35	0.31																																									
3.0%	36	0.30																																									
3.0%	37	0.29																																									
3.0%	38	0.28																																									
3.0%	39	0.27			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																
3.0%	40	0.27	-0.33	-0.33	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93		-0.07	-0.13	-0.20	-0.27	-0.33	-0.33	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17
NPV if tr'tm'nt cost=1			1.87	1.87	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.06	2.03	1.98	1.95	1.89	1.87	1.87	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91
Trenched minus baseline				0.00	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.20	0.16	0.11	0.08	0.03	0.00	0.00	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Tr'ch'd minus b'line over 40y				6.98	Unit cost (£/area)				15	Trenched area per year					804597	Area scaling factor					3.158	NPV (£m)				265.97	Sum of discount factors					22.17	Annual cost (£m)					12.00					

Table C 21 Additional maintenance costs: Major carriageways - surface course untrenched service life: 15 years, 'reference' service life reduction: 20% - 'Partial reduction', 'Different' areas trenched each year, 'One zone' treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73																																									
3.5%	10	0.71																																									
3.5%	11	0.68																																									
3.5%	12	0.66			1	1	1	1	1	1	1	1																															
3.5%	13	0.64											1	1																													
3.5%	14	0.62													1	1																											
3.5%	15	0.60	1	1													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	16	0.58																																									
3.5%	17	0.56																																									
3.5%	18	0.54																																									
3.5%	19	0.52																																									
3.5%	20	0.50																																									
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																
3.5%	25	0.42																																									
3.5%	26	0.41																																									
3.5%	27	0.40																																									
3.5%	28	0.38																																									
3.5%	29	0.37																																									
3.5%	30	0.36	1	1																								1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32																																									
3.0%	35	0.31																																									
3.0%	36	0.30																																									
3.0%	37	0.29																																									
3.0%	38	0.28																																									
3.0%	39	0.27			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																
3.0%	40	0.27	-0.33	-0.33	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.23
NPV if tr'tm'nt cost=1			1.87	1.87	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.10	2.10	2.08	2.08	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.89
Trenched minus baseline				0.00	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.24	0.24	0.22	0.22	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03

Tr'ch'd minus b'line over 40y	5.53	Unit cost (£/area)	15	Trenched area per year	804597	Area scaling factor	3.158	NPV (£m)	210.65	Sum of discount factors	22.17	Annual cost (£m)	9.50		

Table C 22 Additional maintenance costs: Major carriageways - surface course untrenched service life: 15 years, 'reference' service life reduction: 30% - 'Full reduction', 'Different' areas trenched each year, 'One zone' treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																			
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73																																									
3.5%	10	0.71																																									
3.5%	11	0.68			1	1	1	1	1	1																																	
3.5%	12	0.66									1	1																															
3.5%	13	0.64											1	1																													
3.5%	14	0.62													1	1																											
3.5%	15	0.60	1	1													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	16	0.58																																									
3.5%	17	0.56																																									
3.5%	18	0.54																																									
3.5%	19	0.52																																									
3.5%	20	0.50																																									
3.5%	21	0.49			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																			
3.5%	22	0.47																								1																	
3.5%	23	0.45																									1																
3.5%	24	0.44																										1															
3.5%	25	0.42																											1														
3.5%	26	0.41																												1													
3.5%	27	0.40																													1												
3.5%	28	0.38																														1											
3.5%	29	0.37																															1										
3.5%	30	0.36	1	1																														1	1	1	1	1	1	1	1	1	1	1
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32																																									
3.0%	35	0.31																																									
3.0%	36	0.30			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																			
3.0%	37	0.29																								1																	
3.0%	38	0.28																									1																
3.0%	39	0.27																										1															
3.0%	40	0.27	-0.33	-0.33	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.73	-0.80	-0.87	-0.93		-0.07	-0.13	-0.20	-0.27	-0.33	-0.33	-0.09	-0.09	-0.09	-0.09	-0.09	-0.09	-0.17	-0.17	-0.23
NPV if tr'tm'nt cost=1			1.87	1.87	2.27	2.27	2.27	2.27	2.27	2.27	2.25	2.25	2.23	2.23	2.21	2.21	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.14	2.10	2.06	2.02	1.99	1.96	1.93	1.89	1.87	1.87	1.93	1.93	1.93	1.93	1.93	1.93	1.91	1.91	1.89
Trenched minus baseline				0.00	0.41	0.41	0.41	0.41	0.41	0.41	0.39	0.39	0.36	0.36	0.34	0.34	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.28	0.24	0.19	0.15	0.12	0.09	0.06	0.03	0.00	0.00	0.06	0.06	0.06	0.06	0.06	0.06	0.04	0.04	0.03
Tr'ch'd minus b'line over 40y				8.89	Unit cost (£/area)	15	Trenched area per year	804597	Area scaling factor	3.158	NPV (£m)	338.86	Sum of discount factors	22.17	Annual cost (£m)	15.29																											

Table C 23 Additional maintenance costs: Major carriageways - surface course untrenched service life: 10 years, 'reference' service life reduction: 30% - 'Full reduction', 'Different' areas trenched each year, 'One zone' treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79			1	1	1																																				
3.5%	8	0.76						1	1																																		
3.5%	9	0.73								1	1																																
3.5%	10	0.71	1	1								1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64																																									
3.5%	14	0.62			1	1	1																																				
3.5%	15	0.60						1	1	1	1																																
3.5%	16	0.58										1	1	1	1																												
3.5%	17	0.56														1	1																										
3.5%	18	0.54																1	1																								
3.5%	19	0.52																		1	1																						
3.5%	20	0.50	1	1																					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	21	0.49			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																			
3.5%	22	0.47																							1																		
3.5%	23	0.45																								1																	
3.5%	24	0.44																									1																
3.5%	25	0.42																										1															
3.5%	26	0.41																											1														
3.5%	27	0.40																												1													
3.5%	28	0.38																													1												
3.5%	29	0.37																														1											
3.5%	30	0.36	1	1																													1	1	1	1	1	1	1	1	1	1	1
3.0%	31	0.35			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																			
3.0%	32	0.34																							1																		
3.0%	33	0.33																								1																	
3.0%	34	0.32																									1																
3.0%	35	0.31																										1															
3.0%	36	0.30																											1														
3.0%	37	0.29																												1					1	1	1						
3.0%	38	0.28																													1							1	1				
3.0%	39	0.27																														1								1	1		
3.0%	40	0.27	R.V.		-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.10	-0.20	-0.30	-0.40	-0.50	-0.60	-0.70	-0.80	-0.90			-0.57	-0.57	-0.57	-0.71	-0.71	-0.83	-0.83		
NPV if tr'tm'nt cost=1			2.57	2.57	3.21	3.21	3.21	3.16	3.16	3.14	3.14	3.09	3.09	3.09	3.09	3.07	3.07	3.05	3.05	3.04	3.04	2.52	2.52	2.52	2.96	2.91	2.86	2.81	2.76	2.71	2.66	2.61	2.57	2.57	2.71	2.71	2.71	2.66	2.66	2.62	2.62	2.57	2.57
Trenched minus baseline				0.00	0.64	0.64	0.64	0.59	0.59	0.57	0.57	0.52	0.52	0.52	0.52	0.50	0.50	0.48	0.48	0.47	0.47	-0.05	-0.05	-0.05	0.40	0.34	0.29	0.24	0.19	0.14	0.09	0.05	0.00	0.00	0.14	0.14	0.14	0.09	0.09	0.05	0.05	0.00	0.00
Tr'ch'd minus b'line over 40y				11.54	Unit cost (£/area)	15	Trenched area per year	804597	Area scaling factor	3.158	NPV (£m)	439.64	Sum of discount factors	22.17	Annual cost (£m)	19.83																											

Table C 24 Additional maintenance costs: Major carriageways - surface course / surface treatment untrenched service lives: 15 / 7.5 years, 'reference' service life reduction: 20 % - 'Full reduction', 'Different' areas trenched each year, 'Several zones' treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81			0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33																
3.5%	7	0.79																											0.33	0.33	0.33	0.33												
3.5%	8	0.76	0.33	0.33																													0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
3.5%	9	0.73																																									
3.5%	10	0.71																																									
3.5%	11	0.68																																									
3.5%	12	0.66			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																
3.5%	13	0.64																											1	1														
3.5%	14	0.62																													1	1												
3.5%	15	0.60	1	1																													1	1	1	1	1	1	1	1	1	1	1	1
3.5%	16	0.58																																									
3.5%	17	0.56																																									
3.5%	18	0.54			0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33																
3.5%	19	0.52																											0.33															
3.5%	20	0.50																												0.33														
3.5%	21	0.49																													0.33	0.33												
3.5%	22	0.47																															0.33											
3.5%	23	0.45	0.33	0.33																														0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
3.5%	24	0.44			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																
3.5%	25	0.42																											1															
3.5%	26	0.41																												1														
3.5%	27	0.40																													1													
3.5%	28	0.38																														1												
3.5%	29	0.37																															1											
3.5%	30	0.36	1	1																														1	1	1	1	1	1	1	1	1	1	1
3.0%	31	0.35																																									
3.0%	32	0.34			0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33																
3.0%	33	0.33																											0.33															
3.0%	34	0.32																												0.33														
3.0%	35	0.31																													0.33													
3.0%	36	0.30																														0.33				0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
3.0%	37	0.29																															0.33											
3.0%	38	0.28	0.33	0.33																														0.33	0.33									
3.0%	39	0.27			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																
3.0%	40	0.27	-0.57	-0.57	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93		-0.11	-0.23	-0.34	-0.46	-0.57	-0.57	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28
NPV if tr'tm'nt cost=1			2.30	2.30	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.61	2.55	2.48	2.43	2.35	2.30	2.30	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39
Trenched minus baseline				0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.31	0.25	0.18	0.13	0.05	0.00	0.00	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Tr'ch'd minus b'line over 40y				10.60	Unit cost (£/area)				15	Trenched area per year					804597	Area scaling factor					3.158	NPV (£m)			404.16	Sum of discount factors					22.17	Annual cost (£m)					18.23						

Table C 25 Additional maintenance costs: Major carriageways - surface course / surface treatment untrenched service lives: 15 / 7.5 years, 'reference' service life reduction: 20% - 'Full reduction' , 'Different' areas trenched each year, 'One zone' treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81			0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33																															
3.5%	7	0.79											0.33	0.33	0.33	0.33																											
3.5%	8	0.76	0.33	0.33													0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
3.5%	9	0.73																																									
3.5%	10	0.71																																									
3.5%	11	0.68																																									
3.5%	12	0.66			1	1	1	1	1	1	1	1																															
3.5%	13	0.64											1	1																													
3.5%	14	0.62													1	1																											
3.5%	15	0.60	1	1													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	16	0.58																																									
3.5%	17	0.56																																									
3.5%	18	0.54			0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33																															
3.5%	19	0.52											0.33	0.33	0.33	0.33																											
3.5%	20	0.50															0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33															
3.5%	21	0.49																											0.33	0.33													
3.5%	22	0.47																													0.33	0.33											
3.5%	23	0.45	0.33	0.33																													0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
3.5%	24	0.44			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																
3.5%	25	0.42																										1															
3.5%	26	0.41																											1														
3.5%	27	0.40																												1													
3.5%	28	0.38																													1												
3.5%	29	0.37																														1											
3.5%	30	0.36	1	1																													1	1	1	1	1	1	1	1	1	1	1
3.0%	31	0.35																																									
3.0%	32	0.34			0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33																
3.0%	33	0.33																										0.33															
3.0%	34	0.32																											0.33														
3.0%	35	0.31																												0.33													
3.0%	36	0.30																													0.33				0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	
3.0%	37	0.29																														0.33											0.33
3.0%	38	0.28	0.33	0.33																													0.33	0.33									
3.0%	39	0.27			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																
3.0%	40	0.27	-0.57	-0.57	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93	-0.93		-0.11	-0.23	-0.34	-0.46	-0.57	-0.57	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.28	-0.40
NPV if tr'tm'nt cost=1			2.30	2.30	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.69	2.65	2.65	2.63	2.63	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.55	2.50	2.45	2.40	2.35	2.30	2.30	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.35
Trenched minus baseline				0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.35	0.35	0.33	0.33	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.25	0.20	0.15	0.10	0.05	0.00	0.00	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.05
Tr'ch'd minus b'line over 40y				9.15	Unit cost (£/area)					15	Trenched area per year						804597		Area scaling factor					3.158		NPV (£m)			348.86		Sum of discount factors					22.17		Annual cost (£m)				15.74	

Table C 26 Additional maintenance costs: Minor carriageways – surface course / surface treatment untrenched service lives: 30 / 15 years, 'reference' service life reduction: 20 % - 'Full reduction', 'Different' areas trenched each year, 'Several zones' treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																					
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73																																									
3.5%	10	0.71																																									
3.5%	11	0.68																																									
3.5%	12	0.66			0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42																
3.5%	13	0.64																											0.42	0.42														
3.5%	14	0.62																													0.42	0.42												
3.5%	15	0.60	0.42	0.42																													0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
3.5%	16	0.58																																									
3.5%	17	0.56																																									
3.5%	18	0.54																																									
3.5%	19	0.52																																									
3.5%	20	0.50																																									
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																
3.5%	25	0.42																											1														
3.5%	26	0.41																												1													
3.5%	27	0.40																													1												
3.5%	28	0.38																														1											
3.5%	29	0.37																															1										
3.5%	30	0.36	1	1																														1	1	1	1	1	1	1	1	1	1	1
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32																																									
3.0%	35	0.31																																									
3.0%	36	0.30																																									
3.0%	37	0.29																																									
3.0%	38	0.28																																									
3.0%	39	0.27			0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42																
3.0%	40	0.27	-0.67	-0.67	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.86	-0.50	-0.53	-0.57	-0.60	-0.63	-0.67	-0.67	-0.58	-0.58	-0.58	-0.58	-0.58	-0.58	-0.58	-0.58	-0.58
NPV if tr'tm'nt cost=1			1.43	1.43	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.56	1.53	1.50	1.48	1.45	1.43	1.43	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45
Trenched minus baseline				0.00	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.13	0.10	0.07	0.05	0.02	0.00	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Tr'ch'd minus b'line over 40y				4.55	Unit cost (£/area)	12	Trenched area per year	1394451	Area scaling factor	3.158	NPV (£m)	240.21	Sum of discount factors	22.17	Annual cost (£m)	10.84																											

Table C 27 Additional maintenance costs: Minor carriageways – surface course / surface treatment untrenched service lives: 30 / 10 years, ‘reference’ service life reduction: 20 % - ‘Full reduction’, ‘Different’ areas trenched each year, ‘Several zones’ treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76			0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42																
3.5%	9	0.73																											0.42	0.42	0.42													
3.5%	10	0.71	0.42	0.42																												0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64																																									
3.5%	14	0.62																																									
3.5%	15	0.60																																									
3.5%	16	0.58			0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42																
3.5%	17	0.56																											0.42															
3.5%	18	0.54																												0.42	0.42													
3.5%	19	0.52																														0.42												
3.5%	20	0.50	0.42	0.42																													0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																
3.5%	25	0.42																											1															
3.5%	26	0.41																												1														
3.5%	27	0.40																													1													
3.5%	28	0.38																														1												
3.5%	29	0.37																															1											
3.5%	30	0.36	1	1																														1	1	1	1	1	1	1	1	1	1	1
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32			0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42																
3.0%	35	0.31																											0.42															
3.0%	36	0.30																												0.42														
3.0%	37	0.29																													0.42													
3.0%	38	0.28																														0.42				0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
3.0%	39	0.27																															0.42											
3.0%	40	0.27	-0.67	-0.67	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.71	-0.78	-0.86	-0.93	-1.01	-0.67	-0.67	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90
NPV if tr'tmnt cost=1			1.69	1.69	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.96	1.90	1.86	1.82	1.76	1.72	1.69	1.69	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74	1.74
Trenched minus baseline				0.00	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.22	0.17	0.13	0.08	0.03	0.00	0.00	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06

Tr'ch'd minus b'line over 40y	7.45	Unit cost (£/area)	12	Trenched area per year	1394451	Area scaling factor	3.158	NPV (£m)	392.92	Sum of discount factors	22.17	Annual cost (£m)	17.77

Table C 28 Additional maintenance costs: Minor carriageways - surface course untrenched service life: 15 years, 'reference' service life reduction: 13.33% - 'Full reduction', 'Same' areas trenched each year, 'One zone' treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73																																									
3.5%	10	0.71																																									
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64			1	1	1	1	1	1	1	1	1	1																													
3.5%	14	0.62													1	1																											
3.5%	15	0.60	1	1													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	16	0.58																																									
3.5%	17	0.56																																									
3.5%	18	0.54																																									
3.5%	19	0.52																																									
3.5%	20	0.50																																									
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44																																									
3.5%	25	0.42																																									
3.5%	26	0.41			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																				
3.5%	27	0.40																																									
3.5%	28	0.38																																									
3.5%	29	0.37																																									
3.5%	30	0.36	1	1																				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32																																									
3.0%	35	0.31																																									
3.0%	36	0.30																																									
3.0%	37	0.29																																									
3.0%	38	0.28																																									
3.0%	39	0.27			1	1	1	1	1	1	1	1	1	1																													
3.0%	40	0.27	-0.33	-0.33	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92	-0.92			-0.07	-0.07	-0.07	-0.07	-0.07	-0.07	-0.07	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33	-0.33
NPV if tr'tm'nt cost=1			1.87	1.87	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.03	2.03	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87
Trenched minus baseline				0.00	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.16	0.16	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tr'ch'd minus b'line over 40y				3.30	Unit cost (£/area)	12	Trenched area per year	1394451	Area scaling factor	3.077	NPV (£m)	170.13	Sum of discount factors	22.17	Annual cost (£m)	7.68																											

Table C 29 Additional maintenance costs: Minor carriageways - surface course untrenched service life: 20 years, 'reference' service life reduction: 30% - 'Full reduction', 'Different' areas trenched each year, 'One zone' treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73																																									
3.5%	10	0.71																																									
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64																																									
3.5%	14	0.62			1	1	1	1	1	1	1																																
3.5%	15	0.60										1	1																														
3.5%	16	0.58												1	1																												
3.5%	17	0.56														1	1																										
3.5%	18	0.54																1	1																								
3.5%	19	0.52																		1	1																						
3.5%	20	0.50	1	1																		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44																																									
3.5%	25	0.42																																									
3.5%	26	0.41																																									
3.5%	27	0.40																																									
3.5%	28	0.38			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1												
3.5%	29	0.37																														1											
3.5%	30	0.36																															1										
3.0%	31	0.35																																1									
3.0%	32	0.34																																	1								
3.0%	33	0.33																																		1							
3.0%	34	0.32																																			1						
3.0%	35	0.31																																				1					
3.0%	36	0.30																																					1				
3.0%	37	0.29																																						1			
3.0%	38	0.28																																							1		
3.0%	39	0.27																																								1	
3.0%	40	0.27			-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40	-0.45	-0.50	-0.55	-0.60	-0.65	-0.70	-0.75	-0.80	-0.85	-0.90	-0.95	
NPV if tr'tm'nt cost=1			1.50	1.50	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.87	1.87	1.85	1.85	1.83	1.83	1.81	1.81	1.80	1.80	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.75	1.73	1.70	1.68	1.66	1.63	1.61	1.59	1.57	1.55	1.52	1.50
Trenched minus baseline				0.00	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.37	0.37	0.35	0.35	0.33	0.33	0.31	0.31	0.29	0.29	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.25	0.22	0.20	0.18	0.15	0.13	0.11	0.09	0.06	0.04	0.02	0.00
Tr'ch'd minus b'line over 40y				10.26	Unit cost (£/area)					12	Trenched area per year						1394451		Area scaling factor					3.077		NPV (£m)			528.20		Sum of discount factors					22.17		Annual cost (£m)				23.83	

Table C 30 Additional maintenance costs: Minor carriageways – surface course / surface treatment untrenched service lives: 40 / 20 years, 'reference' service life reduction: 20 % - 'Full reduction', 'Different' areas trenched each year, 'Several zones' treated

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73																																									
3.5%	10	0.71																																									
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64																																									
3.5%	14	0.62																																									
3.5%	15	0.60																																									
3.5%	16	0.58			0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42								
3.5%	17	0.56																																		0.42	0.42						
3.5%	18	0.54																																				0.42	0.42				
3.5%	19	0.52																																						0.42	0.42		
3.5%	20	0.50	0.42	0.42																																						0.42	0.42
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44																																									
3.5%	25	0.42																																									
3.5%	26	0.41																																									
3.5%	27	0.40																																									
3.5%	28	0.38																																									
3.5%	29	0.37																																									
3.5%	30	0.36																																									
3.0%	31	0.35																																									
3.0%	32	0.34			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1								
3.0%	33	0.33																																		1							
3.0%	34	0.32																																			1						
3.0%	35	0.31																																				1					
3.0%	36	0.30																																					1				
3.0%	37	0.29																																						1			
3.0%	38	0.28																																							1		
3.0%	39	0.27																																								1	
3.0%	40	0.27			-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.83	-0.85	-0.88	-0.90	-0.93	-0.95	-0.98	
NPV if tr'tm'nt cost=11			1.21	1.21	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.34	1.32	1.30	1.28	1.26	1.25	1.22	1.21
Trenched minus baseline				0.00	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.13	0.11	0.09	0.07	0.05	0.04	0.01	0.00
Tr'ch'd minus b'line over 40y				5.31	Unit cost (£/area)	12	Trenched area per year	1394451	Area scaling factor	3.077	NPV (£m)	273.18	Sum of discount factors	22.17	Annual cost (£m)	12.32																											

Table C 31 Additional maintenance costs: Footways – binder and surface courses plus surface treatment for visual disbenefits, b.c. and s.c. untrenched service life: 30 years, 'reference' service life reduction: 10% - 'Full reduction', 'Different', 'Several zones'

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73																																									
3.5%	10	0.71																																									
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64																																									
3.5%	14	0.62			0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25																										
3.5%	15	0.60																																									
3.5%	16	0.58																																									
3.5%	17	0.56																																									
3.5%	18	0.54																																									
3.5%	19	0.52																																									
3.5%	20	0.50																																									
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44																																									
3.5%	25	0.42																																									
3.5%	26	0.41																																									
3.5%	27	0.40			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1													
3.5%	28	0.38																															1												
3.5%	29	0.37																																1											
3.5%	30	0.36	1	1																															1	1	1	1	1	1	1	1	1	1	1
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32																																									
3.0%	35	0.31																																									
3.0%	36	0.30																																									
3.0%	37	0.29																																									
3.0%	38	0.28																																									
3.0%	39	0.27																																									
3.0%	40	0.27	-0.67	-0.67	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.57	-0.60	-0.63	-0.67	-0.67	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63	-0.63
NPV if tr'tm'nt cost=1			1.18	1.18	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.22	1.20	1.18	1.18	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19
Trenched minus baseline				0.00	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.04	0.02	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Tr'ch'd minus b'line over 40y				3.86	Unit cost (£/area)			16	Trenched area per year				2471527		Area scaling factor			3.158		NPV (£m)			481.63		Sum of discount factors			22.17		Annual cost (£m)			21.73										

Table C 32 Additional maintenance costs: Footways – binder and surface courses plus surface treatment for visual disbenefits, b.c. and s.c. untrenched service life: 30 years, 'reference' service life reduction: 10% - 'Full reduction', 'Same', 'Several zones'

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73																																									
3.5%	10	0.71																																									
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64																																									
3.5%	14	0.62			0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25																										
3.5%	15	0.60																																									
3.5%	16	0.58																																									
3.5%	17	0.56																																									
3.5%	18	0.54																																									
3.5%	19	0.52																																									
3.5%	20	0.50																																									
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44																																									
3.5%	25	0.42																																									
3.5%	26	0.41																																									
3.5%	27	0.40			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																				
3.5%	28	0.38																																									
3.5%	29	0.37																																									
3.5%	30	0.36	1	1																				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32																																									
3.0%	35	0.31																																									
3.0%	36	0.30																																									
3.0%	37	0.29																																									
3.0%	38	0.28																																									
3.0%	39	0.27																																									
3.0%	40	0.27	-0.67	-0.67	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67
NPV if tr'tm'nt cost=1			1.18	1.18	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.26	1.26	1.26	1.26	1.26	1.26	1.41	1.41	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18	1.18
Trenched minus baseline				0.00	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.08	0.08	0.08	0.08	0.08	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tr'ch'd minus b'line over 40y				3.49	Unit cost (£/area)	16	Trenched area per year	2471527	Area scaling factor	3.077	NPV (£m)	424.64	Sum of discount factors	22.17	Annual cost (£m)	19.16																											

Table C 33 Additional maintenance costs: Footways – binder and surface courses plus surface treatment for visual disbenefits, b.c. and s.c. untrenched service life: 40 years, 'reference' service life reduction: 10% - 'Full reduction', 'Different', 'Several zones'

Dis't rate	Year tr't'd	Dis't Factor	Base-line	Year trenched																																							
				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
	0	1.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3.5%	1	0.97																																									
3.5%	2	0.93																																									
3.5%	3	0.90																																									
3.5%	4	0.87																																									
3.5%	5	0.84																																									
3.5%	6	0.81																																									
3.5%	7	0.79																																									
3.5%	8	0.76																																									
3.5%	9	0.73																																									
3.5%	10	0.71																																									
3.5%	11	0.68																																									
3.5%	12	0.66																																									
3.5%	13	0.64																																									
3.5%	14	0.62																																									
3.5%	15	0.60																																									
3.5%	16	0.58																																									
3.5%	17	0.56																																									
3.5%	18	0.54			0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25																						
3.5%	19	0.52																																									
3.5%	20	0.50																																									
3.5%	21	0.49																																									
3.5%	22	0.47																																									
3.5%	23	0.45																																									
3.5%	24	0.44																																									
3.5%	25	0.42																																									
3.5%	26	0.41																																									
3.5%	27	0.40																																									
3.5%	28	0.38																																									
3.5%	29	0.37																																									
3.5%	30	0.36																																									
3.0%	31	0.35																																									
3.0%	32	0.34																																									
3.0%	33	0.33																																									
3.0%	34	0.32																																									
3.0%	35	0.31																																									
3.0%	36	0.30			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				
3.0%	37	0.29																																						1			
3.0%	38	0.28																																							1		
3.0%	39	0.27																																								1	
3.0%	40	0.27			-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.90	-0.93	-0.95	-0.98	
NPV if tr'tm'nt cost=1			1.00	1.00	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.19	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.04	1.03	1.01	1.00
Trenched minus baseline				0.00	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.04	0.03	0.01	0.00
Tr'ch'd minus b'line over 40y				4.47	Unit cost (£/area)	16	Trenched area per year	2471527	Area scaling factor	3.077	NPV (£m)	543.75	Sum of discount factors	22.17	Annual cost (£m)	24.53																											

A charge structure for trenching in the highway

Studies have shown that utility trenching can have a detrimental effect on both the surface condition and the underlying structure of highways, thereby shortening their service lives. In the UK, there is also increasing political and public concern regarding the negative impact of reinstatement patches on the visual appearance of the nation's highways. Analysis of FWD data obtained from reinstatements in carriageways is reported. This estimated that the median reduction in the service life of the pavement structure due to trenching is 17 per cent. The additional maintenance costs incurred by highway authorities due the premature deterioration in the structural and surface condition of carriageways have been estimated assuming this service life reduction. Also, the additional maintenance costs incurred due to the premature deterioration in the structural, surface and visual condition of footways has been estimated assuming a 10 per cent service life reduction due to trenching. The costs for 2007/08 were estimated to be £49.8m for carriageways and £20.3m for footways, although these are considered to be low estimates of the full impact of trenching on highways. A charge structure has been developed that enables charges to be levied against those trenching the highway in order to recover these additional maintenance costs. The charges vary according to the highway condition, and are higher the better the condition. The highest charges for 2007/2008 were estimated to be £45.48/m2 for Major carriageways (Type 0, 1, 2 and 3 roads), £28.74/m2 for Minor carriageways (Type 4 roads), £23.89/m2 for category 1(a) and 1 footways and £11.95/m2 for category 2 to 4 footways. It is proposed that the charges be levied either as part of a permit charge under Section 55 of the Traffic Management Act 2004 or using the reinstatement notices already required under Section 78 of the New Roads and Street Works Act 1991. Using charge rates to recover the additional maintenance costs is considered to be more practical and equitable than a requirement for one particular undertaker to carry out half- or full-width resurfacing.

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