DEVELOPMENT OF A SUSTAINABILITY ASSESSMENT METHODOLOGY FOR UK STREETWORKS PROJECTS

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ABSTRACT

When streetworks are carried out to renew road surfaces or maintain buried pipes and cables, a number of different aspects need to be considered. An assessment tool has been developed so that highway authorities and utility companies can compare different solutions (or 'Scenarios') in terms of the impacts created (See Figure 4.1).

These impacts were best captured by developing a new sustainability assessment methodology that combines qualitative and quantitative methods, and focuses on the needs of the 'one customer' who enjoys access to roads and utilities every day but pays the price through tax, utility bills, congestion and noise. The assessment tool was applied to four Case Studies and the results validated, and it proved beneficial in understanding how the value of streetworks solutions can be evaluated. However, certain input parameters (notably average vehicle delays at streetworks) now need to be investigated further to better understand the uncertainty of the result.

The methodology provides an academic contribution because it incorporates working practices used in the UK, techniques used to measure or calculate certain impacts, and criteria used to consider social or environmental issues, to create a sustainability-based assessment tool that is specifically designed for small scale streetworks projects.

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ABBREVIATIONS AND ACRONYMS

AADT	Annual Average Daily Traffic
AQMA	Air Quality Management Area
ASCE	American Society of Civil Engineers
ASHE	Annual Survey of Hours and Earnings
BB	Balfour Beatty
BBC	British Broadcasting Corporation
CA	Balfour Beatty Utility Solutions
BoE	Bank of England
BSI	British Standards Institution
CBA	Cost Benefit Analysis
CBI	Confederation of British Industry
CDM	Construction, Design and Management
Ce	Carbon equivalent
CEEQUAL	Civil Engineering Environmental Quality Assessment and Award Scheme
CESMM3	Civil Engineering Standard Method of Measurement
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide equivalent
COSHH	Control of Substances Hazardous to Health
CRTN	Calculation of Road Traffic Noise
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
DETR	Department of the Environment, Transport and the Regions
DfT	Department for Transport
DMRB	Design Manual for Roads and Bridges
DST	Decision Support Tools
ESWRAC	European Street Works Research Advisory Council
EToN	Electronic Transfer of Notifications
EU	European Union
FT	Financial Times

GLA	Greater London Authority
GPR	Ground Penetrating Radar
HA	Highways Agency
HAUC	Highway Authorities and Utilities Committee
HAA	Hampshire County Council
HDD	Horizontal Directional Drilling
HMEP	Highway Maintenance Efficiency Programme
HMSO	Her Majesty's Stationery Office
HSE	Health and Safety Executive
ICE	Institution of Civil Engineers
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
LCA	Life Cycle Analysis
LOP	Loss of Productivity
LoPS	London Permit Scheme
MCDA	Multi Criteria Decision Analysis
MM	Mott MacDonald
MMHW	Method of Measurement for Highway Works
MTU	Mapping the Underworld
NJUG	National Joint Utilities Group
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NRSWA	New Roads and Street Works Act
NSG	National Street Gazetteer
NUAG	National Underground Assets Group
ORR	Office of Rail Regulation
OXEMS	Oxford Electromagnetic Solutions
PAT	Project Assessment Tool
PFI	Private Finance Initiative
PM	Particulate Matter

PRF	Productivity Reduction Factor
PTS	Portable Traffic Signals
QLA	Quality Level A
QUADRO	QUeues And Delays at Roadworks
RC	Reinstatement Category
ROI	Return On Investment
SDC	Sustainable Development Commission
HAB	South Gloucestershire Council
UCA	Southern Gas Networks
SI	Sustainability Indicators
SPeAR®	Sustainable Project Appraisal Routine
SSE	Scottish and Southern Energy
UCD	Severn Trent Water
SUE	Subsurface Utility Engineering
SWARD	Sustainable Water Industry Asset Resource Decisions Framework
TM	Traffic Management
TMA	Traffic Management Act
TREI	Total Risk Exposure Index
TRL	The Transport Research Laboratory
UN	United Nations
US	United States
VISTA	Visualising Integrated Information on Buried Assets to Reduce Streetworks
VOCs	Volatile Organic Compounds
HAC	Warwickshire County Council
WebTAG	Transport Analysis Guidance
WHO	World Health Organisation
UCB	Western Power Distribution
WTP	Willingness to pay technique

1 INTRODUCTION AND BACKGROUND

Utility services are essential to society and the maintenance of civilised life: gas, water, electricity, telecommunications and street lighting are considered to be basic services, while disposal of waste is essential for human health. These ‘statutory utilities’ are mainly supplied through pipes and cables that are buried in the ground, and McMahon et al. (2006) report that the repair, maintenance and upgrading of this network requires around 1.5 million streetworks annually.

Streetworks might be considered a subset of the construction activities that occur in the public highway, while the term roadworks might be used to embrace construction activities to do solely with the road structure, but for the purposes of this research the term ‘streetworks’ is used to refer to minor, short term projects and construction activities associated with the repair, maintenance and installation of utility services, as well as any type of road surface reinstatement. A definition for major highway works is given in Section 86(3) of NRSWA and covers work that involves any substantial alteration to the width or level of the highway (HMSO, 1991a). Although it would be possible to include this type of scheme within the assessment tool this is not the intention – it is the smaller scale, short term work that is the intended target, despite there being no simple definition for these works.

When streetworks are carried out a number of different aspects need to be considered. Often a decision needs to be made whether to use an ‘open trench’ working method (where the road surface is excavated to reveal the pipe or cable) or a ‘trenchless technique’ (where the amount of excavation is reduced significantly). Alternatively, consideration might be given to mitigating the risk of damaging underground pipes and cables by carrying out a site survey to obtain more accurate location information. Finally, greater cooperation between different parties could encourage different types of work to be carried out at the same time. Depending on the situation all strategies could be adopted for a particular streetworks project, but a robust method to provide a fair, auditable comparison is needed.

Streetworks create ‘economic impacts’ in the sense that they cost money during design and construction, but they also create a wide number of ‘social impacts’ such as road user delays, and ‘environmental impacts’ such as carbon emissions. When this approach is taken to its natural conclusion, assessing different solutions is about minimising the wider impacts created, of which direct cost is one aspect. Therefore, the limits of applicability for the assessment tool are defined as any type of work carried out in the street, but the broader the aim and objectives become, the greater the number of considerations that will need to be included, and this makes the results less easy to compare with each other.

It is important to acknowledge that there is scope for improvement in working practices as a result of parties being better informed of the wider impacts. Hence, the research develops the concept of the ‘one customer’ who enjoys access to roads and utilities every day, but pays the price through tax, utility bills, congestion and noise. The ‘one customer’ may not own a car or even travel on public transport, but they still use products or services that rely on well maintained roads and utility infrastructure.

1.1 The Research

This research will develop a sustainability assessment methodology that can compare different solutions for streetworks projects. In this sense the term ‘solution’ is the outcome after various aspects and considerations (such as the use of a trenchless technique) have been taken in to account, and possibly used. Each solution or outcome is presented as a 'Scenario', and Scenarios are compared in terms of the impacts created. The results from the methodology can be used in various ways – for example, a highway authority can justify why they require a contractor to use a faster, more expensive working method by making reference to the impacts created. Alternatively, a utility company can question this type of decision by making reference to other possible outcomes ('Scenarios').

In order to fully understand the streetworks industry, it is important to review its historical development and identify who carries out works in the street, because this will set the scene for the development of the assessment methodology. Therefore this will be the starting point for the research.

Different solutions are available to carry out streetworks, and it is logical that each solution will have a particular 'footprint', based on its cost, duration, natural resources used and other factors. This wider view is normally considered as part of a sustainability assessment framework, and therefore the research will critically review the different sustainability frameworks that exist for civil engineering projects. It will then identify the different impacts that are created when work is carried out in the street, and an assessment methodology will be developed from this discussion.

It is important to understand what results are obtained from using the methodology on a real project, because this will demonstrate whether it is useful and can be used by those involved with streetworks projects. Therefore the assessment methodology will be applied to four Case

Studies in order to demonstrate how it can be used to assess the potential impacts created by different outcomes; the results will then be validated. Finally, this allows suitable conclusions and recommendations to be drawn.

1.2 Aims and Objectives

The aim of the research is to develop a sustainability assessment methodology that can compare different solutions for streetworks projects. The objectives of the research are as follows:

1. Carry out a critical review of literature examining working practices in the streetworks industry.
2. Carry out a critical review of the methods used to measure, and where possible assess, sustainability in civil engineering disciplines and practical construction situations.
3. Critically assess the different methods of assessment that might be applied to streetworks, and identify the limitations and assumptions of each method.
4. Develop a methodology that can assess alternative design solutions and working practices for a particular streetworks project.
5. Identify the impacts of streetworks.
6. Apply the methodology to four Case Studies and critically discuss the results.
7. Test the sensitivity of the results
8. Contrast the output from the methodology with the most relevant current existing assessment method (i.e. best current practice)
9. Recommend how more sustainable working practices may be introduced, by making reference to the way streetworks are carried out in the UK.

1.3 Structure of the Thesis

The thesis comprises seven Chapters. Chapter 2 includes a critical review of the streetworks industry including its historical development, the stakeholders involved, the design methods, construction options and working practices that are available, the issues and problems that face the industry, and the gaps in knowledge that exist.

Chapter 3 includes a critical review of sustainability, exploring how sustainability is defined, the assessment tools, methods and criteria that are used to assess sustainability in engineering and other disciplines, and the gaps in knowledge that exist.

Chapter 4 develops a methodology that can assess a particular streetworks project and estimate many of the wider impacts that are created when different solutions are used. Chapter 5 applies the methodology to four Case Studies, carries out a sensitivity check, and contrasts the output from the methodology with an existing assessment method. Chapter 6 includes a summarised discussion of the results from these Case Studies, and Chapter 7 includes conclusions from the research and recommends future work.

2 LITERATURE REVIEW PART 1: THE UK STREETWORKS INDUSTRY

2.1 Introduction

In order to fully understand the streetworks industry, it is important to review its historical development and identify who carries out works in the street, because this will set the scene for the development of a methodology. Therefore this will be the starting point for the research, and it will be demonstrated that a wide number of stakeholders are currently involved with carrying out work in the street. Indeed it is argued that a ‘streetworks industry’ does not really exist - there is simply a need to carry out work within the highway by a number of disparate organisations.

2.2 Streetworks Stakeholders

Highway Authorities in England and Wales, the first group of stakeholders, have a duty to the travelling public to maintain their own highway network and footpaths under the Highways Act (HMSO, 1980). The trunk road network (including motorways), which is valued at £81 billion, carries one third of all traffic and is maintained and operated by the Highways Agency who act in the capacity of a highway authority on behalf of the Department for Transport (Highways Agency, 2011a). Local roads are controlled by a diverse mix of highway authorities that include County, Unitary, City and Metropolitan Councils, plus the London Boroughs and Transport for London (TfL). Skelcher (1992) points out that highway authorities can also act in the capacity of a utility owner through ownership of street lighting and drainage infrastructure.

Highway authorities may subcontract out some of their work. The Highways Agency and some local authorities award fixed period contracts to teams of highway designers and contractors, and Haynes and Roden (1999) argue this allows private sector management skills and resources to be utilised; although Willway and Seldon (1996) question whether these roads could in fact be managed more effectively by state run highway authorities. The contracting out procedure may be time based (Highways Agency, 2011a) in which case ownership remains with the highway authority, or a Private Finance Initiative (PFI) contract (Haynes and Roden, 1999), in which case ownership of the highway is transferred to a private consortium.

Until the 1950s utility services were provided in the public interest, which generally meant that a board controlled monopolies for generation and transmission of power, gas and water. The defence for this idea was predicated on the basis that transmission is a natural monopoly (Newbury and Pollitt, 1997), and some form of state intervention will always be required (Robinson, 1998), but Kay and Thompson (1986) argued that privatisation can lead to efficiencies through competition. Bishop and Thompson (1992) reported that from the 1960s reforms were introduced, which would ultimately end in the privatisation of a number of different industries, as shown in Table 2.1:

Table 2-1: Privatisation of different utility industries (after Bishop and Thompson, 1992)

Industry	Year of Privatisation
Electricity Supply	Spring 1990 / Spring 1991
British Gas	December 1986
Water industry	1989
British Rail	1994-1997
British Telecom	November 1984

As a result of privatisation, ownership of utilities can be bought and sold between companies (FT, 2010a). In this sense, the term 'utility owner' is a relative one, because the 'owner' might change regularly – either through losing a contract, or by being sold to a different company; the term 'utility custodian' would therefore seem more appropriate. There are 21 water companies (Ofwat, 2011a), 12 electricity distribution companies (National Grid, 2011) and 8 major gas distribution companies (Ofgem, 2011a) operating in Britain as a whole. Although these companies effectively own their infrastructure, they do not necessarily supply the utility. For example, there are 18 different companies operating in the UK who supply electricity (Electricity Guide, 2011), but they may not own the infrastructure through which it is supplied. To complicate matters further, utility companies may subcontract design and construction work to outside organisations (e.g. the consultant Mott MacDonald). Because of this, consumers may assume that the company who sends a utility bill is also the same company carrying out work in the street nearby, but this is not necessarily true.

In any case, utility companies that carry out work in the street are undeniably 'stakeholders' in the streetworks industry, so their motivations and role need to be clearly understood. As they are commercial companies it is logical that they will act to maximise profits, and to an extent this is confirmed by FT (2010b) which demonstrates how much influence shareholders can have. However, Haar and Jones (2008) point out that this profit is not guaranteed, and so it will be difficult to introduce new working methods if they are more expensive than standard practice.

To balance out this simple profit driven mentality, utility companies are regulated by organisations seeking to protect the best interests of utility consumers, who constitute the third group of streetworks stakeholders. However the literature details that these ‘consumer interests’ are separated, because different utility industries are dealt with separately. For example in the water industry, Ofwat sets the price that water companies can charge consumers at a level that will allow them to “protect consumers’ interests while ensuring efficient companies can carry out and finance their functions” (Ofwat, 2011b), and every five years these price limits are reviewed in terms of the service that customers receive. In the gas and electricity industries, the total revenue that each electricity or gas distribution company can collect from customers is currently set in the Ofgem Price Control Review (Ofgem, 2011b). The level of funding must allow them to run an efficient business as well as finance their activities, and Ofgem places an incentive on utility companies to improve efficiency and ‘quality of service’ (the service being a supply of gas or electricity). Ofgem is currently replacing the price control system with the ‘RIIO’ process (Ofgem, 2011c), where Revenue = Incentives + Innovation + Outputs; the intention is that RIIO will financially punish inefficient companies that fail to meet performance targets that are set in consultation with consumers. Separate to this, the Health and Safety Executive imposes its own requirements in terms of the replacement of aged metal pipes (HSE, 2011).

Overall, there is a strong focus on ‘efficiencies’ when discussing the operation of utility service companies, and this suggests delivering the same service at a lower cost. This drive to minimise costs exists for highway authorities as well (HMEP, 2011) yet there appears to be a very limited definition of what service the customer actually wants – for example Ofgem has a policy recognising that the gas and electricity industries have an impact on the countryside and communities (its ‘sustainability policy’, Ofgem, 2011d), but one of its most recent

Sustainable Development Focus reports (Ofgem, 2011e) makes no reference to streetworks at all.

Society benefits from basic utilities such as running water or a broadband internet connection, but it also pays the price through utility bills, taxes and road user delays, and the environment is affected in different ways. Therefore it stands to reason that a focus on minimising bills (i.e. choosing the cheapest option) is unlikely to capture some of the advantages that alternatives can offer. For example, if a utility provider decided to choose a more expensive working method that reduces road user delays then the utility customer might benefit overall. However, the question arises as to whether this solution will ever be chosen if regulators only encourage the minimisation of utility bills.

As Marvin and Slater (1997) observe, above the ground there is a road surface, owned and maintained in the public interest via tax and paid for by the travelling public (the fourth main group of streetworks stakeholders, due to the fact that they will suffer road user delays and other impacts through streetworks) whilst below it are privatised utilities owned by profit-driven companies. These two types of organisation have very different priorities which cannot be easily combined or reconciled; and Whitehouse (2003) points out that the privatisation process (in this case of the railways) is not always successful. The number of services considered to be essential by society has grown through time, and this growth has been matched in the number of stakeholders involved with utility streetworks (Butcher, 2010a), and therefore it cannot be assumed that the system as it exists today is optimal; it is simply how the situation has evolved through time.

It is interesting to compare what happens on the road network with the rail network. Between 1994 and 1997 British Rail was privatised, and Railtrack was given ownership of the railway infrastructure on 1st April 1994 before being floated on the stock exchange in 1996. As noted by Efford (2001), there was a conflict between the priorities of nationalised and privatised organisations, even more so than for highways (Vickerman, 2004), and due to serious concerns over safety Railtrack went in to administration on 7th October 2001 (Whitehouse, 2003). Its successor (Network Rail) is regulated by the Office of Rail Regulation, an 'independent safety and economic regulator for Britain's railways' (ORR, 2011), but rail passengers themselves are protected by Passenger Focus, the "independent passenger watchdog (*with a*) mission to get the best deal for passengers" (Passenger Focus, 2011).

It is difficult to apply this model to streetworks; if a highway authority operates in the same capacity as Network Rail then there is no equivalent to the Office of Rail Regulation to monitor or regulate how they make decisions. If Ofgem and Ofwat (collectively) carry out a similar role to Passenger Focus then they represent consumers of a utility; but this still leaves a gap because the 'consumer rights' of road users are not protected by a formal regulatory body. In order to make this analogy work, a paradigm shift would be required: if the 'income' paid by utility customers and tax payers were to be spent by one organisation, how would it be used to optimise the negative impacts that are created? Berrie and Berrie (1993) suggest that regulation of the utility industries cannot be left entirely to state or market forces alone, but the separation between utility companies and highway authorities makes value difficult to measure.

This suggests it is important to consider the 'one customer' who pays various utility bills and road taxes. Organisations such as Ofwat and Ofgem regulate different industries, but the consumers being supplied by these industries are not asked by Ofwat and Ofgem if they want fewer traffic jams (for example). This suggests that defining true value first of all requires an understanding of the wider impacts that are created by utility streetworks, then it is necessary to optimise those impacts (i.e. minimise negative impacts and maximise positive impacts) rather than focus on how to interpret 'the customer'. However before this can be done, there is a need for further context on the regulation of the streetworks industry.

2.3 Legislative and Regulatory Background

Following the Horne report (HMSO, 1985), the New Roads and Street Works Act 1991 (NRSWA; HMSO, 1991a) was introduced on the 1st January 1993 to replace the Public Utilities Streetworks Act, which Deacon (1995) argues was no longer capable of meeting the demands of the general public for the quality of road infrastructure, partly due to a strong adversarial approach being taken by highway authorities and utility owners. Marvin and Slater (1997) stated that the introduction of NRSWA formed part of a more general devolution from centralised Government, and for highways this involved placing specific responsibilities for traffic management onto local authorities. NRSWA grants utility companies a statutory right to work in the street (but a corresponding duty to cooperate), and places a duty on highway authorities to coordinate streetworks and minimise disruption on the highway (HMSO, 1991a). Brady et al. (2001) suggest that NRSWA was introduced with the expectation of cooperation rather than confrontation, but following the drafting of the Act various utility industries were privatised and this led to a proliferation of companies involved. Brady et al. (2001) add that NRSWA was introduced to reduce the disruption that is generated by poor coordination, but question this limited aim.

NRSWA allows a highway authority to charge a utility company money if their project creates unnecessary negative impacts. For example, the highway authority decides a ‘reasonable period’ for different types of utility repairs, and if a project over-runs then Section 74A of NRSWA allows them to charge penalty fees. HMSO (1991a) states that the highway authority has discretion to either reduce or waive the charges, and it should examine the particular circumstances of each case; the extent to which this has happened is unknown, although it was recently reported that Councils in England have charged utility companies £31m in fines for over-running roadworks in the past three years (BBC, 2011a). It is important to note that Section 74 charges do not apply to work carried out on behalf of a highway authority itself (HMSO, 1991a), and therefore it is not possible to measure the timeliness of highway projects in terms of the over-run charges paid; equally it is logical to suggest that these charges will partly be seen as a source of income for the local authority, particularly in the current era of austerity. It cannot simply be assumed that over-run charges are always in the customer’s best interests; a much broader assessment of costs and benefits appears to be required.

The introduction of NRSWA was followed by a more fundamental change in roads policy, as highways began to be viewed as a problem in need of management and constraint (Dudley and Richardson, 1998; Canning et al., 2010). The introduction of the Traffic Management Act (TMA; HMSO, 2004) in 2004 reflected this change in perspective. The TMA transferred further responsibilities to local highway authorities and created the role of a ‘Traffic Manager’ who must ensure the ‘expeditious movement’ of traffic on the road network (DfT, 2004a), most importantly by allowing a highway authority to charge for access to road space (HMSO, 2004). The stakeholders involved must use their best endeavours to coordinate streetworks under Sections 59 and 60 of the Act by forward planning when and where utility companies can carry out streetworks (DETR, 2001; DfT, 2009). However, Deacon (1995) points out that there is no formal qualification available to teach people the best way to plan and organise these works, and neither is there monitoring of the decisions made.

In 2008 the Traffic Management Permit Scheme (England) Regulations were introduced (HMSO, 2008a), allowing highway authorities to introduce a permit scheme on their network. It is an alternative to the NRSWA 'Notice System' and is currently being used in Kent, Northamptonshire and 18 London boroughs (Kent, 2011; Northamptonshire, 2011; City of London, 2011). This permit scheme supersedes the notice requirements of NRSWA and gives authorities greater powers to regulate, monitor and coordinate works on the highway than the traditional Notice System. Under NRSWA, highway authorities do not have to respond to every Notice that is served upon them, but under a permit scheme they are required to process every permit. Since its introduction in 2010, Hawthorn (2011) states that the permit scheme has created a more cooperative environment, and has reduced the number of days of working in the street. Most recently, the Department for Transport (DfT) has announced plans to introduce a new lane rental charge on the most congested parts of the network (DfT, 2012), and this will mean that up to £2,500 can be charged for each day of occupancy at certain pinch points. The value of such charges is currently being debated at the highest levels of Government (HMSO, 2011) as well as in the media (BBC, 2011b).

Thus, clearly utility companies are being charged penalties and fines to take account of the negative impacts that they cause. This is perhaps not surprising given the fact that utility companies are commercial organisations, and it suggests that a high value (but more expensive) solution will only be chosen by a utility company if they are incentivised to adopt it; therefore the debate would naturally move on to the best way to provide such an incentive. It is important that such considerations are acknowledged and this wider context is appreciated by any research programme that aims to develop an assessment tool. It is equally important to acknowledge that there is scope for improvement in working practices as a result of parties being better informed of the wider impacts. The next Section reviews several of these 'alternative working practices' that might be adopted.

2.4 Current Issues and Working Practices

Several examples of good practice for streetworks illustrate well the benefits to be gained from adopting alternative working practices, but in each case it is necessary to go beyond standard practice to achieve these benefits, and this will incur additional costs.

Utility companies store network records that show the location of their buried pipes and cables, but in the UK there is a wealth of evidence that suggests existing utility records are often incomplete and inaccurate (HSE, 2001; HAUC, 2002; NUAG, 2008), even if the situation has improved from that in which Marvin and Slater (1997) estimated that only 50% of buried infrastructure could be accurately located. A similar problem exists in the US (Jeong et al., 2004; Bernold, 2005), and it is therefore not surprising that an active research agenda has developed around the issue (Boukhelifa and Duke, 2007; Beck et al., 2009; Metje et al., 2011; Royal et al., 2011).

Beck et al. (2007) demonstrated that organisations use a number of different systems to store, edit, analyse and view their own network records. This limits their ability to integrate data (Beck et al., 2008), so the VISTA project (visualising integrated information on buried assets to reduce streetworks) was developed as a response (VISTA, 2011). NUAG (the National Underground Assets Group), an industry group made up of utility companies and highway authorities, built on this approach and recently launched a new web based record sharing system (Farrimond, 2011), but Parker (2009) points towards some negatives here: 'unless there is a statutory requirement, each utility company will determine whether to make their data available through such a framework'.

Given this free choice about whether to become involved with new initiatives, it is logical to assume that solutions will be tailored to different needs: NUAG will introduce a new system that addresses the requirements of NUAG members. Logically, it is unrealistic to expect 100% of utility owners and local authorities to become involved with this particular initiative so it cannot be the only idea that, in the words of Sterling et al. (2009), will 'provide documented examples of solutions to administrative and legal issues'. Viewed in this way, it is one potential solution amongst others.

To illustrate this point it is interesting to examine the National Streetworks Gazetteer, a source of information that appears to have been missed out in much of the literature. Utility owners have a statutory right to work in the street (HMSO, 1991a) but before work can begin they must notify highway authorities of upcoming streetworks projects so that the work can be coordinated (DfT, 2009). This transfer of information is carried out electronically (DfT, 2008), an idea first trialed even before the introduction of NRSWA (Mason and Nitze, 1990), and is managed through the National Street Gazetteer (NSG) website made available through a partnership of UK local authorities. The NSG conforms to BS7666, a British Standard designed to 'enable the consistent definition of streets and their compilation into street gazetteers' (BSI, 2006), and Beaumont et al. (2005) point out that it is one of several 'geoportals' that play an increasingly important role in the delivery of efficient public services. Butcher (2010a) explains that after the introduction of NRWSA (HMSO, 1991a) it was unexpectedly difficult to start a computerised streetworks register, and therefore only the 'Electronic Transfer of Notifications' (EToN) process through the NSG was introduced (DfT, 2008).

However, the potential for NSG to expand its remit is highlighted by Quiroga and Pina (2003) who developed an inventory tool in the US for a state highway network that not only recorded highway works, but also recorded the location of utilities, details of the utility owner, service type and infrastructure size. Given this potential, an equally valid (but highways focussed) alternative to the NUAG record sharing portal in the UK might be to store and share accurate location information through the NSG. However, Parker (2009) states that utilities are concerned about the 'security issues' of the information stored, and therefore it is likely this idea would be opposed because utilities want clear ownership and control of their information; on the other hand highway authorities may not want to take responsibility for the information stored and supplied.

These practical issues are not important at this stage; instead it is more useful to broaden the debate. The NUAG portal has been put forward by one particular stakeholder as a solution to a problem (sharing network records more easily), but this raises the question of how its value can be decided, which in turn raises a second question - value for whom? The industry structure identified by Marvin and Slater (1997) means that highway authorities and utility owners each have a narrow view of their customer, and this implies that the stakeholders involved with streetworks will each have their own agenda. Therefore, it is valid to ask how the best interests of the 'one customer' are being served by a particular solution.

Parker (2008) makes clear that inaccurate utility records present a risk that must be mitigated, because this will reduce the likelihood of damage being caused to third party utilities and move closer to the goal of 'eliminating hazards and risks during design' (HMSO, 2007). In practice this will never happen completely, and therefore it is only possible to manage risk through understanding the reliability of information, which in turn requires a designer to obtain information at the level of accuracy that is needed (Ryan and Anspach, 2003). Uncertainty and data quality have a close link (Boukhelifa and Duke, 2007).

In the US it is possible to allocate information about the location of buried infrastructure to one of four 'Quality Levels' ranging from Quality Level 'A' (QLA) down to QLD to indicate the degree of confidence that can be placed in it (ASCE, 2002). Initial planning stages will generally be based on Quality Level 'D' (QLD) or QLC, but as design progresses QLB and QLA may also be called upon if it is required. Obtaining progressively higher qualities of positioning causes risks to reduce, but this comes with an increase in costs, and a judgement must be made on the degree of confidence in utility locations needed for a specific job, because obtaining the highest quality of information indiscriminately will not be cost efficient (Noone, 2004).

This is only one, albeit important, aspect of a wider profession called Subsurface Utility Engineering (SUE) which is usually carried out by a firm specialising in utility engineering, surveying, geophysics and data management (Jeong et al., 2004) and allows risk to be mitigated during design rather than construction. Zembillas (2002) states that in 1989 the SUE process was recognised in the US as a professional service rather than a contracting service. The potential for such an approach in the UK was emphasised by Hide et al. (2003), who indicated that up to half of construction accidents in the UK could have been avoided by a design change. It is therefore encouraging that there is a drive to introduce similar techniques in the UK (MTU, 2012).

In the environment of privatised utilities, ownership of assets can be bought and sold between companies (FT, 2010a), so the incoming company will inherit network records that were created beyond their control. It is therefore perhaps unsurprising that utility 'owners' are not held responsible for the accuracy of their own records (HSE, 2001), and add a disclaimer to that effect (HAUC, 2002). Ultimately in the UK, responsibility is taken by the contractor who is working in the street - even if they have been given inaccurate information in the first place (HSE, 2001). By following SUE, Lew (1997) states that this standard disclaimer is changed to one that clearly states responsibility for the location of underground features (for the quality level shown). Huber et al. (2003) indicate that this risk mitigation allows the contractor to reduce or remove the amount they put aside as a contingency against damage to utilities buried in the street.

Jeong et al. (2004) found that urban schemes with a high concentration of utilities benefit the most from SUE, and Arcand (2006) show that the earlier in the design stage that utility information is gathered, the more use it will be. States in the US that do consider utilities at the early stages of a project show a lower frequency and severity of utility conflicts (Goodrum et al., 2008), and Lew (1997) recommends that SUE should be used on all projects that are publicly funded and where underground features may be encountered. Vanier (2001) suggests that it would be beneficial for a central repository of information to demonstrate shared experiences and best practice in SUE.

Given this clear body of evidence stating the potential benefits of using SUE it is perhaps surprising to note that there is no direct equivalent to ASCE (2002) in the UK, although there is increasing pressure for this to happen (MTU, 2012). Two design codes (DfT, 2005; HSE, 2001) currently deal with how utilities should be diverted as part of highway schemes, and how safety can be improved when working with buried utilities, but neither allows for the idea of Quality Levels to be introduced, and both are based around the use of existing drawings obtained from utility companies.

There have been several attempts made to quantify a general 'Return on Investment' (ROI) from using SUE (Jeong et al., 2004; Lew, 1997; Bernold, 2005; Arcand and Osman, 2006), but the most commonly quoted study was carried out by Purdue University on behalf of the Federal Highway Administration (Lew, 2000). The study examined 71 projects in the US and began with a review of old utility records (i.e., QLD and QLC) and then compared them with the more accurate location information obtained from the SUE process (QLB and QLA) to understand the differences and 'determine the benefits of SUE'. The guiding concept in the study was to interview those involved with each project to obtain 'exact' costs, i.e. those that can be obtained accurately such as obtaining test hole data and costs associated with eliminating utility damage, alongside 'estimated' costs which were difficult to quantify with a high level of certainty. Next, records were examined to compare similar projects that did and did not use SUE to understand the existence and quantities of charge orders, extra work orders, time extensions and other claims. Other costs could not be estimated with any degree of certainty, and the report suggests that these 'qualitative costs' may in fact be significant compared to the real costs, but they were not included in the study.

Lew (2000) quoted an average return of US$4.62 for every US$1 spent on SUE, but others have carried out similar research and obtained different values. For example Jeong et al. (2004) estimate a typical ROI of US$12.23 from previous studies, but this has a high standard deviation of US$29.04 with a range of values between 59 cents and US$206.67. In an earlier study, Lew (1997) suggests a saving of between US$7 and US$15 in the US for every US$1 spent. The North Carolina Department of Transportation computed cost savings of US$6.63 for every US$1 spent on SUE for in-house work (Bernold, 2005), whereas Arcand and Osman (2006) put forward a ROI of between US$2.05 to US$6.59. Lew (2000) claims that his study is an 'independent and impartial review' that followed these other studies.

Sinha et al. (2007) and Jung (2011) take this type of analysis one step further. They define, and cost, 11 benefit factors in their assessment of SUE, which include economic issues (such as utility damage costs), social issues (such as traffic delay costs) and environmental issues (such as environmental impact costs); Sinha et al. (2007) calculate an average ROI of US$22.21 whereas Jung (2011) calculates an average ROI of US$13. However, these studies take a questionable approach to calculating benefits, as made explicit by Jung (2011): "The B/C *(benefit / cost)* ratio of SUE projects was much higher than that of non-SUE projects. The difference of B/C ratio can be explained by how the benefits of SUE are quantified. For SUE projects, all possible problems caused by inaccurate utility information were considered to quantify the benefits, while direct costs to resolve actual problems that happened during construction were factored into the benefits for non-SUE projects". In other words, when a ROI is calculated it is assumed that all possible problems will actually occur, but this level of benefit may not actually be achieved.

It is argued that such an approach is open to criticism and accusations of bias. There are clear and obvious advantages in obtaining more accurate information about buried utilities, as this will reduce the likelihood of damage being caused during construction, but this does not justify the approach taken. The more balanced calculation is for problem projects that have occurred in the past; but such studies must be accompanied by an acceptance that SUE is only one piece of a jigsaw. The aim should always be to improve how streetworks are carried out (by any means), not promote one particular idea, and this implies that the value of different solutions is important, but it must be calculated in a fair and balanced way.

In any case, there appears to be a good deal of variation in the ROI calculated, but this stands to reason: for example in an urban setting there are likely to be more pipes and cables buried beneath the ground than a rural setting, and therefore greater potential for damage costs; contexts are different and no two streetworks projects are precisely the same. Noone (2004) supports the view put forward by Lew (2000) and Jung (2011) that 'qualitative' savings are not easily measurable, and may be far greater than the direct costs. Goodrum et al. (2008) suggest that consideration should be given to a far wider range of impacts in an assessment of value, not just the direct costs payable by the project owner. Furthermore, if assessment is to go beyond a consideration of direct costs then it is logical to ask whether a monetary unit of measurement is the best approach in all cases.

Because there is no standard method used to calculate these ROIs it is difficult to compare them, and therefore it is argued that a ROI approach is useful, but it needs to be more transparent: if each study had clearly defined what costs had been included and excluded and what assumptions had been made they would be more useful. If several different scenario can be compared then a more transparent debate can occur about a ROI, but it should not be assumed that all possible problems will always occur – for example, a 'with damage' scenario could be compared with a 'mitigation / no damage scenario', but these two should rightfully be compared with a third scenario of 'no mitigation / no damage' (this being the typical, status quo scenario). The point here is that the third scenario is high risk, and the level of risk is shown by the costs associated with the 'with damage' scenario.

It is possible to carry out a site based survey to detect the location of buried pipes and cables, as this will help to mitigate the risk of causing damage when work is carried out. If this type of SUE survey is carried out as part of the SUE process then a suitable ground survey detection device such as Ground Penetrating Radar (GPR) will need to be selected for the site (Hutchins and Sinha, 2009). To do this it is important for surveyors to have a detailed knowledge of the response of soils from electromagnetic waves (Metje et al., 2007), so it is worrying that Jeong et al. (2004) state that only 3% of SUE staff are geophysicists. This is an area of current research, and the Mapping the Underworld (MTU) project is currently focussed on developing a multi sensor device that is able to detect all types of utilities in all ground conditions (Metje et al., 2007), a research theme that complements three others in mapping, data / knowledge management and asset tagging (Hao et al., 2008). The project has support from industry (Burtwell et al., 2003) and has the potential to detect underground utilities more easily, and understand the requirements of different stakeholders (Royal et al., 2010; Thomas et al., 2009a). MTU complements a more general focus from industry and academia on using new technologies in utility engineering (Sterling et al., 2009; 3M, 2011; ESWRAC, 2011) as well as optimising the different detection techniques that are available (Pieraccini et al., 2009). Again, this multi sensor device appears to be a solution worth testing in order to understand its value.

SUE also provides an opportunity for greater partnering and cooperation between different organisations who are involved with streetworks, (Zembillas, 2004; Scott, 2004; Worlton and Squire, 2004), and it is evident that UK highway authorities and utility companies will likewise be encouraged to work ever more closely together (for example DfT, 2009; DfT, 2011a). Fuller (2009) demonstrates the potential of such cooperation: Staffordshire County Council has been involved in a number of measures to improve successful cooperation between different parties during streetworks, and in one case an estimated 32 weeks of work was reduced to just 10 weeks because different organisations coordinated their work. The value of this approach in terms of the 'one customer' is evident, and therefore fostering cooperation between the stakeholders involved with streetworks is equally presented as an idea worth promoting in the UK, in the same sense as SUE operates in the US, or the MTU device could potentially be used globally.

The idea of greater cooperation blends with the traditional view of partnering (Latham, 1994; Egan, 1998), and this cooperation can be made more formal by transferring responsibilities. For example, a contractor working on behalf of a highway authority might carry out work on behalf of a utility (Huber et al., 2003; Zembillas, 2004; Chou et al., 2006), and this type of cooperation has been proved effective at reducing delays (Ellis et al., 2005). This type of formal partnering is not common practice in the UK, but DfT (2005) does at least make it possible: diversion work may be carried out by "the undertaker (i.e. utility owner) either directly or using subcontractors; by the (highways agencies) scheme contractor; or by a combination of the above". Therefore it can be stated it is possible, but not common, for such an approach to be adopted in the UK.

The literature reviewed in this Section points towards a number of different solutions that can be used to solve a particular problem, so it would be unfair to simply assume that one particular solution is the only and best available. Therefore it is argued that there is an urgent and essential need to develop a transparent process that can compare the value of many different solutions as part of a consistent, rigorous and balanced assessment framework. Fuller (2009) had to go beyond standard practice to achieve benefits, and this suggests a broad range of possible outcomes need to be considered for an assessment process to be useful.

2.5 Conclusions from the Literature Review Part 1

Streetworks are necessary to the continuance of civilised life. They inevitably cause disruption, but benefit society and can be considered a necessary evil. There are many stakeholders in streetworks ranging from the travelling public and business to the nationalised highway authorities and the privatised utility companies, and tensions necessarily arise between the various parties. This is a very odd situation, and is different to the railways where Network Rail owns the track and the land on which the track sits.

Society is protected from some of the potentially serious impacts of streetworks by regulation and legislation in the case of the highways authorities, while the interests of utility consumers are protected by regulators. Given that streetworks impact on individuals, communities and businesses in all sorts of different ways, the situation is highly complex. One of the core underlying dilemmas concerns the 'who benefits, who pays?' question, which in turn begs the question of who is 'the customer'? This is a major challenge, but one of vital importance to the smooth running of our villages, towns and cities, both now and in a future in which traffic and population densities are projected to increase.

Added to this complex picture is a wide range of technologies (e.g. Metje et al., 2007) and best practice working methods (e.g. Fuller, 2009) that can be used to carry out streetworks. They all have different impacts associated with them, and indeed the impacts are varied and numerous and their reach is truly extensive. Moreover engineers are under ever increasing pressure to balance economic, social and environmental concerns; in other words to work more sustainably. Such a broad view is commonly considered to be essential, and so a sustainability assessment framework may provide the best way forward, and this will be explored in more detail in the next Chapter.

3 LITERATURE REVIEW PART 2: SUSTAINABILITY

3.1 Introduction

Chapter 2 has demonstrated that there is a need for a balanced and broad assessment of the social, environmental and economic impacts associated with streetworks projects. Such a broad view is commonly considered to be an essential aspect of a sustainability assessment framework, but many such frameworks exist. Therefore, Chapter 3 will explore sustainability in more detail.

The idea of 'sustainable development' as an explicit concept can be traced back to 1987 when the World Commission on Environment and Development defined it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). The most common general assessment framework is based on the three pillars of sustainability: Environmental, Economic and Social. The environmental and economic aspects of this 'triple bottom line' are generally easier to quantify than the social elements, but considering any one of the three pillars in isolation presents problems, because it is difficult to advance one element of sustainability without having an impact, and often a negative effect, on the other two (Parkin et al., 2003; Hunt et al., 2008a; Lombardi et al., 2012) - what Elghali et al. (2008) refer to as 'Pareto optimality'.

Evidence of the effects of current activities on human health and on worldwide economies is overwhelming, and the concepts of sustainable development and adapting to climate change are now firmly embedded within mainstream policies at international (UN, 2009), European (EU, 2011) and national levels (DEFRA, 2011); and the UK has a legally binding framework to tackle the problems of climate change (HMSO, 2008b). There is now a growing awareness amongst UK policy makers that it is necessary to understand the full range of impacts that transport has on urban areas (Cabinet Office Strategy Unit, 2009), and that these social, economic and environmental impacts need to be fairly distributed across the different groups and generations that make up society (SDC, 2011).

When the full spectrum of sustainability issues is included in the assessment process, some strange results are produced: for example, DEFRA (2009) shows how Spanish tomatoes are more environmentally damaging than English tomatoes if assessed on the basis of 'food miles', but the opposite is true if wider issues such as the amount of energy required to heat a greenhouse in the UK, and the source of this heat, are also considered. In short, all of the factors, and impacts, of an activity must be considered in any rigorous analysis.

3.2 Sustainability and Civil Engineering Projects

Parkin et al. (2003) point out that there is a need to be explicit about the sustainability credentials of a project, and this has forced a reappraisal of how things are done in civil engineering. This reappraisal of a civil engineer's activities is possibly as complicated in the case of streetworks as in any application: streetworks are ultimately carried out on behalf of society (the user and ultimate client), but an engineer has to meet the needs of the immediate client (in some cases by acting on behalf of the client, in others acting on behalf of shareholders), whilst ensuring minimal environmental impact (the wider context of the work). Finally, there is a social imperative: that part of society being served and receiving benefits in the long term does not always map well onto that part of society being adversely impacted in the short term.

Jowitt (2004) states that engineers need to be fully aware of the economic, social and environmental dimensions of their activities and should be more skilled in meeting these objectives; but this is only an extension of a civil engineer's core mission: minimising cost, maximising quality and delivering on time while engineering for society in harmony within the environment. Therefore it can be argued that the core issues of sustainability have been at the heart of a civil engineer's role ever since the profession emerged, albeit that the balance across the 'three pillars' of sustainability has not always been drawn.

However, Jowitt (2004) also makes clear the inherent difficulties in achieving the goal: the concept of sustainability needs to be established in the area in which the activity is being played out (see Lombardi et al., 2012); each subject area has its own specific considerations that need to be made explicit before they can be assessed (Jefferson et al., 2007); the considerations need to be judged at the very start of the project's thinking (see Lombardi et al., 2012 on sequencing); the requirements at the planning stage need to be dealt with differently when dealing with new installation than when amending an existing infrastructure system (Hunt et al., 2009); and Lombardi et al. (2011) note that different parties are likely to conceptualise this problem in different ways. Streetworks have their own specific context and considerable complexities; the only way to make them more sustainable is to create a bespoke, comprehensive and balanced assessment framework before these methods are used.

Technology has developed through time, and Elms and Wilkinson (1995) usefully separate four distinct technological eras. The first is the 'primitive' stage, where man's needs were met individually and on an immediate basis – gathering food and finding shelter principally for the individual. Following this, a more urban society emerged as the second era in which people developed specialist skills and supply chains lengthened, and this was based on experiential knowledge: skills were repeatable, but not based on science or technical rationality. This was replaced by the third 'technical rationality' era where mass production, standardisation and interchangeability were created. Supply chains grew even longer as few people had all of the skills required to meet their own needs. From this era we have canals, highways, railways and ports, but also congestion, air pollution, global warming and social injustice. The narrow technical disciplines did not allow for an appreciation of the wider consequences at the 'system' level, and solutions looked at the complication (detail) rather than the complexity (structure). These advances were based on the assumption that fossil fuels, and indeed all resources, are endless and that the economy will indirectly 'mop up' the social and environmental impacts of meeting our needs - through social security and environmental regeneration for example. However, as Parkin et al. (2003) point out, these effects are not embedded in the true cost of goods and services on sale.

This era of technology has quite recently been replaced by the fourth 'systems / holistic' era (Elms and Wilkinson, 1995). In this era a balance needs to be drawn between the economic, social and environmental impacts of technology. Complex, poorly defined problems and needs have to be joined with scientific understanding, and a much broader concept of 'systems performance' is required. Jowitt (2004) puts forward the idea that simple, unimportant problems can be solved through prevailing, technology-based design standards, but if we are to solve today's important, invariably complex problems they can only be addressed by a non-rigorous inquiry. The same author also points out that tomorrow's (or perhaps today's?) drivers are more about lifestyle issues than about technological development, certainly in the developed worlds economies, and as other economies develop and expand through time these lifestyle issues will gain importance and / or change. However, this is not an entirely new idea, for example Schön (1987) suggests something similar with his description of a "varied topography of professional practice", where manageable problems are located on a high ground overlooking a swampy lowland involving, messy, confusing problems that defy technical solution.

If it is possible to assess streetworks at this 'systems' level, delivering such a solution in real life would be more problematic because of the separation identified in Chapter 2 between a publicly owned highway (the customer being the road user) and the privatised utility (the customer being the consumer of an essential service such as gas, water and electric). For example, works within the highway are covered by specific pieces of legislation (HMSO, 1991a; HMSO, 2004), and the main focus of this legislation is on reducing the delays caused by streetworks, but McMahon et al. (2006) point out that utility owners will cite the need to consider the cheapest direct cost (i.e. economic) option, which will often be open trench digging, even though alternatives such as trenchless technologies have the potential to reduce delays substantially (Tighe et al., 1999) when compared with their direct cost (Zhao and Rajani, 2002).

The justification for choosing the cheapest option is variously presented as an obligation to shareholders (Guest, 2011), a need to comply with regulator's demands (Webber, 2011), or a need to provide an essential service to the customers at a minimum cost (Clarke, 2011). The freedom to choose the least direct cost option seems to oppose the rationale behind existing legislation, and raises questions about how a reduction in delays can be achieved – even if it is accepted that a focus on delays is the most sustainable policy.

It has been shown how the results of a broad, wider ranging assessment sometimes defy logic and produce outcomes that are counterintuitive (DEFRA, 2009). Furthermore, without carrying out such an assessment, it is not possible to clearly state how streetworks delays are related to sustainability goals, or to use the vernacular how 'sustainable' or 'unsustainable' the activity causing the delay truly is. Therefore, it is first necessary to fully understand all of the impacts that are associated with streetworks, not focus on one impact in particular (road user delays for example), or even the needs of one particular customer group (such as utility customers).

3.3 The Impacts of Streetworks

McMahon et al. (2006) report that utility streetworks (i.e. those works associated with the maintenance of utility pipes and cables buried beneath the highway) cost a total of £1.5 billion per year in terms of construction costs (of which, interestingly, £150 million is estimated to be due to damage to third party utilities), whereas the 'indirect costs' such as road user delays and trade lost to local business are estimated at £5.5 billion per year (in 2006 prices). The study usefully defines the following 'costs' of utility streetworks, as shown in Table 3.1:

Table 3-1: Costs attributed to streetworks, after McMahon et al. (2006).

Activity	Cost
Planning and design costs	• site survey to locate existing apparatus, infrastructure, trees etc • risk assessment • design • consultation with interested parties • engineering and cost assessment of the proposed technique • issuing of notices
Material and construction costs	• labour and plant • cost of pipe and bedding material • reinstatement • traffic management
Project costs	• Supervision of the construction works • Diversion of existing services • Administration, such as the maintenance and exchange of notices and records • Lane rental costs

Potential damage costs	• Increased insurance premiums
	• Increased insurance excesses
	• Compensation payments
	• Loss of income
	  o Short-term (particularly significant for telecoms)
	  o Longer term (may lose business to competitors)
	• Damage to brand/image
	• Cost of restoring brand/image
	• Cost of repair work
	  o Variable costs will depend on the number of repairs
	  o Fixed cost of resources represent a lost opportunity cost i.e. the resources used to fix the repair could be used to provide better service or win business elsewhere
	• Payments under Section 74 of NRSWA (1991)
	• Negative image/loss of brand image

Costs to highway users	• Costs associated with traffic delay (queuing and moving through works)
	• Costs associated with traffic diversion
	• Increased vehicle operating costs
	  o Greater fuel costs
	  o Increased maintenance (oil, tyres etc.)
	  o Depreciation
	  o Cost of repairing damage from accidents
	• Delays to public transport

Activity	Cost
Safety (reduced safety for motorists, pedestrians, and site staff)	• Costs associated with injury • Costs associated with loss of life • Emotional costs of above
Costs to business	• Reduced sales • Reduced output

Costs to local community	• Reduction or loss of amenity
	    o Loss of parking spaces
	    o Access to home/shops/public spaces
	• Reduced revenues to local authority
	    o Loss of parking fees
	• Damage to property (long-term)

Costs to highway authority	• Reduced pavement life • Increased maintenance costs • Accelerated deterioration on diversion routes

Environmental Costs	• Damage to trees
	    o Damage to canopy (by mechanical plant etc.)
	    o Damage to roots
	• Increased air pollution
	• Increased noise pollution
	• Surface and ground water pollution
	• Production of waste
	• Increased use of natural resources
	• Imported bedding materials
	• Increased construction mess
	• Increased visual intrusion

The report is important in terms of the number of impacts it identifies, and the fact it focuses specifically on work carried out within the highway rather than other engineering disciplines, but it is not sufficiently comprehensive. Firstly it uses the term ‘streetworks’ to refer specifically to utility repairs and maintenance, but excludes what it calls ‘roadworks’ (repairs and maintenance carried out to the road surface itself), whereas an assessment method covering all types of work carried out in the street should be sufficiently comprehensive to cover both; the ‘one customer’ is unlikely to appreciate this difference. Secondly the report presents all negative effects in terms of a monetary cost, but if it is accepted that a wide range of both social and environmental impacts need to be considered then it may not be possible to measure them using a monetary unit, and these would, de facto, be excluded from the analysis, so at the very least an assessment method must be capable of using other units of measurement. Nevertheless, significant weight is placed on McMahon et al. (2006) in terms of the breadth of impacts that should be considered in an assessment tool.

Boyce and Bried (1998) use the term 'social cost accounting' to assess different streetworks 'scenarios' by considering direct costs as well as 'social costs' (such as those associated with motorists following a longer diversion route). They argue that if the savings in social costs for one option outweigh its additional direct costs then this is a beneficial option. This approach points towards a Cost Benefit Analysis (CBA), a method widely used by civil engineers, which assumes that if the value of benefits exceeds the value of costs then the project is justified (Snell, 1997). While this is self-evidently true, the difficulty arises in the mismatch between who pays and who benefits. As supported by Marvin and Slater (1997), when streetworks are carried out the project owner may well be a commercial utility company, but many of the indirect costs generated by their work (such as wasted fuel used in queuing) affect those who are not direct customers of the organisation carrying out the work (i.e. road users).

Vickridge et al. (1992) use a similar 'social cost accounting' method to calculate the lane rental charge that might be applied when utility streetworks are carried out on traffic sensitive routes, in order to mitigate the costs of the disruption caused. To do this they focus mainly on costs associated with congestion, but state it is difficult to quantify the 'costs' associated with noise, vibration and air pollution. Nevertheless, it is interesting to note that something very similar to the lane rental scheme that is currently being considered (DfT, 2011a) was discussed twenty years ago.

In a separate study, Boyce and Bried (1994) apply the general CBA process to a utility streetworks project (the construction of a storm drain in Oakland, California) by assessing different streetworks scenarios (working methods). They consider direct costs such as construction, as well as indirect costs such as increased travel time, loss of productivity due to noise and reduced sales tax and parking ticket revenue. The specific methods they use to assess each impact are assessed more fully in Chapter 4, but similar to Vickridge et al. (1992) they also found that direct costs are easier to assess than less tangible impacts such as the loss of productivity. Their study compares ‘open trench’ and ‘no dig’ scenarios, clearly states what assumptions have been used, and attempts to quantify a wide range of impacts. This appears to offer a logical, sensible approach.

When CBA is applied to a utility streetworks project the ultimate benefit could be considered to be a regular supply of utilities; the cost being the temporary impact of the work as it is carried out, but Boyce and Bried (1994) make it clear that their study is not quantifying the benefits of a storm drain when it is in use. It seems logical that to do so would add a further level of assessment to the study, and when applied to utility streetworks this raises some more philosophical points: does society’s right to a regular supply of basic utilities need to be questioned? Should the quality of service provision following the work be assessed in a positive way? This demonstrates the importance of defining the boundaries of an assessment.

The construction method itself may have positive and negative aspects: if a trenchless technique is used instead of an open trench working method then this might have advantages in the sense that the work can be carried out more quickly. However, this ‘advantage’ could be viewed in a different way – a negative impact (road user delays) has been reduced. Alternatively, an open trench might have other positive aspects, i.e. it is possible to see exactly what is buried beneath the ground and assets can be tagged. Again this could be viewed in a different way – the likelihood of damage and other negative impacts being caused (either now or in the future) is being reduced because buried pipes can be carefully revealed, recorded and tagged, and this reduction in potential negative impacts is itself the advantage. Therefore, a ‘benefit’ is herein considered to be a reduction in any negative impact associated with streetworks, but it is recognised this approach is somewhat subjective, and that the arguments on both sides are valid and finely balanced.

The mismatch between who pays and who benefits is less of an issue for transport schemes, because they are generally planned and paid for by public sector organisations using money collected through taxes. When new ‘transport interventions’ are being assessed (such as an improvement to an existing highway, or less likely, a new highway) a CBA is used to capture the economic, social, environmental and financial impacts of the intervention (HMSO, 2003). For example, a new highway scheme may allow road users to travel along a particular route and experience less delays. If the reduction in journey time is estimated, this can be multiplied by the number of drivers who use the road each year. This can then be measured as a cost based on the value of time, and therefore the ‘Cost’ of the scheme that is being funded through road tax can be compared with its ‘Benefits’ to the tax payer, such as permanent savings in road user delays.

Transport schemes are easier to assess in this way than utility schemes because there is not a separation between the project owner and the particular customer being affected, and this again supports the argument that it is important to consider the best interests of the 'one customer'. However the CBA process relies on the values calculated being accepted by all parties, but Parkin et al. (2003) again suggest that costing environmental or social issues is difficult as they are valued differently by various stakeholders. Surahyo and El-Diraby (2009) concur, and suggest that it is not possible to develop a universal standard for assessing these impacts. Therefore it is difficult to see how a straightforward CBA method used in isolation can accommodate the variety of issues that need to be considered in a proper sustainability assessment of streetworks.

This literature demonstrates that it would be unfair to assume that all negative impacts associated with streetworks are best measured or calculated using a monetary unit of measurement, and a sustainability assessment method must at the very least consider other ways to measure impacts. The approach must embrace other attempts to consider wider impacts in civil engineering projects (Allouche and Glichrist, 2005), as well as an acknowledgement of the 'carbon footprint' as a means to measure resource efficiency (ICE, 2006) and the need to work within what our planet can provide (Townend and Rogers, 2011).

Huang et al. (2009a and b) offer a useful alternative approach, and use a process called Life Cycle Analysis (LCA) to develop and apply an assessment tool for the construction and maintenance of asphalt pavements, expressing the output as a 'carbon footprint' instead of a cost. As Pennington et al. (2004) state, an LCA is a tool used to assess and compare the environmental impact of goods and services, and Rebitzer et al. (2004) explain that an LCA practitioner will tabulate the emissions and consumption of resources in a product's life cycle at every stage - including raw material extractions, energy acquisition, materials production, manufacturing, use, recycling and ultimate disposal, and indirect changes in other systems may also be accounted for.

Huang et al. (2009a and b) note the importance of transparency when using LCA - the user must state the origin, limitations and assumptions used in the calculation process, because other data sources could have been used and this would change the result. However, Bovea and Gallardo (2006) state that comparing different LCA results in terms of a single score can in itself hide important information, and offer a low degree of transparency. This implies that having transparency in the assessment process is key.

The 'carbon footprint' approach has been applied elsewhere. For example, Flower and Sanjayan (2007) examine the carbon footprint of manufacturing concrete, whereas Sihabuddin and Ariaratnam (2009) quantify the carbon footprint of trenchless and trenched technologies; although somewhat inevitably these studies are not sufficiently comprehensive as they do not consider impacts such as emissions due to delayed traffic, and are therefore considered to be unnecessarily limited in their scope and aim of assessment. Thomas et al. (2009b) estimate carbon emissions from the use of aggregates in a large redevelopment project in Birmingham, and although the scope of their assessment is limited in terms of this current research, it is interesting to examine their general approach.

Thomas et al. (2009b) develop a number of different 'scenarios' and clearly state the calculation process and boundaries selected. For example, they recognise that noise and the impact of the work on road users will have an impact on sustainability, but they consider these effects to be outside the scope of their particular study. It is argued this is a logical and defendable approach: they clearly state their aim and scope of assessment, they then use scenarios to clearly identify what outcome is being tested, and then clearly state the calculation method used, and the result obtained. This appears to be inherently sensible, and it should be remembered that in Chapter 2 the ROI approach that was applied to SUE (Jeong et al., 2004; Lew, 1997; Bernold, 2005; Arcand and Osman, 2006) suffered because the studies did not have this level of transparency. If it is clearly stated what calculation steps has been used then this provides an opportunity for different methods of calculation to be substituted, and this allows the sensitivity of the results to be tested.

Parkin et al. (2003) suggest that in the future it is likely that the LCA process will justify a move away from selling products (where responsibility for disposal is dispersed) and a move towards leasing products and providing services, thereby maintaining control over the material embodied in the product and the high value of reuse and recycling. However, LCA suffers from the same limitations as CBA in the sense that if it is used alone it will not capture all of the impacts (in this case social or economic), because it is typically used to calculate environmental impacts.

ISO 14040 (ISO, 2006a) sets out the generic approach that must be taken in any LCA assessment, and ISO (2006b) defines four different phases as shown below:

1. the goal and scope definition phase
2. the inventory analysis phase

3. the impact assessment phase
4. the interpretation phase

ISO (2006b) clearly states that although an LCA is normally used to calculate environmental impacts, there is no reason why the general methodology cannot be applied to social or economic aspects, and therefore the simple four stage process outlined above does offer a sensible generic approach. In order to carry out a sustainability assessment it is necessary to be aware of all relevant impacts associated with a project; it is then necessary to measure each impact and then analyse the results, but this raises the question of how the term 'relevant impacts' should be interpreted. This implies a need to know all of the possible impacts that a streetworks project can have, but it is argued this is simply not possible, because the situation is complex, and problems are interrelated. This suggests it is important to state what impacts have been included and excluded from the study; and this is again related to the scope and aim of assessment. For example, if the longer term secondary impacts of traffic (Verhoef, 1994; Cabinet Office Strategy Unit, 2009) are excluded from an assessment of a short term temporary streetworks projects, it would be important to clearly state this in the 'goal and scope' of the assessment at Stage 1.

It is argued that because of this complexity, ISO (2006a and b) offer a sensible reference point. For example, Huang et al. (2009a and b) and Boyce and Bried (1994) define a scope and aim for their assessment, but interestingly neither attempts to consider the best interests of the 'one customer' who enjoys access to roads and utility services every day, but pays the price through various taxes, utility bills, road congestion, noise, pollution and so on. For their inventory analysis, Huang et al. (2009a and b) concentrate on environmental issues, whereas

Boyce and Bried (1994) consider the direct costs of a project and add a limited number of social impacts that can be easily monetised. This serves to illustrate that it is all stages of the LCA assessment that must be addressed by the 'wider view': a well-defined goal and scope will inform the elements to be included in the inventory analysis as well as the impacts that need to be assessed; attempts to broaden the scope at the impact analysis stage might result in impacts being omitted and a compromised analysis. Therefore it is logical that McMahon et al. (2006) present a viable starting point for a Stage 2 'inventory analysis' because they consider a wide number of economic, social and environmental impacts that are created by streetworks; whether all of these impacts should be measured as monetary costs is still to be decided.

In any case, once a suitable list of impacts has been selected then each impact needs to be measured or assessed, but Parkin et al. (2003) again note how difficult this can be for social and environmental impacts. More broadly, Jowitt (2004) points out that a 'quantitative' approach is not good at capturing people's opinions, ethics or conflicts. Thomson et al. (2009) suggest that sustainability assessment is increasingly seen as a way to mediate between stakeholders with different visions, requirements and areas of expertise because it has the ability to combine hard and soft measures; Devuyst (2000) suggests that it should primarily be a communicative process. Put another way, decision makers are now forced to work within their institutional boundaries but outside of their professional knowledge (Hurley et al., 2008). The preceding discussion has focussed on ways to establish the scope of the impacts that need to be measured, but the challenge remains of how to include non-technical, or 'qualitative', approaches to assess options in engineering, and Section 3.4 will examine this issue in more detail.

3.4 Sustainability Indicators and Decision Support Tools

Given that eight years ago there were more than 200 different definitions of 'sustainable development' (Parkin et al., 2003) it is clearly difficult to define sustainability, let alone achieve it, so to help with assessing what makes a particular idea 'more sustainable' than another, a large number of Sustainability Indicators (SIs) and Decision Support Tools (DSTs) have been developed. This Section discusses a number of different methods that are available.

BREEAM (2012) is a well recognised assessment method and rating system for buildings that is used to measure their environmental performance in terms of energy and water use, health and well-being, pollution, transport, materials, waste and ecology. The method uses recognised measures of performance and compares them against established benchmarks in order to assess a building during design, construction and use, but it is of limited use because it assesses buildings.

CEEQUAL (the Civil Engineering Environmental Quality Assessment and Award Scheme) is an assessment and award scheme that is designed to demonstrate the commitment of the civil engineering industry to environmental quality and social performance (CEEQUAL, 2011). Projects are scored by a trained CEEQUAL Assessor, and this is reviewed by a CEEQUAL Verifier, who then makes a recommendation whether to award a certificate for the project. CEEQUAL is based on the following major design considerations, with the final score for each area being weighted by a percentage as follows:

- Project Management (10.9%)
- Land Use (7.9%)

- Landscape (7.4%)
- Ecology and Biodiversity (8.8%)
- The Historic Environment (6.7%)
- Water resources and the Water Environment (8.5%
- Energy and Carbon (9.5%)
- Material Use (9.4%)
- Waste Management (8.4%)
- Transport (8.1%)
- Effects on Neighbours (7.0%)
- Relations with the Local Community and other Stakeholders (7.4%)

Each of these major design considerations is made up of very specific sub objectives, such as 'a need to provide evidence that the design team has actively considered the merits of designing for a larger flood event than required by Planning Policy Statement 25'. Lendrum and Feris (2008) were faced with a choice between developing a bespoke assessment system for their own projects or using CEEQUAL, and the latter was chosen due to its rigour, comprehensive nature and creditability (both internally and externally). This implies that the development of an entirely new assessment method may suffer from what Holt et al. (2010) describe as 'tool fatigue'. The project assessed by Lendrum and Feris (2008) was valued at £2 million and the CEEQUAL assessment cost £10,000, but this cost was largely due to the fact that evidence was gathered retrospectively (which is more expensive), and the authors do state that this cost cannot be used as a benchmark for other similar sized projects. When the list of CEEQUAL awards is interrogated it is mainly large, one off, multi discipline construction projects that appear in the awards list, but a new set of criteria for term maintenance contracts was recently introduced (CEEQUAL, 2011) and this does offer better possibilities, but there is no evidence yet available that points towards its success.

Nevertheless, this literature implies that there is a considerable cost involved with becoming involved with a 'real world' CEEQUAL assessment. CEEQUAL can be applied to many types of engineering project, but its generality results in a large number of criteria and it is therefore a time consuming process to use. Given the very large number of streetworks carried out annually, a simpler and more easily used method is required. In addition, Fuller (2009) had to go beyond standard practice to achieve improved coordination of streetworks, but it is not clear how CEEQUAL would promote such a solution because the best possible multi disciplinary team is unlikely to exist in the first place. Nevertheless there is no reason why the criteria contained within CEEQUAL could not be adapted for a small streetworks projects or more importantly, included within an impact inventory for streetworks, and such an adaptation would have the advantage of being based on a well recognised 'brand'.

Another example of a DST is SPeAR® – the Sustainable Project Appraisal Routine, developed by Arup (Arup, 2011) – which assesses projects using criteria categorised under a four-way bottom line (Economic, Social, Environmental and Natural Resources). Holt et al. (2010) successfully adapted the SPeAR® criteria for use in geotechnical engineering projects, due to a lack of specific methods to assess work in this discipline, and Jefferson et al. (2007) took a similar approach for environmental geotechnics projects. This literature implies that SPeAR® could potentially be adapted to assess a streetworks projects; whether it offers the best possible approach to do this is another question.

Hurley et al. (2008) examine how sustainability is related to asset resource decisions in the water industry. Again they begin with a review of SPeAR® but then move on to a second tool called SWARD (the Sustainable Water Industry Asset Resource Decisions Framework) and combine these two DSTs into a Project Assessment Tool (PAT), which includes criteria from both SWARD and SPeAR®, as well as other criteria suggested and agreed upon by project partners. They apply the PAT to two initiatives: one aimed at reducing the amount of rainwater discharged to sewerage systems, the second considering a range of water-related issues for the planning and construction of new housing and other developments in the UK. Clearly these applications have little to do with utility streetworks, and Luckhurst (2003) suggests this limitation is more widespread – his Sustainability Indicators are used to assess an 'asset management' role rather than utility streetworks per se.

Highway Authorities engage in relatively minor road maintenance activities but a DST does not exist for this type of small-scale work either. Greenroads (2012) is a points-based sustainability rating system for the design and construction of roads. It outlines a collection of sustainability best practices (or "credits") that are based around the design and construction stages of a project, with the number of points scored being an indication of the relative sustainability of a given project. Although useful to review, the tool is again restricted by its use - it assesses road construction and maintenance specifically, rather than any type of small scale temporary work carried out in the street.

The Department for Transport's 'Transport Analysis Guidance' (WebTAG) process (DfT, 2011b) is based around five 'objectives for transport': Environment, Economy, Safety, Accessibility and Integration. Although these objectives are not specifically expressed in terms of sustainability, WebTAG does refer to the DfT's 'Sustainable Development Policy Statement' (DfT, 2011c). Therefore, it is indirectly related to an assessment of sustainability, but the problem (again) is that it cannot be directly applied to streetworks – it is used to assess major highway and transportation projects and is far too complex to use for small-scale construction activities.

This analysis reinforces the argument for an assessment method that is specifically designed to consider all types of small-scale work in the street, but the separation between nationalised highways and privatised utilities identified by Marvin and Slater (1997) suggests that its intended use would need to be carefully defined. Different utility industries are regulated separately, and all of these different privatised industries need to work within a publicly owned highway – which is itself the cause of work due to a need for roads to be resurfaced and maintained. It is these temporary projects that should be the focus of assessment, and the different working methods available need to be compared, but this is not in itself an 'asset management decision' in the way that Hurley et al. (2008) use the term.

The large number of DSTs and SIs available has led some to question their usefulness – Howlett et al. (2000) suggest that much of the measurement of indicators has largely resulted solely in the measurement of indicators, and Bell and Morse (2001) question the fundamental validity of SIs completely. Their study looks at car density, which is often quoted as a measurement of sustainability (lower densities being more sustainable), but it is not possible to exactly measure this density for every road and at every moment in time. Instead, a cheaper method is used (car density is measured at a specific place and time) but this inevitably involves human judgement and compromises, and often results in an 'indicator of an indicator'. In addition it would be possible to capture an 'experienced' car density by the very people affected. Given this fact, Bell and Morse (2001) give a convincing argument that multiple perspectives of the same issue are inevitable.

Hunt et al. (2008a) demonstrate the potential for conflict between indicators (i.e. satisfying one criterion might result in another being impossible to satisfy), and Sahota and Jeffrey (2005) note that DSTs are rarely used because they are too detailed, time consuming and complex. However, it is not correct to conclude that DSTs using SIs are valueless; Hurley et al. (2008) found that DSTs can potentially break down a complex decision into its constituent parts by having a comprehensive structure that considers all of the economic, social and environmental aspects of a proposal – others might term this a 'systems engineering' approach – while Hunt et al. (2008a) simply point to the need for a consistent, coherent and holistic approach to deriving SIs.

Elghali et al. (2008) suggest that choosing the optimum solution in terms of sustainability requires the consideration of the opinions and priorities of multiple stakeholders. One method that can be used to capture and compare different opinions is Multi Criteria Decision Analysis (MCDA). Steele et al. (2009) recognise that the importance of MCDA lies in its ability to address the problems of competing decision objectives. Elghali et al. (2008) concur, stating that the theory explains mathematically how a 'rational individual' acting as the decision maker would choose the option having the maximum 'subjective expected utility' against a set of pre-determined criteria. Hunt et al. (2008a) suggest that MCDA's primary advantage is that it can involve a number of different stakeholders who individually assess a project against a single list of criteria; when agreement on the value of certain criteria cannot be reached, the stakeholder group explores how a range of different values affects the result and thereby measure its ‘sensitivity’.

Elghali et al. (2008) state that the different MCDA methods are already supported by UK government policies and business communities, and are derived from the three bases of social, economic and environmental impacts, and therefore have many of the characteristics required to assess sustainability issues. Thomson et al. (2009) found that the MCDA approach has been found to support a structured discussion of different categories of knowledge, on equal terms. On the other hand, it has been criticised by Sahota and Jeffrey (2005) as being too detailed, time consuming and costly, and created by people who do not fully understand the relevant attributes. Hunt et al. (2008b) stress that MCDA has greatest benefit at the early stages of a project when different options are being compared; at some point a decision will need to be made on which one of those options is taken forward to design and construction, and by this point all views must have been properly considered and the trade-offs managed (Lombardi et al., 2012).

It is apparent, therefore, that a full MCDA process is far too involved for every streetworks project, and would be impossible for emergency work. There might, though, be value in conducting MCDAs for generic types of streetworks activity and using such analyses to inform decisions if suitably tempered by site-specific considerations. However, it must be recognised that streetworks affect the local community in many different ways, and it is unlikely that anyone outside of that community will be able to predict accurately and completely what these impacts might be for any particular case.

Moreover Fong (2003) and Hurley et al. (2008) point out that civil engineering projects are often 'one off', and Thomson et al. (2009) suggest that the high level of complexity and relative nature of 'sustainability assessment' means that no one individual assessment tool has yet been developed that is sufficiently holistic, multi dimensional, and capable of addressing the environmental, economic and social impacts of a project. While these observations are valid, certainly for larger projects, a focus on the specific construction activities associated with streetworks, combined with the inclusion of qualitative assessments alongside the engineer's more traditional use of quantitative indicators and their measurement, would provide a practical means of assessing sufficiently comprehensively and accurately, if not precisely, the impacts of streetworks and hence how they perform in terms of sustainability. If reference is again made to the four stage process outlined in ISO (2006a and b) then it can be stated that a 'qualitative' approach only differs from a 'quantitative' approach at Stage 3: a quantitative approach attempts to calculate and quantify impacts, whereas a qualitative approach develops a set of SIs and criteria to prompt a designer to consider particular issues.

Elghali et al. (2008) present an interesting 'combined' approach for assessing the impact of design decisions for a road maintenance scheme; they use MCDA, LCA and CBA. It was found that using LCA-derived data within an MCDA framework worked best, whilst CBA was also helpful but only if used in very clearly defined contexts. This study demonstrates that a number of different techniques can be employed, and it is interesting to note that if only one approach had been used (LCA, MCDA or CBA) then some aspects would not have been considered. However, if such a study were to be rigorously applied to streetworks it would need to involve a very wide range of stakeholders, and it would perhaps be unlikely that a consensus would be so easily reached. Furthermore, it cannot be assumed that all stakeholders will give quantitative criteria – Bell and Morse (2001) indicate that qualitative opinions are also likely to appear.

3.5 Conclusions of the Literature Review Part 2

It is evident that engineers undertaking streetworks are in urgent need of a Decision Support Tool that can steer them through the 'swampy landscape' of decision making. There are many general sustainability assessment tools and frameworks available, but they are too difficult to use, or perhaps more pertinently too difficult to make specific to the case of streetworks, in the expectation of delivering a comprehensive and balanced outcome. In spite of this considerable complexity, the literature supports the argument that an effective Decision Support Tool can be created if the scope is narrowed such that it is specific to streetworks – a bespoke DST for streetworks is both required and possible to deliver.

Quantitative methods are available to calculate certain impacts, criteria are useful for impacts that cannot easily be calculated, LCA is good for measuring environmental impacts, and a monetary unit suits the measurement of direct and certain indirect costs, but is far less reliable for other social and environmental impacts. Given the lack of a universally accepted method to measure or assess all impacts, the literature would suggest that a sustainability assessment process must be capable of using more than one technique to assess impacts; furthermore it must be capable of identifying the limitations and assumptions that are inherent in each method (because ultimately this is why different results are obtained). It would be too complicated to try and state every limitation for every technique at this stage, and instead it is more important to develop a clear way of dealing with these limitations. The point here is that various techniques are available to calculate certain impacts, and therefore it is logical to conclude that a methodology for assessing sustainability for streetworks must be capable of incorporating different techniques in order to conclude which is most appropriate, but initially it must choose one for it to be used at all.

A benefit might be viewed in a positive or negative way. For example, a trenchless technique may allow work to be completed more quickly which is a benefit, but on the other hand it might be described as a reduction in a negative impact (road user delays). A 'benefit' is herein considered to be a reduction in any negative impact associated with streetworks, but it is recognised that this approach is somewhat subjective, and that the arguments on both sides are valid and finely balanced.

Boyce and Bried (1994) use scenarios to test different solutions, and it is argued that this approach is valid because of the separation between nationalised highways and privatised utilities identified by Marvin and Slater (1997). As demonstrated in Chapter 2, utility companies that are regulated by consumer groups have a very narrow view of 'the customer', focus on efficiencies, and thereby minimise direct costs, whereas a more expensive solution might deliver greater advantage to the customer. The argument here reverts to the definition of 'the customer' whose interests are being served differently by national and private organisations. For this reason any assessment must be capable of assessing a number of different scenarios, some of which will be created specifically to address the best interests of the 'one customer' who benefits from access to utility services but suffers the wider impacts of streetworks. This will identify whether standard practice encourages a high value solution, and more importantly demonstrate where changes can be effected to create the greatest benefits for society as a whole.

4 DEVELOPMENT OF A METHODOLOGY TO ASSESS SOME OF THE WIDER IMPACTS CREATED BY STREETWORKS

4.1 Introduction

As identified in Chapter 3, there is currently no sustainability assessment tool specifically developed for small scale, temporary streetworks projects. Although several different methods exist for other engineering works, none of these is suitable, and so a new streetworks-specific tool needs to be developed. In addition, the complicated regulatory situation as well as the disparate industry as discussed in Chapter 2 both need to be considered.

The approach taken must be based on assumptions and rational arguments since the robustness of the results will depend on the structure of the model and the ability to produce objective judgements; therefore it is important to identify clearly what considerations have been used (and ignored) to create it. Ultimately, a compromise must be struck: the model must be as simple as possible in order to be usable, but at the same time it must be broad enough to provide an adequately comprehensive assessment. This will inevitably lead to limitations, yet the methodology can be adapted or extended straightforwardly.

The methodology provides an academic contribution because it takes elements from working practices used in the UK to carry out streetworks, along with elements used to measure or calculate certain impacts, as well as elements from criteria used to consider social or environmental issues, and combines them within an assessment approach that is grounded in the field of sustainability, and designed specifically to assess short term temporary streetworks. The aim of developing the methodology (and model upon which it relies) is not to produce new mathematical theories or computer software, but to logically represent many of the wider impacts created when utility streetworks are carried out in different ways.

The assessment tool will estimate the negative impacts that are created when work is carried out in the street. Streetworks can be carried out in a number of different ways, and this wide choice is available at the planning, design or construction stages of a project. Different decisions made during the planning process can have dramatically different impacts on local communities and the environment, so the assessment tool will be capable of assessing various 'Scenarios'.

4.1.1 Uses for the Assessment Tool

The assessment tool can be used by local authorities and utility companies. For example, a highway authority may wish to introduce a new lane rental scheme allowing them to charge a daily rate for occupancy of certain pinch points on the highway network, but this requires them to prove the value of any charges imposed (DfT, 2011a). The assessment tool can be used to compare this daily charge with a monetised measure of road user delays, carbon emissions and other impacts that are created during one day of work at a particular location. If the charge is less than the wider costs associated with the work then arguably it is 'fair', or justified.

Alternatively, a utility company may have certain requirements imposed on them by a highway authority before they can carry out work in the street; for example, they may have to use a trenchless technique along certain roads. If there are perfectly valid reasons why this decision is not the best value, the utility company can use the assessment tool to prove why this is so, by making reference to the wider impacts that are created. The highway authority will then need to respond in a similar way, and a broader discussion of value can therefore be encouraged.

However, it is intended that the assessment tool will primarily address the needs of the 'one customer' and not the project owner. For example, if a utility company is carrying out work then their customer might be a consumer of that utility, but the conclusions from Chapter 2 identify a much wider group of stakeholders that may be affected by this work. Highway users will be delayed, council staff will need to administer the streetworks notices, and tax payers / utility customers (e.g. society at large) will need to bear the monetary costs of all these activities. It is this wider focus that needs to be addressed as part of the assessment tool, not the needs of any one group.

The assessment tool includes various methods that can be used to estimate impacts, but it is important to note that these techniques can be replaced if direct data are available. For example, a method is given to estimate staff costs, but if an organisation is using the assessment tool for its own projects then their actual staff costs can replace these estimates. Given that the needs of 'the one customer' are not currently represented by any one organisation, it is unlikely that all of the original data required will be immediately available, and where these gaps exist the methodology is used to provide estimates of the missing data.

While the methodology is developed for immediate application in the UK, it can be applied universally: this may require a consideration of which impacts to adopt and whether country-specific assessment techniques (e.g. enforced by legislation) need to be amalgamated into the assessment, or government policies taken into account.

4.1.2 Introduction to the Assessment Process

In Chapter 3 it was argued that ISO (2006a and b) offer a sensible generic approach for assessing streetworks, because they can be used as a reference against which other assessment methods can be compared. ISO (2006b) clearly states that although an LCA is normally used to calculate environmental impacts, there is no reason why the general methodology cannot be applied to social or economic aspects. Therefore, ISO (2006a and b) are used as a basis to develop a new assessment tool for streetworks projects, which is based around the four core stages of an LCA:

1. the goal and scope definition phase
2. the inventory analysis phase
3. the impact assessment phase
4. the interpretation phase

Firstly therefore, some guidance is required as to how the goal and scope of an assessment will be defined.

4.1.3 The Goal and Scope Definition Phase

A clear and unequivocal statement of aims and objectives will always be required when the assessment tool is used; indeed this is the first stage of the assessment process. ISO (2006b) states that the scope, system boundary and level of detail for an LCA depends on the subject and its intended use, and the depth and breadth of a study can vary significantly depending on its goal. These are logical statements, but they must be adapted to suit the needs of assessing streetworks projects.

Huang et al. (2009a and b) use LCA to develop an assessment tool for the construction and maintenance of asphalt pavements, and they apply their tool to one particular case study along the A34 road. In so doing they make reference to the four stage LCA process stated above and importantly, they clearly define a goal and scope for their study. Although their assessment tool has a different objective to the current research it is used in the same area of engineering, and if their approach is adapted this will create a process to define the goal and scope of an assessment for streetworks projects that is couched within existing literature. Therefore when an assessment is carried out, the goal and scope of assessment will mirror the approach taken by Huang et al. (2009a and b), although this will necessarily require some adaptation. This is explored in more detail in Sections 5.3.2, 5.4.2, 5.5.2 and 5.6.2.

4.1.4 The Inventory Analysis / Impact Assessment Phases

ISO (2006a and b) state that 'life cycle inventory analysis' and 'impact assessment' are the second and third phases of an LCA, and they require input / output data for the system being studied, as well as additional information to help assess a system's 'environmental significance'. Huang et al. (2009a and b) closely follow the LCA process, so they analyse these two stages separately, but equally they have a fairly limited scope of assessment (focussing on environmental impacts), whereas Chapters 2 and 3 have identified a wide range of impacts and considerations that should be included in an assessment of streetworks projects. Given this, it is argued that a bespoke approach can justifiably be taken (albeit one that reflects the wider objectives of an LCA), and therefore the assessment tool combines these two phases in to one stage, called 'impact assessment'. It is therefore important to define a process for what impacts should be included and excluded.

4.1.5 Primary and Contributory Impacts

In order to carry out a sustainability assessment it is necessary to be aware of all relevant impacts associated with a project; it is then necessary to measure each impact and then analyse the results, but this raises the question of how the term 'relevant impacts' should be interpreted. This implies a need to know all of the possible impacts that a streetworks project can have, but it is argued this is simply not possible, because the situation is complex, and problems are interrelated. However it is necessary to break down this complex situation into discrete categories to develop the analysis, what some term a 'systems engineering' approach (Dandy et al., 2008; Kossiakov et al., 2011).

In order to address this issue, 8 'primary impact categories' were defined, and 'contributory impacts' were allocated under each one. These primary and contributory impacts were created from the wider literature, and help an assessor to consider the less obvious activities and considerations that need to be included within an assessment. The decision process for categorising impacts as primary or contributory was iterative and, inevitably, somewhat subjective, because the professional experience and background of the decision maker will have an influence.

The process began with a wide ranging review of literature. This included general sustainability assessment methodologies, design codes for highways and utilities, quantitative methods that are available to calculate or measure certain impacts, and qualitative methods that are used to consider those impacts that cannot be quantified. It soon became clear that a large number of issues that occur during streetworks might create negative impacts, and that some of these need to be grouped together under wide categories.

For example, wasted fuel might be generated when traffic follows a longer diversion route, or it might be generated when traffic queues at the works themselves. As both of these events result in wasted fuel they are categorised as 'contributory impacts', both giving rise to a 'primary impact' (wasted fuel). Similarly, noise might be created by construction machinery or when stationary traffic accelerates, so 'noise' is the primary impact here, and the use of construction machinery and queuing traffic are both contributory impacts that give rise to a primary impact. If each individual event is categorised separately then the results of the assessment become difficult to appreciate because an endless list of potential impacts would be required. As the embryonic assessment tool was used and the literature was reviewed, it was found that 8 was the smallest number of categories that could be defined.

It is logical that McMahon et al. (2006) present a viable starting point for this 'impact assessment' stage for two reasons. Firstly their study identifies a wide number of economic, social and environmental impacts that are created by streetworks (although other literature will also need to be reviewed). Secondly, their study lists various activities that are carried out during a project, as shown in Table 3.1.

However, the focus needs to become broader still if the best interests of ‘the one customer’ are to be addressed, and this is why other literature has been reviewed, but it is argued that this evolutionary process should not end - Jefferson et al. (2007) make a valid point when they state that only through greater use of an assessment system can a consensus be reached as to what elements should be considered. Therefore it is intended that the list of contributory impacts will be developed further as the assessment tool is used, both in the Case Studies and beyond.

The 8 primary impact categories have been defined thus; others might choose different categories but would need to ensure broad coverage of possible activities in so doing. The full list of primary and contributory impacts can be seen in Appendix A.

- Direct Costs of Design and Construction
- Road User Delays
- Carbon and Other Air Emissions
- Noise Pollution
- The Impact of Reinstatement
- The Safety Impact
- The Impact on Business and the Community
- Other Environmental Impacts

4.1.6 The Interpretation Phase and Sensitivity of the Results

ISO (2006a and b) states that life cycle interpretation is the final phase of the LCA procedure where the results are summarised and discussed. The findings of the interpretation phase may take the form of conclusions and recommendations for decision-makers, and are intended to provide a readily understandable, complete and consistent presentation of the results in accordance with the goal and scope definition of the study; the interpretation phase may involve the iterative review of data. These ideas are examined more in Section 5.2.

The remaining Sections of this Chapter will define the primary and contributory impacts that are used in the assessment tool, as well a method that will be used to assess each one. The Sections have been grouped together under the 8 primary impact categories, the first of which is ‘direct costs of design and construction’.

4.2 Direct Costs of Design and Construction

4.2.1 Background

There are a wide range of design and construction costs which all contribute equally to this impact and are measured in a single unit (£). McMahon et al. (2006) and Brady et al. (2001) both indicate that these costs can arise in the following ways, all of which will now be defined as contributory impacts, because each gives rise to one primary impact (‘direct costs of design and construction’).

- Costs associated with obtaining network records
- Monetary costs of administration, such as the maintenance and exchange of notices and records
- Design costs
- Costs of site survey to locate existing apparatus, infrastructure, trees etc and to determine the ground conditions
- Cost of preparing a risk assessment
- Cost of consultation with interested parties
- Engineering and cost assessment of the proposed technique
- Cost of issuing of notices for works
- Redesign costs

During construction the following impacts can also arise, and the following list (taken from McMahon et al., 2006) has been reworded and added to the list of contributory impacts:

- Labour and plant to excavate and lay the pipe/cable
- Cost of pipe/cable, bedding material and imported fill
- Reinstatement / resurfacing of the trench
- Traffic management
- Cost of erecting barriers around work
- Cost of supervision during construction
- Additional works (signing and strengthening) along the diversion route
- Pavement damage to the diversion route
- Cost of diverting existing services (as applicable)

- Natural resources use (water, power, materials for pipes and other building materials)

McMahon et al. (2006) go on to state that when the street is excavated, cables and pipes owned by 3rd parties may be damaged, and this event will result in the following costs being incurred, each of which is now defined as a contributory impact in any Scenario where damage occurs:

- Compensation and repair costs due to damage caused to underground utilities
- Compensation and repair costs due to damage to adjacent property
- Increased insurance premiums / excess
- Compensation payments
- Short term loss of income
- Longer term loss of income (may lose business to competitors)
- Cost of restoring brand/image
- Lost opportunity cost
- Payments under Section 74 of NRSWA (HMSO, 1991a)

In the methodology it is necessary to assess direct costs at a project level so that this particular impact ('direct costs of design and construction') can be compared with others, and therefore it is necessary to develop an easily applicable way to estimate the direct costs that arise from different types of streetworks.

4.2.2 Existing Methods of Assessment for Direct Costs

Work is carried out in the street by both highway authorities and utility owners, and the 'project owner' will be liable for many of the direct costs incurred. The aim here could be to determine standard rates for different types of work, combining labour, materials and plant costs for each, and integrate them to cover all of the construction activities. A logical starting point for such an approach is a study carried out by Zhao and Rajani (2002), who developed standard rates for installing different diameter water and sewer pipes in the US and Canada. However, such costs can be heavily context dependent, and thus very many different cost alternatives would need to be created; such an approach is likely to prove impractical and/or the results could too easily be called into question. However, this lack of accuracy is the result of a more significant problem (being that direct costs are opaque, making value difficult to assess).

An alternative approach is offered by DfT (2004b), which defines the extent of streetworks by the number of days of carriageway occupation, the number of works executed, the number of excavations and the average area. This survey provides a uniquely detailed dataset covering the average duration and size of excavation for different utility industries (i.e. electricity, telecommunications, gas and water). It therefore offers the potential for developing standard costs that are directly proportional to the typical size of excavation, or typical duration of the work, for different industries, but unfortunately does not include day rates for labour costs. One source for such data is the 'Office for National Statistics Annual Survey of Hours and Earnings' (ASHE, 2011), and the 90th percentile gross annual pay for the 'skilled construction and building trades' is £34,760. Assuming 30 days annual leave per year, this averages at £150 per day, excluding National Insurance and tax (in 2011 prices), which will be the value used for site workers where original data do not exist.

The average area could be used as a proxy measurement for materials, and even labour costs. If there was buy in for this approach from industry stakeholders then a reasonable day rate could be agreed, but this is unlikely to happen so it is felt that a ‘standard rate’ approach is over simplistic, although a built in calculator could be created for individual organisations if they decide to adopt the assessment method themselves.

The 3rd edition of the Civil Engineering Standard Method of Measurement (CESMM3, 1991) provides a breakdown of materials and labour categories, but the Spon's Civil Engineering and Highway Works Price Book (Langdon, 2011) includes standard rates for the plant, labour and materials for common tasks associated with civil engineering construction projects. Labour rates are regularly updated in line with the latest Construction Industry Joint Council wage agreement, and the book is recognised as a standard reference by the UK Royal Institute of Chartered Surveyors, thus yielding authoritative data. However, since the activities relate to general civil engineering projects, and not specifically streetworks projects, some quantities and tasks may need to be estimated using the ‘nearest equivalent’ standard rate. Nevertheless robust and defensible costings can be generated, so this approach will be used to estimate construction activities as required.

To the construction costs must be added the design costs - though Langdon (2011) is of no help in quantifying these so informed estimations must be used - and the costs associated with ‘third party’ damage. Streetworks always incur a risk that existing underground pipes and cables might be damaged. Compensation for this damage lies with the project owner and includes repair costs and loss of brand image. McMahon et al. (2006) refer to several studies of damage being caused to buried utilities, although the source data are impossible to obtain. Clow (1987), quoted in McMahon et al. (2006), referred to 75,000 incidents of 'third party' damage in the UK, with a total cost of £25 million. This averages £333 per event, which appears very low and no justification is given of how this value was calculated. Bartlett (2004), also quoted in McMahon et al. (2006), states that BT suffered 27,000 incidences of damage for which BT claimed a total of £35 million. This averages approximately £2,600 per event, or £2,900 at 2011 costs.

Such limited information demonstrates the difficulty of establishing a standard rate for the direct costs of damage, but this cost is often excluded from analyses and should therefore appear in the methodology. For the purposes of this research a sum of £2,900 will be used to represent the 'third party' damage and compensation costs. Clearly there are many shortfalls with this approach – telecommunications equipment cannot easily be compared with gas, water and electricity infrastructure, so the costs of repair will also vary, but how can this problem be easily resolved? If the values used in the methodology are questioned by industry then it is argued this type of debate should be considered a positive step forward.

The additional time spent repairing damage will create road user delays, noise and carbon emissions, so these impacts will also need to be considered in a 'with damage' Scenario. If streetworks projects over run then local authorities can charge Section 74 payments under NRSWA, which is another example of a cost that may well be included. If a site survey is carried out separately to the main construction this will cost money, and might require traffic management to be installed (cones to close off one lane or maybe even a temporary contra flow). This demonstrates how difficult it is to be prescriptive about exactly what costs and associated impacts should be included; the literature may not identify all possible contributory impacts that generate direct costs and therefore a clearly defined scope and aim of assessment is essential.

4.2.3 Chosen Method of Assessment for Direct Costs

Ultimately only project owners themselves will be able to accurately account for these costs because they vary across different organisations, and several are related to the unit costs of staff. Precise and detailed data cannot easily be analysed, yet it is necessary to quantify the level and variation of this impact across different Scenarios. A logical deduction is required so that this impact can be compared between different Scenarios, because McMahon et al. (2006) indicate it is unrealistic to expect them to be readily available. Therefore where necessary, the direct costs associated with labour and materials will be estimated using the Spons manual (Langdon, 2011) and (ASHE, 2011) because they offer a way to break down a complex job in to more easily managed items.

However, it will still be necessary to make assumptions because Spons does not consider design costs, so these 'wider costs' will need to be accounted for by using logical arguments. A clearly defined scope and aim of assessment, and careful selection of relevant costs, is essential, and through time the list of contributory impacts can be expanded. Utility damage will be measured as a separate Scenario, valued at £2,900 for damage and compensation costs. Because it is difficult to quantify as a cost, loss of brand image will be scored as part of the 'impact on business and the community' category, explored in more detail in Section 4.8.

4.3 Road Users: Time Delays and Wasted Fuel

4.3.1 Background

The ability for streetworks to create road user delays is well documented (DfT, 2002; DfT, 2004b; Abbott et al., 1995), but an easily applicable method to estimate the impacts of road user delays in different situations is required. McMahon et al. (2006) as well as Brady et al. (2001) both support this view by identifying the impacts below, which will now be reworded and added to the list of contributory impacts for this primary impact.

- queuing prior to reaching the works
- reduced traffic flow through the works
- the need to accelerate/decelerate adjacent to the work area
- additional fuel costs along the diversion route if it is longer.

DfT (2002) states that roadworks restrict the flow of traffic and this may mean there is insufficient capacity for the normal traffic flow, which is when queues begin to form. Brady et al. (2001) state that delays generated by streetworks represent a substantial part of the total congestion on UK roads because the temporary changes in highway layout, available carriageway width and work activities have a number of effects on traffic flow. They state that because the available highway area dictates the maximum traffic flow, congestion is inevitable where streetworks reduce the area to less than that required, and this view is supported by DfT (2004b), who modelled many types of streetworks using this assumption. Abbott et al. (1995) state that disruption from 'highway schemes' (as opposed to 'utility streetworks') can be created by the utility work that is associated with them, as this may extend way beyond the extent of the main project itself. Finally, CEEQUAL (2011) contains criteria that prompt a designer to consider whether transport impacts have been considered and minimised.

This literature indicates that the road user delays, which are created by streetworks, are potentially significant and therefore this impact should be defined as a primary impact of streetworks.

4.3.2 Existing Methods of Assessment for the Impacts of Road User Delays

For the purposes of this research it is necessary to develop a method to assess the impacts of road user delays at a project level. Therefore, it is important to understand how traffic delays are currently considered and dealt with for different types of project. Firstly, this concept will be examined for major highway schemes along motorways or trunk roads, and this is because congestion is nearly always considered for these schemes using CBA, whereas congestion is not specifically modelled for smaller utility repair schemes, and therefore this presents a logical starting point.

The definition of 'major highway works' is given in Section 86(3) of NRSWA and covers work that involves any substantial alteration to the width or level of the highway (HMSO, 1991a). The Design Manual for Roads and Bridges (DMRB) is used to assess road user delays for this type of work, specifically the QUADRO manual (DfT, 2002). QUADRO (QUeues And Delays at Roadworks) is a computer program providing a method to calculate the total cost of major road maintenance works, which is made up of the direct cost of works as well as the costs imposed on road users during the work (delays, vehicle operating costs and accident costs). Outputs include the speed, queuing, and diversionary behaviour of traffic on an hourly basis.

Because QUADRO can be used to predict road user delays it is a possible way to model streetworks, but one key shortfall is that "the program cannot be used for detailed assessment of traffic management arrangements, since it is not able to distinguish fine differences in site layout" (DfT, 2002). The program was developed primarily for use in rural areas, and although it can be used within urban schemes a detailed representation of complex diversions is not 'practicable'. DfT (2002) suggests that in these complex cases, the overall traffic effects of the scheme should be modelled using a separate package and then standard parameters can be used to value the cost of these delays. Clearly this is not a practicable option for assessing large numbers of streetworks projects, and therefore a more widely applicable method is required.

DfT (2004b) examines in detail the road congestion that is created by utility streetworks, and is a key reference for this Section. It was prepared before the introduction of the TMA and the London Permit Scheme and therefore some of the detail is out of date, but it remains an important study in terms of estimating road user delays and congestion because of its level of detail. The study monitors the effectiveness of NRSWA Section 74 charges (for unreasonably prolonged occupation of the highway) in reducing disruption due to utilities streetworks by examining the 'proposed' and 'actual' timing of real projects, thereby identifying any over run or early finish.

DfT (2004b) also estimates the total annual cost of congestion created by utility streetworks at £4.3 billion. This conclusion was controversial with the utilities industries, who commissioned (through the ‘National Joint Utilities Group, NJUG) a separate report to comment on its findings (Goodwin, 2005), which estimated the cost of congestion £1 billion. This huge difference needs to be explored in greater detail because it will identify what assumptions and calculation methods were used, why the results are so different, and if these methods can be applied in ways that will predict road user delays and congestion at a project level. This detailed examination is included in Appendix B.

DfT (2004b) can be used to estimate the typical daily cost of road user delays for streetworks on different types of roads, as shown in Tables 4.1 and 4.2. These delays are categorised according to the ‘Reinstatement Category’ (RC) of the road, which is a function of commercial vehicle traffic flow (HMSO, 2010). Five different RCs exist, each limited by the amount of commercial vehicles using the road, and DfT (2004b) assumed that the limiting flow of commercial vehicles in each RC was the actual flow of commercial vehicles. This was then pro rated by an average percentage breakdown of other vehicle types using the road (DfT, 1994a) to estimate the total traffic flow for the road in question.

This estimated traffic flow is shown in Table 4.1 as the ‘Annual Average Daily Traffic’ (AADT) for rural areas, but it was noted that a higher proportion of commercial vehicles use rural routes than urban centres. Therefore, a separate percentage breakdown of vehicle types for the London Boroughs was made available, and this breakdown was then used to estimate the AADT for all urban areas, as shown in Table 4.2. It is assumed that the AADT value for RC0 in Table 4.1 is a typographical error, and should read 32,000.

Table 4-1: Daily cost of delays at rural streetworks (£) by reinstatement category, Annual Average Daily Traffic (AADT) and length of works, after DfT (2004b).

RURAL					
Reinstatement category	Typical AADT flow	10m	50m	100m	200m
0(=5)	<320,00	2,500	3,000	3,300	4,000
1	16,000	7,850	9,050	10,250	11,000
2	12,000	1,610	2,100	2,600	3,530
3	8,000	780	970	1,200	1,625
4	4,000	335	415	515	700

Table 4-2: Daily cost of delays at urban streetworks (£) by reinstatement category, Annual Average Daily Traffic (AADT) and length of works, after DfT (2004b).

URBAN					
Reinstatement category	Typical AADT flow	10m	50m	100m	200m
0=5	40,000	25,000	25,000	25,000	25,000
1	24,000	9,000	12,000	15,000	17,000
2	16,000	3,450	5,150	7,000	8,800
3	10,000	385	535	710	1,025
4	6,000	200	280	375	550

DfT (2004b) is potentially very useful for this current research because it offers a way to estimate congestion at a project level, so any criticism or promotion of the approach must be fair and balanced. Goodwin (2005) appears to have been driven by the utility industries as a response to a study driven by highway authorities, and to choose between these approaches is in no way 'taking sides'. Nevertheless, the discussion in Appendix B suggests that DfT (2004b) and the 'bottom up' approach it uses is more rigorous in its analysis than Goodwin (2005), who takes a 'top down' approach. Furthermore, DfT (2004b) is suitable for the current research because it allows an estimation of road user delays to be made at a project level for different types of roads, and to an extent this is an argument for its use. Unless site measurements are taken, the uncertainty of the predicted value will never be known but it will still be possible to compare different options in a fair way. Therefore, in the methodology the values contained within Tables 4.1 and 4.2 will be used to estimate road user delays for utility streetworks projects on different types of road. If the actual traffic flow is known then the values in Tables 4.1 and 4.2 can be pro rated accordingly.

If a diversion route is longer than the original route taken by vehicles then this will result in more fuel being burnt. Boyce and Bried (1994) use this extra distance as the basis to calculate time delays as well as vehicle operating costs, which are based on the mileage rate for works vehicles. This is a valid approach, but the modelling carried out in DfT (2004b) includes the possibility that diversion routes were taken. Therefore it is argued that the typical delay values shown in Tables 4.1 and 4.2 can be used to average out the effects of longer diversion routes. However this is only for general assessment – if the scope and aim of assessment mean that it is particularly important to consider the costs of traffic following a longer diversion route then this specific contributory impact will need to appear in the output, and the traffic delay will need to be modelled separately without the use of Tables 4.1 and 4.2.

The modelling techniques used in DfT (2004b) were complemented with a limited amount of site based delay data, but the report suggests that this site based approach provides only a 'restricted illustrative example' of the congestion impact on a typical utility streetworks project, and cannot be used as a general model to estimate delays. This conclusion appears odd; if a sufficient number of site measurements for road user delays were measured it seems logical that a 'statistically significant' data set could be developed, even though it would still need to be decided what level of statistical significance is required. Streetworks carried out within urban areas are complex, but their impacts are not completely random, so it appears odd that no relationship at all could be established, at any level of significance. DfT (2004b) indicates the typical delays that might be caused at different types of project, but the uncertainty of these values can only be verified through site measurements.

DfT (2004b) expresses road user delays as a cost. Tables 4.1 and 4.2 are based around an average value of time fixed at £11.28 per hour, and therefore if the figures currently shown were to be divided by this amount, the overall delay in hours would be generated. However, it is necessary to understand the background to this value (£11.28 per hour) because this will partly indicate the reliability of the result, and to do this it is necessary to examine how time is valued in transport appraisal schemes.

WebTAG unit 3.5.6 (DfT, 2011b) sets out the procedure for the valuation of time in a CBA and states that time spent travelling during work is a cost to a business, whereas non work time is not. It is assumed that in a free labour market the measure of productivity for an employee is their salary, and the national average salary is the basis for the cost of work time that is featured in CBA. Work journeys exclude the commute to work, and values for non work time are based on a willingness to pay; for example a more expensive but quicker journey. This willingness to pay varies across different income groups, the value of the journey purpose, and the comfort of the journey itself, whereas the average salary for all workers is fixed.

WebTAG unit 3.5.6 (DfT, 2011b) states that it may be appropriate in a CBA to assume a common value of time for all vehicles, which is £11.28 per hour in 2002 prices. However, this represents a different type of limitation inherent in DfT (2004b). If a more detailed breakdown of vehicle type and journey purpose were known, then the cost of time could be valued more accurately (as it would be based on work and non-work values), but if this new average value of time were used then the daily costs shown in Tables 4.1 and 4.2 would differ. Nevertheless, £11.28 per hour is the cost of time used in DfT (2004b), and the methodology will therefore calculate the average delay per vehicle in seconds by dividing the costs shown in Tables 4.1 and 4.2 by £11.28, the AADT and 3,600. Once this average delay in seconds has been established, all further cost of time calculations will use 2011 values by using an inflation calculator (BoE 2011), not the 2002 value used in DfT (2004b).

Road user delays can now be estimated using 2011 figures by monetising the cost of delay time, but there is also a cost associated with the wasted fuel burnt while queuing. Therefore the discussion will now move on to the calculation of this fuel consumption. As well as examining the cost of time, WebTAG unit 3.5.6 (DfT, 2011b) also includes values for vehicle operating costs, which include fuel, oil, tyres and longer term vehicle maintenance. Fuel consumption can be estimated using Equation 1, derived using the UK Road Vehicle Emission Factors Database:

Equation (1):

$$L = (a + b.v + c.v^2 + d.v^3) / v$$

Where:

L = consumption, expressed in litres per kilometre;

v = average speed in kilometres per hour; and

a, b, c, d are parameters defined for each vehicle category.

The parameters in Equation 1 vary for different types of vehicle and are included within WebTAG unit 3.5.6 (DfT, 2011b). Table 4.3 shows fuel consumption in litres, whereas Table

4.4 represents fuel consumption in pence. This is a ‘resource cost’ (based on 2002 values), which includes fuel duty but excludes VAT, because business drivers can reclaim their VAT. Non work vehicle drivers cannot do this, and therefore it would be fairer to include VAT for these drivers, but unfortunately this breakdown of driver and passenger types is unlikely to be known. Hence, the values shown in Table 4.4 will be used to estimate the cost of fuel consumption as a ‘resource’ cost, but this cost will be updated to 2011 values.

Table 4-3: Parameters used in Equation 1 to calculate fuel consumption in litres per km, after WebTAG unit 3.5.6 (DfT, 2011b).

	Parameters			
Vehicle Category	**a**	**b**	**c**	**d**
Petrol Car	1.042850982	0.04483725	-4.913E-05	2.1781E-06
Diesel Car	0.480988603	0.064502969	-0.00057759	4.54155E-06
Average Car	0.9574479	0.04782644	-0.00012946	2.53734E-06
Petrol LGV	1.628611034	0.067231691	-0.00077899	1.05213E-05
Diesel LGV	1.082489985	0.059963265	-0.00044831	8.31097E-06
Average LGV	1.162824392	0.061032451	-0.00049695	8.63611E-06
OGV1	1.564481329	0.260097879	-0.00378306	3.24446E-05
OGV2	3.613294863	0.42026914	-0.00494704	3.82806E-05
PSV	4.115603124	0.306464813	-0.00420643	3.65263E-05

Table 4-4: Parameters used in Equation 1 to calculate fuel consumption in pence per km, after WebTAG unit 3.5.6 (DfT, 2011b).

	Parameters			
Vehicle Category	**a**	**b**	**c**	**d**
Petrol Car	17.41561140	0.74878208	-0.00082047	0.00003637
Diesel Car	8.85019030	1.18685463	-0.01062766	0.00008356
Average Car	16.23678447	0.81105989	-0.00219537	0.00004303
Petrol LGV	27.19780427	1.12276924	-0.01300913	0.00017571
Diesel LGV	19.91781572	1.10332408	-0.00824890	0.00015292
Average LGV	21.09944859	1.10743382	-0.00901716	0.00015670
OGV1	28.78645645	4.78580097	-0.06960830	0.00059698
OGV2	66.48462548	7.73295218	-0.09102554	0.00070436
PSV	75.72709748	5.63895256	-0.07739831	0.00067208

When a vehicle is delayed it will consume a different amount of fuel than if it is in free flow conditions, and the parameter ‘a’ in Table 4.3 can be used to estimate fuel consumption per hour when a vehicle is stationary. To estimate fuel consumption in the methodology, it will be assumed that the time delay calculated from Tables 4.1 and 4.2 in DfT (2004b) represents the actual time that vehicles are stationary in a queue (even though this is not the case, and is therefore a limiting assumption). The fuel consumption whilst stationary will then be calculated using parameter ‘a’ in Table 4.3. This approach was recently used in the preparation of an Advice Note for the Highways Agency (Highways Agency, 2011b), which includes the calculation of fuel consumption using parameter ‘a’ to help compare different types of highway technology schemes such as CCTV cameras and controlled hard shoulder running. This provides some validity for the assumption.

It is assumed that Equation 1 can accurately estimate fuel consumption, but as it is widely used in transport appraisal this is not unreasonable. However, the method is clearly limited, because as Abbott et al. (1995) point out, fuel consumption will depend on the number of stop / start movements, the temperature of the engine, and the type of car, and none of these factors is taken into account.

4.3.3 Chosen Method of Assessment for the Impacts of Road User Delays

The impact of streetworks on traffic is potentially very significant and many other impacts are directly related to it, including noise, air quality and impact on the local community and business. DfT (2004b) is based around a robust and rigorous assessment process, and offers an opportunity to allocate average delay costs to different types of streetworks in a way that can be widely and easily applied. However, this approach suffers from several limitations including the value of time used, the assumption that Reinstatement Category can be used as a proxy measurement for traffic flow, the assumptions used in the modelling, and the limitations inherent within the algorithms used in the software.

Nevertheless, it is necessary to find a widely applicable method that can estimate road user delays for different types of project because these data will not always be available, and it is argued that this need outweighs the limitations inherent within DfT (2004b). Therefore, Tables 4.1 and 4.2 taken from DfT (2004b) will be used to estimate average delays at different types of streetworks projects by dividing the total cost by the value of time used in the study - £11.28. If the traffic flow is known, the average delay in seconds per vehicle can then be estimated. Ideally these estimated values would be compared with site based data as this would present an opportunity to define the statistical significance of the predicted delay, but these data were not available and it is necessary to develop the methodology using the best available knowledge.

Once this estimated delay is obtained, it will be assumed that each vehicle is stationary for that amount of time. Then, Equation 1 will be used to calculate fuel consumption for this stationary time in different Scenarios. This offers a widely applicable method but its accuracy can be called in to question, because fuel consumption will actually depend on the number of stop / start movements, the temperature of the engine, and the type of vehicle (Abbott et al., 1995). Nevertheless, it is argued that the estimation of delays from DfT (2004b), and the calculation of fuel using Equation 1 are both valid, because they allow different options to be compared on a fair basis.

4.4 Carbon and Other Air Emissions

4.4.1 Background

McMahon et al. (2006) state that streetworks often create a need for traffic management which causes traffic to stop, accelerate and break. Abbott et al. (1995) state that this acceleration and deceleration movement has been shown to lead to additional emissions in low speed journeys, and this finding is mirrored by DfT (2007). McMahon et al. (2006) also point out that diversion routes may involve additional mileage which will create air emissions; and additional traffic flow is created by workers, construction traffic and deliveries. Brady et al. (2001) state that previous studies on air pollution have not defined the exact contribution that streetworks make, but the works can raise pollution to unacceptable levels.

Abbott et al. (1995) indicate that emission rates are strongly influenced by the precise conditions for combustion within the engine: the amount of fuel relative to air, the temperature and pressure in the cylinder, and engine timing. DfT (2007) states that in an internal combustion engine, energy is derived from the burning of hydrocarbon fuel in air and the main by-products are carbon dioxide (CO_2) and water vapour (H_2O). Some of the fuel is not burnt (or is only partially burnt), and this means that the exhaust fumes will contain carbon monoxide (CO), volatile organic compounds (VOCs), and particulate matter (PM) containing carbon and other substances. Additionally, at the high temperatures and pressures found in the combustion chamber some of the nitrogen in the air and fuel is oxidised, forming mainly nitric oxide (NO) and nitrogen dioxide (NO_2), the sum total of which is abbreviated as NOx. The compounds CO, VOCs, NOx and PM have normally been regarded as the pollutants of most concern, and therefore emissions are restricted in many countries.

CO_2 is a major contributor to global warming but is also considered to be an atmospheric pollutant. Carbon Trust (2012) notes that some greenhouse gases have a greater impact on climate change than others, so gases are allocated a 'carbon dioxide equivalent' value (CO_{2e}) or a 'carbon equivalent' value (C_e), which is the amount of carbon dioxide or carbon which would have to be released in order to have an equal impact in terms of global warming.

Allouche and Gilchrist (2004) define the most common health problems associated with air quality as respiratory illness, cardiovascular disease, allergies, anxiety and annoyance. DfT (2007) indicates that if pollutants are known or suspected carcinogens then no absolutely safe exposure level can be defined. In 1997 the Kyoto Agreement was signed by the UK Government, and this created a legally binding agreement to reduce the amount of six greenhouse gases by an average of 5.2% below 1990 levels by 2012 at the latest, with the UK committed to a reduction of 12.5% (UN, 1998). CO_2 is the most important greenhouse gas, and annual emissions have increased by 80% between 1970 and 2004, with transport accounting for 13.1% of all greenhouse gases globally (IPCC, 2007). In 2008 the UK was the first country in the world to introduce a long term, legally binding obligation to reduce its emissions of greenhouse gasses by at least 80% by 2050 compared to 1990 levels (HMSO, 2008b).

The National Air Quality Strategy for the UK sets out air quality standards and objectives for reducing levels of health-threatening pollutants (DEFRA, 2007). The

Environment Act (HMSO, 1995) requires all local authorities in the UK to review and assess air quality in their area, and if levels of certain pollutants exceed the allowable limits then that area should be designated an Air Quality Management Area (AQMA), (HMSO, 1995). Finally, CEEQUAL contains criteria that prompt a designer to consider air quality and carbon emissions and minimise their impact (CEEQUAL, 2011).

Given this weight of literature it can clearly be argued that air emissions are potentially significant, and can have social, environmental and economic ramifications. Therefore, this impact should be classified as a primary impact of streetworks.

4.4.2 Existing Methods of Assessment for Carbon and Other Air Emissions

Borrego et al. (2006) note that no air pollution modelling technique is perfect, and Belalcazar et al. (2010) highlight that there is an ongoing debate about the parameters that should be used in air quality studies. Vardoulakis et al. (2002) categorise three groups of uncertainties: those associated with model physics, the data used and the uncertainty of turbulence in the environment. Abbot et al. (1995) indicate that there are a large number of different techniques that can be used to measure and predict air pollution, but it is difficult to select the best measurement programme and to analyse the results. This literature highlights some of the problems inherent with modelling air quality and it suggests that a detailed analysis of traffic flow and speed is required, because otherwise the accuracy of the results may be called in to question.

Abbot et al. (1995) suggest that site measurements can prove far from conclusive themselves, and it is very costly to carry out air quality monitoring studies at different sites. Therefore, the triple bottom line of sustainability becomes important – even if the accuracy of air quality models or measurements can be established, it is still necessary to develop an easily applicable method that can estimate this impact. Moreover, many streetworks projects do not last long enough for their impact to be assessed in this way, and in some cases the overall air pollution may actually be lower than when traffic is free flowing because traffic is diverted elsewhere.

DfT (2007) sets out the procedures that should be used to assess the impact of air quality from highway schemes, but if this document were followed then utility schemes would never be assessed, because they do not increase traffic after the work is completed. To some extent this is because DfT (2007) was created to assess highway schemes (which very often do have such an effect), but the general argument is still valid; utility streetworks projects appear to be too short term to have a significant air quality impact from traffic if DfT (2007) is followed.

DEFRA (2004) sets out a completely different approach that could be used to assess the impact of carbon and other air emissions. It uses a willingness to pay technique (WTP) to generate empirical estimates of how much people in the UK are willing to pay for reductions in the health risks associated with air pollution. However, other research suggests that this type of result is highly subjective (Abbot et al., 1995) and it is therefore rejected.

An alternative approach is put forward by The Greater London Authority who produced a guidance document for air quality issues (GLA, 2006), but this is intended for longer term construction projects. It states that if a site has a footprint less than 1000 square metres, and will only cause an 'infrequent' impact on sensitive sites, then it is considered low risk. Neither DfT (2007) nor GLA (2006) is being put forward as an argument to exclude air quality from the methodology; they simply highlight the fact that no recognised method is available to easily assess air quality issues for streetworks. Therefore, such an approach must be found for the methodology.

DfT (2007) suggests that QUADRO can estimate carbon emissions as part of its analysis of road user delays. This has the advantage that it is widely recognised, but again is not easily carried out if a separate model has to be developed for every scheme, and is therefore rejected as being economically unviable. Buckland and Middleton (1999) developed an approach that allows the estimation of air pollution from traffic in urban street canyons, but in terms of highway design this is not well recognised and once again is not aimed at utility streetworks, and is therefore rejected.

A more viable alternative is WebTAG unit 3.3.5 (DfT, 2011b), which can be used to calculate the carbon equivalent (C_e) or carbon dioxide equivalent (CO_{2e}) emissions that are generated from burning fuel. First of all, fuel consumption in litres is estimated from Equation 1 (see Section 4.3). Secondly, this fuel consumption is converted into carbon emissions by multiplying by the grammes of carbon estimated to be released from burning one litre of petrol or diesel, as outlined in Table 4.5.

Table 4-5: Carbon emissions per litre of fuel burnt, after WebTAG unit 3.3.5 (DfT, 2011b).

Year	Emissions from petrol/bioethanol blend (gCarbon/litre)	Emissions from diesel/biodiesel blend (gCarbon/litre)
2005/6/7	637.91	719.73
2008	632.18	694.91
2009	619.64	699.00
2010	620.18	699.82
2011	614.73	693.82
2012	610.36	688.64
2013	607.09	684.82
2014	606.27	684.0
2015	606.27	684.0
2016	606.27	684.0
2017	606.27	684.0
2018	606.27	684.0
2019	606.27	684.0
2020 and	606.27	684.0

It is argued that the process outlined in WebTAG unit 3.3.5 (DfT, 2011b) offers a good compromise – a widely recognised approach that is easily applicable to different schemes. It can be linked with the calculation of fuel consumption that was explored in Section 4.3, and presents an opportunity to calculate air emissions in terms of their carbon equivalent value. However, this ease of use is not in itself a complete justification for its use, and several limitations are associated with the chosen method.

Firstly, WebTAG unit 3.3.5 (DfT, 2011b) assumes that all of the carbon in transport fuel is converted to carbon dioxide, but openly states this is a limitation because in reality some carbon will be released as particulates or hydrocarbons. Secondly, it assumes a steady traffic speed, but this takes no account of the findings of Abbott et al. (1995) and DfT (2007) who both indicate that the acceleration and deceleration movement leads to additional emissions in low speed journeys. Thirdly, the chosen approach does not model the effect of emissions at all, and therefore makes no distinction between a congested urban canyon and a rural environment, even though the effect on air quality must almost certainly be different.

All of these criticisms are accepted, but an equally valid argument is that an assessment method must be economically sustainable (i.e. easily applied), so a quick and easy method must be available if air quality / carbon emission issues are to be featured in the methodology and displayed each time it is used. Certainly air quality issues should not be excluded because of accuracy issues, as this would seek to hide a significant impact. Finally, it is argued that the possibility still exists for a more detailed assessment to be carried out for particular projects if it is felt necessary (for example if longer term work is carried out in an urban area with an AQMA), but unless this is required then the procedure outlined in WebTAG unit 3.3.5 (DfT, 2011b) should be used to assess carbon emissions, which will be taken as a proxy measurement for other pollutants (which is itself a simplification). If a detailed breakdown of traffic is not known then the average emissions from petrol and diesel will be used, and this is another limitation that must be considered.

This carbon emission will then be expressed as a cost using the process outlined in DECC (2010), which is summarised within WebTAG unit 3.3.5 (DfT, 2011b). As the emission is not created by electricity generation or an energy-intensive industry, it is 'non-traded', and using the 'central' estimate for 2011, WebTAG unit 3.3.5 (DfT, 2011b) states that the cost of one tonne of carbon emissions is taken to be £158.87. This will be the value used in the methodology, which is based on 2011 figures.

WebTAG unit 3.3.5 (DfT, 2011b) goes on to state that the contribution to greenhouse gas emissions from all aspects of a project must be considered, and this includes those resulting from such activities as the manufacture of cement, but it states that there are practical difficulties in reliably and consistently estimating these emissions, and therefore they are not required to be considered within the current version of the WebTAG document. This does not prove they are insubstantial; it just indicates that they are difficult to measure, and therefore the emissions due to the manufacture and delivery of materials, and those associated with the use of plant and machinery, need to be explored in more detail to understand if they can be included within the methodology.

One possible approach to calculate CO_2 emissions for building materials is put forward by Thomas et al. (2009b), who calculate CO_2 emissions resulting from the use of aggregates in a large construction project in Birmingham. This offers a comprehensive and logical approach for calculating the CO_2 emissions associated with aggregate use, and therefore this method could be used to calculate these values in the methodology. However, Thomas et al. (2009b) will not capture CO_2 emissions for other types of building materials, and in utility streetworks it is unlikely that whole loads of materials will be used on just one utility streetworks project. Similar observations can be made for Chiu et al. (2008) who estimate the environmental impact of different asphalt road surfaces; this general approach needs to be applied much more broadly if it is to be of use.

A more widely applicable approach for factoring embedded energy is to use a proprietary piece of software that can incorporate CO_2 emissions associated with the manufacture of different building materials, and this approach will be taken in the research. The software chosen is called ‘CapIT’ and has been created by the cost consulting firm Franklin and Andrews, and is arranged in a format that complies with CESMM3 (1991). Fiske (2012) states that CapIT calculates CO_2 emissions from a number of different sources. The creators carried out primary research using LCA analysis software, and then consulted manufacturer’s data and public domain information such as the University of Bath's ‘Inventory of Carbon & Energy’ (Bath, 2012). The latter has a list of building materials with CO_2, CO_{2e} and embedded energy values per unit weight of building material. Therefore, if the quantities of building materials are known, the energy associated with their production will be estimated using CapIT.

However, CapIT will not help with calculating the air emissions associated with the delivery of building materials, and at this stage it is interesting to review a study carried out by Huang et al. (2009b). They examined a major road maintenance scheme, and assessed air emissions for different scenarios using a LCA approach. Their study considers (and separates out) the air emission contributions made by road traffic, as well as construction traffic and deliveries. Although such an approach was aimed at a major road maintenance scheme, they note an interesting conclusion: given the long life of a pavement, Huang et al. (2009b) argue that the majority of emissions will come from the traffic using the road – in other words the emissions from deliveries and construction traffic are small in comparison to the emissions from traffic using the road.

Because deliveries for small projects are unlikely to be specifically for one job, an alternative approach would be to look at annual figures (i.e. the total mileage and therefore fuel consumption associated with all deliveries for a particular utility company) and then divide this figure by the total number of projects carried out, but these data were not available. The conclusions from Huang et al. (2009b) suggest that the impact of air emissions from construction traffic and delivery vehicles is not hugely significant when compared to emissions from traffic, and therefore the study is partially used as a justification to exclude this impact from most assessments. However, CEEQUAL (2011) states that the transport of goods, materials and staff to and from a work site can cause considerable nuisance to local people, and this implies the impact cannot be so easily dismissed; therefore it will feature as a contributory impact that can be specifically modelled if required.

4.4.3 Chosen Method of Assessment for Carbon and Other Air Emissions

It is necessary to consider the additional air emissions that are associated with delayed and queuing traffic. To do this, the approach outlined in WebTAG unit 3.3.5 (DfT, 2011b) offers an assessment method that is recognised within industry and is easy to calculate, and it shares some of the formulae already selected in Section 4.3. First of all, fuel consumption will be estimated based on average delay, traffic flow and vehicle composition, and then the carbon emissions associated with this volume of fuel will be calculated as a carbon equivalent. Finally this carbon will be converted to a monetary cost using a value of £158.87 per tonne, taken from WebTAG unit 3.3.5 (DfT, 2011b).

Building materials require energy for their production, and this will have an air and carbon emission associated with it. If included within an assessment, these air emissions will be measured using the CapIT software developed by Franklin and Andrews.

Delivery vehicles to and from each site will also have an associated air emission, and for longer term schemes this impact may well become significant. However, the conclusions from Huang et al. (2009b) indicate that this impact is probably not significant for short term work, and therefore it will not be considered in most assessments, but will still appear as a contributory impact.

4.5 Noise Pollution

4.5.1 Background

The World Health Organisation (WHO, 1992) defines noise annoyance as "a feeling of displeasure evoked by noise". Allouche and Gilchrist (2004) state that common physiological responses associated with noise include high blood pressure, cardiovascular disease, tiredness, irritation and stress. WHO (1992) point out that exposure to noise is commonly expressed as the average sound intensity over a specific time period (such as 24 hours); but this could consist of a large number of almost inaudible noises or fewer events of a higher level. McMahon et al. (2006) highlight that streetworks can generate significant levels of noise, which can originate from the plant and machinery involved, or from queuing traffic at the works or along diversion routes. Abbott et al. (1995) state that appreciable levels of noise are created by traffic queuing, and vibrations can be transmitted through the ground or air.

BSI (2009b) defines a vibration as a wave that travels through materials, and as the wave passes through the receiving point the particles of matter undergo a vibratory or oscillatory motion. BSI (2009b) highlights that some individuals will be more sensitive to vibration than others, and vibrations can cause anxiety, which can in turn disturb sleep, work or leisure activities. An associated problem is that vibrations can create structure borne noise, which can be an additional irritant to occupants of buildings (for example, loose fittings are prone to rattle and movement). Although the physical properties of vibration are different to noise, it is felt on balance that noise should be used as a proxy measurement for vibration, although this is based on the assumption that they are directly proportional, and are both caused by the plant and machinery used during construction, and that the likelihood of vibration damage increases with noise.

CEEQUAL (2011) contains several criteria that prompt an engineer to consider and mitigate noise and vibration at the design stage of a project, and there is an established legislative background surrounding the impacts of noise and vibration. The Noise and Statutory Nuisance Act (HMSO, 1993) makes noise in the street a statutory nuisance, and the Environmental Protection Act (HMSO, 1990) grants local authorities the power to serve an abatement notice on project owners if a 'statutory nuisance' exists (and both noise and vibration can cause a 'statutory nuisance').

This literature (which includes legal requirements) indicates that both noise (and as a proxy, vibration) is potentially significant negative impacts associated with streetworks and should therefore be defined as a primary impact of streetworks. This will then make it possible to assess and compare the noise or vibration impacts for different Scenarios in some way.

4.5.2 Existing Methods of Assessment for Noise

The document 'Calculation of Road Traffic Noise' (DfT, 1998) uses a quantitative approach to assess the noise impacts of a new road or transport scheme. The procedure begins by dividing a road into segments, and then calculates a basic noise level for each segment using traffic flow, composition and other data. Therefore the document represents a useful calculation method to assess free flow traffic noise, and this noise level could then be reasonably considered as the noise level 'before' work starts.

Abbott et al. (1995) state that CRTN was devised to predict traffic noise from statistically 'normal' compositions of traffic, and the simplifications included may reduce the accuracy when dealing with changes in traffic speed, composition and flow. DfT (1994b) states that CRTN is based on data that are at least 15 years old, and the surveys used as its basis were conducted at sites where road traffic was the dominant noise source. Wetzel et al. (1999) highlight a limitation with noise prediction techniques in general, because different methods often predict different values, and none of these may be the same as site measurements. Therefore, although the method described by DfT (1998) could be used to calculate the noise from free flow traffic its result could be called in to question, and it will not help to estimate noise from queuing traffic, or the noise created by construction machinery.

BSI (2009a) suggests that the likelihood of complaints associated with noise will increase when there is a large difference between the industrial noise and the existing background noise, and the longer the duration of activities on a site the more likely it is that noise from the site will prove to be an issue. Boyce and Bried (1994) found it difficult to assess the impact of noise on the productivity of businesses and quality of life for local residents. Stansfeld and Matheson (2003) state that the perception of having control over a noise source may reduce its threat, and BSI (2009a) states that good public relations and communication are important; WHO (1992) note that there are considerable differences in people's reaction to the same noise.

This literature indicates that if different people are affected by noise and vibration in different ways then a simple quantitative assessment method may not fully recognise the personal disturbance caused. In an ideal world perhaps the level of encompassing disturbance and annoyance, rather than the level of noise, would be measured, but problems arise as to how this can be practically carried out for every streetworks project, or whether this could be carried out for a range of representative streetworks projects from which to draw. Therefore if the duration of the work differs between solutions the estimated noise during construction will be multiplied by the duration of the work. If the duration is the same then the total traffic delay will be used as a proxy measurement, because it is argued this will take account of the 'accumulative' impact being made. Hence, it is necessary to estimate the noise created during construction.

BSI (2009a) states that a pragmatic approach needs to be taken when assessing the noise effects of construction projects; procedures for large projects are different to small projects (which may not need to be assessed at all, or might only require the general consideration of noise effects and mitigation). It states that obtaining noise measurements directly is likely to be more accurate than any predictive techniques, and given this general confidence in site measurements it would be very useful to collect field measurements over a large number of sites that involve different physical situations and technologies. In this way a statistically significant data set for noise levels could be developed, and then these standard and accepted values could be used more widely in the future to predict noise levels before work starts, but unfortunately these data are not available. However Abbott et al. (1995) note the high cost of such surveys, and given the annual number of streetworks projects, it would not be economically sustainable to carry out such measurements for every project.

Ballesteros et al. (2010) offer a useful and potentially widely applicable method (albeit with limitations). They divide up the stages of a typical construction project into five different categories – namely excavation, frameworks and walls, walls and brickwork, facilities, and roof. They then use site measurements to analyse the features of sound emission associated with each stage, which includes excavation (a task often carried out during streetworks). Because their study is based on site measurements, and these measurements include a contribution from different types of plant and machinery, it is argued that this presents a 'widely applicable method' to assess the noise levels that are created during a typical streetworks projects. However, there may be no direct correlation between the noise created at a large construction site and the noise created at utility repair streetworks project. On the other hand, Morillas et al. (2005) apply a similar approach to free flowing traffic at different types of streets in Spanish cities, and their results show a clear stratification between street types, so it is argued this (perhaps unsurprising) observation adds some validity to the general approach.

4.5.3 Chosen Method of Assessment for Noise

The literature and methods reviewed above all have their limitations, and noise may affect people differently, but assessment of noise is still worthwhile because this will allow different Scenarios to be compared with respect to noise. In terms of sustainability it is necessary to develop an 'economically accountable' (e.g. cheap to use) technique to assess the noise (and therefore vibration) created when streetworks are carried out. This means the method must be simple, widely applicable, capable of assessing accumulated impact, and able to compare the degree of variation that exists between different options.

The literature indicates that noise created during a streetworks project will be more annoying than background traffic noise, and that the duration of the noise is a deciding factor in the amount of annoyance caused. Therefore if the duration of solutions differ, their noise impact will be measured by multiplying estimated noise levels by the duration of the work. If the duration is the same but the traffic delay differs the traffic delay will be used as a proxy, based on the argument that this will take account of the 'accumulative' impact of noise created by queuing traffic. These approaches have limitations. Excavation will not continue for the whole of the project duration, but it is likely that intermittent noise would prove both distracting and irritating to those close to the site, so this simplification is not unreasonable. Traffic creates noise as it queues through he works, so this proxy measurement is also justified.

The noise level during construction will be taken as the worst case noise emitted during the excavation stage of the Ballesteros et al. (2010) study – read as 78dB L_{eq}.

The worst case has been taken in order to highlight the potential impact that can possibly be created, but it is noted that this does not take account of a person's threshold to noise at prescribed levels.

4.6 Highway Reinstatement

4.6.1 Background

The Horne report (HMSO, 1985) resulted in the development of a Specification for the Reinstatement of Openings in Highways, the most recent edition of which was published in 2010 (HMSO, 2010). This sets out the requirements for reinstatement in terms of performance, excavation, backfill, compaction and remedial works for different 'Reinstatement Categories' of road. Section 71 of NRSWA (HMSO, 1991a) states that undertakers must reinstate in compliance with this specification, and they must ensure that performance standards are met, whereas Section 78 allows highway authorities to charge utilities for the cost of repairing long term damage that has been caused by poor reinstatement.

There is evidence that reinstatement can have a negative impact on the condition of the original road. McMahon et al. (2006) state that poor compaction of the road surface can lead to water ingress, which can cause premature structural failure and deterioration of the road. Khogali and Mohamed (1999) highlight that excavation of the road involves digging through the asphalt surface, sub-base and subgrade soils to reach buried facilities, and state that removing this material reduces the lateral support to materials in the uncut road sections. Khogali and Mohamed (1999) state that although there is no agreed quantitative method to evaluate the effect of reinstatement on pavement life, the same tools currently used for the analysis of structures could be adapted to predict road deterioration.

The Transport Research Laboratory (TRL) has carried out a very important study into the impact of reinstatement (Zohrabi and Burtwell, 2003) and their report includes a detailed literature review of studies from the UK and other countries. A majority of the studies reviewed show that sections of pavement with trenching show a much greater deterioration than areas with no trenching, and a weakened zone around the trench appears, varying from 1 to 1.5m away from the trench itself. The same authors detail a separate study carried out by Fleming and Cooper (1995) who monitored the settlement characteristics of over a hundred trench reinstatements in and around Southampton, which showed significant settlement during the early stages. In contrast, Zohrabi and Burtwell (2003) review a study carried out at the TRL pavement test facility, which found no consequential damage in four reinstatements, and no need for maintenance to the trenches. However, this study is laboratory based and its conclusions are in sharp contrast to the findings of several other (site based) studies, and hence it is rejected.

This literature (which includes legal requirements) indicates that the impact of reinstatement is potentially significant, and therefore it should be classified as a primary impact.

4.6.2 Existing Methods of Assessment for the Impact of Reinstatement

Fleming and Cooper (1995) show clear evidence suggesting that the impact of reinstatement is directly proportional to the skills of those who carry out the work.

Furthermore, Burtwell and Spong (1999), and Zohrabi and Burtwell (2003) both identify good compaction as being an important way to mitigate the impact of reinstatement. Overall, this literature justifies the argument that there is a clear link between poor workmanship and the impact of reinstatement. Therefore a 'CEEQUAL type' criterion could possibly be developed prompting the designer to ensure a good standard of work on site, or alternatively a criterion could be developed that tests compliance with the Specification for the Reinstatement of the Highway (HMSO, 2010). Such a qualitative criterion would not be limited to promoting construction methods only; equally it could promote any working method that can be proved to reduce the impact of reinstatement.

For example, Zeghal and Mohamed (1998) developed a unified North-American guide for best-practice reinstatement that is capable of addressing site specific issues, construction materials and environmental conditions, so there is some justification to promote such a system within qualitative criteria. Similarly, Zohrabi and Burtwell (2003) review a study carried out in Santa Monica where utility companies need to submit 5 year repaving plans to avoid repetitive street trenching, and it is logical that if such an approach fostered more coordination then the overall impact of reinstatement will be reduced, simply because less of it goes on. Again, there is some justification for the inclusion of such a process within qualitative criteria. However, it is argued that this would move further away from the original issue – how should the impact of reinstatement be measured? The literature explored in the preceding paragraph points towards Scenarios that might be assessed, but it does not point towards an impact assessment method.

Another possible way to measure the impact of reinstatement is as a monetary cost (i.e. a charge made by a highway authority in order to take account of the impact of reinstatement), and several such charges are explored by Zohrabi and Burtwell (2003) in their international studies. They demonstrate that most of these charges consider the age and importance of the road, some distinguish between longitudinal and transverse trenches, some are applied 'per opening', and some are charged for each square metre or length of opening. However, the rate of charges varies a great deal – between £15 and £100 per square metre, depending on the age of the pavement. Specifically, Zohrabi and Burtwell (2003) state that in California it was found that a road surface overlay of 40mm to 50mm was found to be the most effective way of avoiding adverse effects of trenching, and so local authorities imposed additional charges on this basis to take account of the impact caused. Furthermore, they state that a similar charge was introduced in San Francisco in California, but it was found that the charge need not be imposed when the age of the pavement reached 20 years because at this stage no premature aging would occur.

Therefore, it can be concluded that one possible way to measure the impact of reinstatement is as a cost that is proportional to the cost of resurfacing the highway. However, these charges would not take account of the wider impacts created by any resurfacing work that has been brought forward, and are therefore likely to under estimate the true impacts. Nevertheless, it should be considered whether such a cost is a fair measurement. On the one hand, a charge for every project is not fair because in the UK the entire highway is not actually resurfaced after every trenching by a utility, on the other hand the structural stability of the road will almost certainly be affected even if trenching does not occur, and therefore a charge might be considered fair. A broader view would be to ask whether the 'one customer' would achieve value from such a charge, and arguably a certain amount of pragmatism is necessary: if a highway is designed for a 25 year lifespan it is unrealistic to expect it to be untouched for 25 years; it must be accepted that the road will need to be reinstated at regular intervals across its lifetime. This prompts a different type of question – is a 25 year design life really suitable for a busy urban road with many pipes and cables buried beneath it?

Nevertheless, it is felt that measuring the impact of reinstatement as a monetary cost is best because it will seek to highlight the potential costs that can arise from poor reinstatement. The unit cost of resurfacing a highway could be pro rated for the area of excavation, and because Zohrabi and Burtwell (2003) include a Californian study that found an overlay of 40-50mm is sufficient to prevent damage, a worst case depth of 50mm resurfacing might be used to calculate the impact as a proxy cost.

However, Langdon (2011) does not contain such a cost – the nearest equivalent is the cost of constructing an entire highway, including earthworks, pavement, line markings etc. Several highway types are included, and the cost per metre length of highway is presented as an estimate. For example, based on data provided in Langdon (2011), a single lane rural road is typically 7.3m wide, and the average cost of construction is £1,338 per metre length. The total area of highway surface in this case would be 7.3m wide * 1m length of carriageway = 7.3 m^2. This is an average cost of £183 / m^2. The same calculation for a dual carriageway is £97 per m^2 and this is likely to be because of economies of scale – dual carriageways will run for tens or even hundreds of kilometres. The Langdon (2011) cost includes earthworks, fencing, barrier work and lighting, so this will overestimate a proxy cost of reinstatement. On the other hand, reinstating a utility repair scheme is very small scale, even when compared with constructing a 1m length of single carriageway road. Therefore it is arguably reasonable to use a nominal proxy rate of £183 / m^2 to measure the impact of reinstatement for all types of highway.

Unfortunately, this means that no distinction can be made for organisations that carry out reinstatement particularly well, and therefore it provides little incentive for improvement. This limitation is accepted, because such a performance monitoring process could still be developed as a separate Scenario, and its impacts can be measured in that way.

4.6.3 Chosen Method of Assessment for the Impact of Reinstatement

The discussion in this Section has revealed that the impact of reinstatement is potentially significant and should therefore feature in the methodology. One possible way forward would be to measure this impact in terms of a qualitative criterion as this could measure the performance of an organisation in terms of the quality of their workmanship. However, it is argued that this is a way to mitigate damage, and not a measurement of damage per se, and is therefore rejected, even though it might be used as a proxy measurement.

On balance, it is argued that the impact of reinstatement should be measured as a proxy cost because this will highlight the potential costs that can arise from poor reinstatement. However, this should not be taken as an indication that utilities should actually be charged that amount; it is highly likely that a road will be dug up many times before it reaches the end of its life and pragmatically this has to be accepted. The cost will be pro rated from Spons (Langdon, 2011) and based on the price of constructing a new single carriageway, all purpose road – £183 / m^2. This price includes earthworks, fencing, barrier work and lighting and this will over estimate the proxy price, but economies of scale mean that there is a degree of underestimation as well. Arguably if a proxy measurement is used these issues are not critically important, and to a degree they will balance each other out anyway.

4.7 Health and Safety (H&S)

4.7.1 Background

McMahon et al. (2006) highlight that speed changes, visual disruptions and frequent stops increase the likelihood of traffic accidents occurring at streetworks; and construction activities expose workers to risk, therefore streetworks pose a health and safety hazard to both the general public and construction workers. Abbot et al. (1995) state that driver stress is defined as an adverse mental and physiological effect experienced by drivers, which can induce discomfort, fear and tension, and can lead to drivers becoming more aggressive towards other road users and more inclined to take risks. Brady et al. (2001) also noted that the inquisitiveness of the travelling public means that a driver may be distracted or slow their speed, and this in itself is an obvious safety risk. WebTAG unit 3.4.1 (DfT, 2011b) explains that accidents can cause physical damage, personal injury and emotional loss.

The existing health and safety system came into being through the Health and Safety at Work etc Act in 1974 (HMSO, 1974). This created a single legal framework for health and safety regulation through which the Health and Safety Executive (HSE, 2011b) can enforce the law in the workplace. A fundamental principle of this system is the need to reduce risks 'so far as is reasonably practicable'. This term sets a high legal standard: a duty holder must take all possible precautions up to the point where the taking of further measures would be grossly disproportionate to any residual risk.

The Construction, Design and Management (CDM) Regulations (HMSO, 2007) were introduced by the Health and Safety Executive's Construction Division to improve safety in the construction industry, and on large projects a person is appointed to the role of 'CDM co-ordinator', who then has responsibility for compliance with CDM. There is a general expectation under CDM and by the HSE that all parties involved in a project will co-operate and co-ordinate with others. Finally, the CEEQUAL manual includes criteria that prompt a designer to consider health and welfare issues, and amend a design accordingly.

This literature includes legal requirements and highlights the potential human costs that can result from poor safety. Therefore, safety will feature as a primary impact within the methodology.

4.7.2 Existing Methods of Assessment for the H&S

Boyce and Bried (1994) use the cost of insurance premiums to assess the health and safety impact of different working methods by proxy, but McMahon et al. (2006) suggest that such data would be difficult to obtain in the UK due to commercial sensitivities, so this approach is rejected. Kolator (1998, quoted in McMahon et al., 2006) states that trenchless techniques are 4 times safer than open trench working methods, but it is not known what particular risks have been included and excluded in this assessment, so it is difficult to see how it can be easily used.

WebTAG unit 3.4.1 (DfT, 2011b) defines three types of casualty according to the severity of the injuries sustained (fatality, serious and slight). Hopkin and Simpson (1995) set out how the monetary costs associated with these different types of accident can be calculated, and this is the approach that is widely used in COBA for new highway schemes to calculate the monetary cost of accidents saved (or generated) by a new transportation scheme. Using this method, the total costs of an accident consist of the costs of each individual casualty (the value of lost output, the cost of medical support and an estimated cost of pain and distress) plus other costs associated with each accident (for example property damage, insurance costs and police fees). WebTAG unit 3.4.1 (DfT, 2011b) notes that more than one casualty may result from one accident, and the accident value varies between urban and rural areas because there are a different number of casualties per injury accident between these categories of road. Table 4.6 gives costs estimated in 1994 values.

Table 4-6: Breakdown of accident costs, after Hopkin and Simpson (1995).

Casualty severity	Lost output	Casualty-related costs (per casualty) Human costs	Medical & support	Total
Fatal	£272,690	£510,880	£510	£784,090
Serious	£11,500	£70,910	£6,970	£89,380
Slight	£1,220	£5,190	£520	£6,920
All casualties	£5,880	£20,750	£1,470	£28,100
Accident severity	**Damage to property**	**Accident related costs (per accident) Insurance administration**	**Police costs**	**Total**
Fatal	£5,880	£160	£1,020	£7,070
Serious	£2,710	£100	£140	£2,950
Slight	£1,590	£60	£30	£1,690
All injury	£1,840	£70	£60	£1,980
Damage only	£1,020	£30	£2	£1,050
All accidents	£1,070	£30	£6	£1,110

This approach is logical and rigorous, and the monetary values are the standard costs used in COBA studies, but the approach would only be useful where a specific injury occurs in a Scenario and therefore it is rejected.

McMahon et al. (2006) note that there are no data specifically measuring accident rates at streetworks, so they interrogate the number of fatalities that occur in the 'extraction and utilities industries' and the number of fatalities that occur from trench collapse. These rates will include non-utility industries, as well as general construction work, so they use assumptions to estimate that there are '2 or 3' fatalities and 50 'major' injuries that occur each year to site operatives due to streetworks. Using the values contained within Hopkin and Simpson (1995), this would equal an average value of 2.5*£784,090 + 50*£89,380 = £6,429,225 in 1995 prices. This excludes any 'slight' injuries that may occur due to streetworks, and assumes that a 'major' injury in McMahon et al. (2006) is the same as a 'serious' injury in Hopkin and Simpson (1995). Using an inflation calculator (BoE, 2011) in 2011 values this is equal to £10,141,167.

This annual cost could also be calculated as a daily rate; DfT (2004b) states that there is an average of 519,966 days of work carried out by utility companies every 6 months - a total of 1,039,932 days per year. This is an average 'cost' of £9.75 per day, or alternatively a likelihood that a fatality will occur of 0.0000024% per day of work. There is a logical argument that would support the measurement of health and safety based on the duration of the work, which could be measured in time, as a percentage likelihood or as a monetary 'cost', but this approach would not allow a distinction to be made between different working methods that have the same duration and is therefore rejected. Furthermore, the values are so low that they do not adequately reflect the potential suffering and implications that will occur from a fatality or serious injury.

In terms of the health and safety impact for the general public, WebTAG unit 3.4.1 (DfT, 2011b) assesses the safety impact of a new transportation scheme on vulnerable people, and begins with an examination of accident records. This is followed by an analysis of the effects of physical changes in road layout and traffic flows, which is then measured as a percentage reduction or increase in the chance of an accident occurring. Although streetworks will not generally result in permanent changes to highway layout, the general principle could be used to assess health and safety for road users in 'with' and 'without' streetworks Scenarios. Moreover, there is an argument that the health and safety impact of streetworks for the general public should be considered separately to risks for construction workers: for example, lane rental charges will only apply during peak hours (DfT, 2011a) and this will encourage night time working, but it is likely that this will increase risks for construction workers but reduce risks for road users.

Syachrani et al. (2010) offer an interesting approach that focuses on one particular type of streetworks project (the rehabilitation of culverts). They identify different activities (for example 'welding and cutting'), and each activity has potential hazards (such as 'fire burns and explosion'). Through an industry survey, each activity was given a severity score based on the potential injury that might occur, as well as a score measuring the likelihood of it occurring. The sum total was defined as the Total Risk Exposure Index (TREI) for that particular working method, which is made of different activities. This is a logical and rational approach, but is limited because it only examines the repair of culverts, and therefore cannot be more broadly applied.

Instead, the general approach taken by Syachrani et al. (2010) will be adapted. The Health and Safety risk for different options will be assessed using a document created by the engineering consultant Mott MacDonald called a ‘Health & Safety Risk Assessment’. This form prompts a designer to identify individual hazards, the associated consequences and impacts (‘severity’) of that hazard, and the probability of it occurring. The spreadsheet then asks what mitigation might be carried out, and uses a fixed formula to calculate a risk category as ‘high’ ‘medium’ or ‘low’, both before and after any mitigation.

This approach allows the risk category to be established using a set procedure. The spreadsheet will be adapted by prompting a user to define the ‘worst case’ health and safety situation for an assessment - this is the initial risk level. Next, different Scenarios will be outlined, including any mitigation involved, and the resulting risk level following this mitigation will be assessed. The resulting ‘low’, ‘medium’ or ‘high’ score will be valued as 1, 2 or 3 in the summary of results, so that the H&S impact can be easily compared with other numerical outputs, as shown in Table 4.7:

Table 4-7: Example H&S risk assessment spreadsheet.

Health & Safety Risk Assessment

Title									
Work Activities									
Worst case	Consequence / Impact	Persons at risk	Initial risk level			Scenarios being tested	Residual risk level		
			Severity	Likelihood	Risk Level		Severity	Likelihood	Risk Level

Guidelines on how to complete the HRSA

1. Record the hazard or aspect, e.g. exposure to noise, entering a confined space, etc
2. Identify the worst-case effect of the hazard
3. Identify who could be affected by the risk, e.g. contractors, members of the public, etc
4. Evaluate the level of risk for each hazard, by identifying its severity of harm and likelihood, using the risk matrix shown below
5. Ascertain if high risk, can hazard be avoided?
6. Identify control measures
7. Evaluate the level of risk for each hazard, taking into account the effect of the control measure(s)

Severity of Harm	Severity Index		**Likelihood**	Probability Index
Death or major injury	3		Harm is most likely to occur	3
Lost time injury or illness	2		intermediate likelihood	2
All other injuries or illnesses	1		Harm is least likely to occur	1

Risk Level	Probability Index		
Severity Index	1	2	3
1	L	L	M
2	L	M	H
3	M	H	H

4.7.3 Chosen Method of Assessment for Health and Safety

A method to assess the H&S risk of different options needs to be broad enough to consider many situations. In addition, simple factors of safety such as that put forward by Kolator (1998, quoted in McMahon et al., 2006) are unable to easily categorise individual hazards and risks, and it is difficult to understand what has been included and excluded to calculate them. On the other hand, Syachrani et al. (2010) offer an interesting approach that examines activities, hazards, and the likelihood of them occurring. It is argued this approach is widely applicable and transparent, so to calculate the H&S risk in the methodology, a H&S spreadsheet used by Mott MacDonald will be adapted.

4.8 The Impact on Business and the Community

4.8.1 Background

McMahon et al. (2006) state that streetworks will affect the local community through reduced access, which might affect access to homes, shops and public spaces. Local Authorities may lose parking fees, and the work might produce waste, rubbish, and dirty streets. Project owners may suffer from a negative impact on their brand image from problem streetworks. Local businesses are an integral part of the local community, and McMahon et al. (2006) state that businesses located near to streetworks may be affected due to reduced trade and delays to employees; they also face reduced reliability of deliveries to customers and from suppliers. Businesses located further afield may be affected due to a need to travel through the works site. A number of CEEQUAL criteria prompt a designer to consider ‘community consultation’, ‘social performance’ and ‘social issues’. Clearly this is an important issue, and therefore the impact of streetworks on the local community and business needs to be defined as a primary impact.

4.8.2 Existing Methods of Assessment for the Impact on Business and the Community

WebTAG Unit 3.5.12 (DfT, 2011b) outlines a questionnaire that could possibly be used to assess the impact of a project on local business, but it is difficult to see how this type of time consuming questionnaire could be used for every streetworks project. Allouche and Gilchrist (2004) consider the impact of long term construction projects on business in Canada, and suggest that construction activities have a measurable negative impact on economic activities within a certain radius of the site, which they refer to as an 'influence zone'. Streetworks projects are much shorter in duration but occur more frequently, and therefore it is argued that the accumulation of these impacts from short duration streetworks is perhaps more relevant than the impact per project.

Allouche and Gilchrist (2005) attempt to quantify the loss of productivity for a local business during a construction project as a product of employee numbers, output, duration and a 'productivity reduction factor' for specific industries. However, this approach relies on the relevant reduction factors being known or collected in the UK, and will still miss some types of impact - for example a delivery vehicle driving from Portsmouth to Plymouth may be delayed at Southampton, and this delay might cause it to miss a 'just in time' delivery, but such an impact cannot be measured using this particular approach put forward by Allouche and Gilchrist (2005), and therefore it is rejected.

Allouche and Glichrist (2004) examine 'indirect valuation techniques', and summarise a willingness-to-pay technique that was used to assess a new sewer interceptor in parkland. However, it is difficult to see how such a method could be used more widely, and raises a question of usefulness – after all, the local community is unlikely to reach a consensus, or directly pay this extra cost. Each streetworks project is unique, it is virtually impossible that a consensus could be reached for this WTP approach, and does it suggest that the community would actually pay this amount? For these reasons this approach is rejected.

Butcher (2010b) states that under the Gas (street works) (compensation of small businesses) regulations 1996, a gas company must pay compensation for loss of turnover sustained by a small business. The Federation of Small Business report that mean turnover for a small business in the UK is around £524,000 (FSB, 2012), and in the past local businesses have claimed that their turnover is affected by 65% (Devon, 2012) or even 75% (Wishaw, 2012) when streetworks are carried out. These figures appear high, and such compensation payments will not always be due, but commercial sensitivity means exact figures are difficult to obtain. Therefore it is argued that a rational approach for measuring compensation would be to calculate 10% of average turnover, which is equal to £524,000 / 365 days * 10% = £143 per day. This will be the value used in the methodology to measure the compensation paid to all local business. As the assessment tool is used more on actual projects, this value can be questioned and adapted, and if the actual cost of compensation is known this value can be substituted.

DfT (1993) states that construction can cause loss of access due to the presence of heavy construction traffic. This indicates that ‘reduced access’ is a potentially significant impact on the local community, and although utility repairs cannot be avoided simply because of severance, it might be argued that mitigation at extra cost is justified because this will reduce the score of the severance impact. DfT (1993) uses a descriptive approach to describe this impact as ‘slight’, ‘moderate’ or ‘severe’, with the descriptions based around number of people affected, the percentage change in traffic and the amount of mitigation put in place.

This type of categorisation might be used to deal specifically with the issue of severance, but many others impacts are likely to exist. For instance, Boyce and Bried (1994) identify reduced sales tax and revenue from parking as other potential impacts on the community, and note that pedestrians may have to avoid a streetworks site by walking along a longer diversion route. McMahon et al. (2006) state that many highways and footways have trees growing nearby, and tree damage will have a number of environmental, economic and social impacts (NJUG, 1995).

This debate could continue, but it is highly unlikely that every possible impact on the community can be predicted by anyone who lives outside of that community. Furthermore, different groups of people will score the severity of a particular impact in different ways (for example a cyclist will be affected by the temporary closure of a cycle path more than a pedestrian). Therefore, a similar approach to the assessment of the health and safety impact will be used to assess the impact on business and the local community.

Again, the ‘worst case’ situation will be defined, followed by a description of each Scenario, including any mitigation involved. The resulting community impact will then be defined after this mitigation, and the scoring will use a similar method as the Mott MacDonald H&S Risk assessment spreadsheet. Similarly, ‘low’, ‘medium’ and ‘high’ levels of impact will score ‘1’, ‘2’ or ‘3’, as shown in Table 4.8. The situation is complex, and community impacts are both interrelated and difficult to predict, so it is argued that the use of localised criteria and a standard method of scoring will provide a sufficiently adaptable, but rigorous approach for measuring such qualitative impacts.

Table 4-8: Example H&S risk assessment spreadsheet.

Community Impact Assessment

Title	
Work Activities	

Worst Case Community / Social Impact	Consequence / Impact	Persons affected	Initial level of impact			Scenarios	Residual impact level		
			Severity	Likelihood	Risk Level		Severity	Likelihood	Risk Level

Guidelines on how to complete the HRSA

1. Record the community or social impact, e.g. blocked access to property, closed footpath
2. Identify the worst-case effect of the community impact
3. Identify who could be affected by the impact, e.g. pedestrians, cyclists etc
4. Evaluate the level of risk for each community impact, by identifying its severity of harm and likelihood, using the risk matrix shown below
5. Identify control measures
6. Evaluate the level of risk for each hazard, taking into account the effect of the control measure

Severity of Impact			**Likelihood**			**Impact Level**			
	Severity			Probability			Probability Index		
	Index			Index		Severity			
						Index	1	2	3
Worst case impact	3		Impact is certain or near certain to occur	3		1	L	L	M
Intermediate impact	2		Impact is likely to occur	2		2	L	M	H
Impact is minimised	1		Impact is least likely to occur	1		3	M	H	H

4.8.3 Chosen Method of Assessment for the Impact on Business and the Community

Compensation to local businesses will be measured as £143 per day whenever it applies. As the assessment tool is used more on actual projects this value can be questioned and adapted, and if the actual cost of compensation is known this value can be substituted. The Mott MacDonald spreadsheet used to assess health and safety risk will be adapted and used to measure all other community impacts.

4.9 Other Environmental Impacts

4.9.1 Background

McMahon et al. (2006) define a number of 'environmental impacts' and these are shown in Table 3.1, two of which (air pollution and noise pollution) are considered as primary impacts. It is, however, necessary to consider as many potential impacts as is 'reasonably practicable' and CEEQUAL (2011) highlights several possible impacts not mentioned by McMahon et al. (2006). However, the methodology needs to be both rationalised and balanced, and each new impact adds to the complexities of assessment. Every design is context specific and the context will dictate which impacts should be treated separately in the analysis and appear in the output. It is important to clearly identify which issues have been omitted as having negligible impact, which have been combined and which have been dealt with discretely, along with the reasoning. Thus the methodology remains relevant regardless of which set of primary and contributory impacts is adopted. This Section will gather together several other impacts and manage them.

4.9.2 Management of Other Environmental Impacts

The following considerations referred to by McMahon et al. (2006) and CEEQUAL (2011) might be removed from the analysis, combined with 'Other Environmental Impacts', or analysed separately such that it appears on the radar diagram:

- Land use: the methodology applies to the maintenance and replacement of buried utilities, therefore as a general rule no permanent land take is required.
- Land contamination by hazardous materials: clear guidelines exist, i.e. the COSHH legislation (HMSO, 2002) on what is and is not likely to be relevant to include; a judgement can then be made as to whether it should feature in the analysis based on the site specific context.
- Landscape issues: the impact of reinstatement on a newly resurfaced road or pedestrian area can affect local aesthetic quality, either temporarily (e.g. emergency repair in block paving) or permanently.
- Ecology and biodiversity: this is a potentially very important issue. Certain species of plants and animals are protected by legislation such as the Wildlife and Countryside Act (HMSO, 1981) and Local Biodiversity Action Plans can be produced at a local, county or even company levels. However, it is only likely to feature explicitly in exceptional cases, though tree damage might more commonly be relevant (NJUG, 1995).
- Flood risk: this is only likely to feature in exceptional cases.
- The historic environment: this impact will not apply to most streetworks projects but could be important in exceptional cases.
- Water resources and the water environment: water is a valuable resource, and is protected at national level through the Water Resources Act 1991 (HMSO,

1991b) and European level through the Water Framework Directive (EC, 2012). Where relevant it should be included in the analysis, along with pollution of ground water.

- Light pollution: light can adversely affect a local neighbourhood during works and unnecessary lighting can waste energy. However, unless streetworks continue for many days or weeks and are carried out at night, in general this impact will be of minor importance, and it is likely to be an unavoidable impact in terms of health and safety provision.

4.9.3 Management of Other Environmental Impacts: Conclusion

The methodology needs to be both rationalised and balanced; each new impact adds to the complexities of the assessment. This Section has identified many wider impacts that may occur when streetworks are carried out. These impacts include biodiversity issues, ground water pollution and light spillage, but they have been removed from the selected methodology because it is felt that their impact is minimal or embedded within other impacts, or their inclusion would make the methodology unwieldy, or because it is argued that other legal requirements already exist.

However every design is context specific and the context will dictate which impacts should be treated separately in the analysis and appear in the output. It is important to clearly identify which issues have been omitted as having negligible impact, which have been combined and which have been dealt with discretely, along with the reasoning. Thus the methodology remains relevant regardless of which set of primary and contributory impacts is adopted.

4.10 Summary

This Chapter has discussed and assessed a number of impacts which need to be considered in the methodology. The literature was consulted to determine how best to assess the various impacts, and it became clear that not all impacts can be assessed objectively using quantitative methods. Some impacts need to be assessed using qualitative measures whilst others, even though important, cannot be measured easily and should not be included in a practical assessment tool.

A summary of the assessment tool is shown in Figure 4.1. Each of the stages in the assessment process is cross referenced to Case Study 1 in Chapter 5, including appropriate tables, figures and sections. It should be noted that the scope and aim of assessment is likely to be different every time the assessment tool is used, but Figure 4.1 can be used to illustrate the assessment process using Case Study 1 as an example.

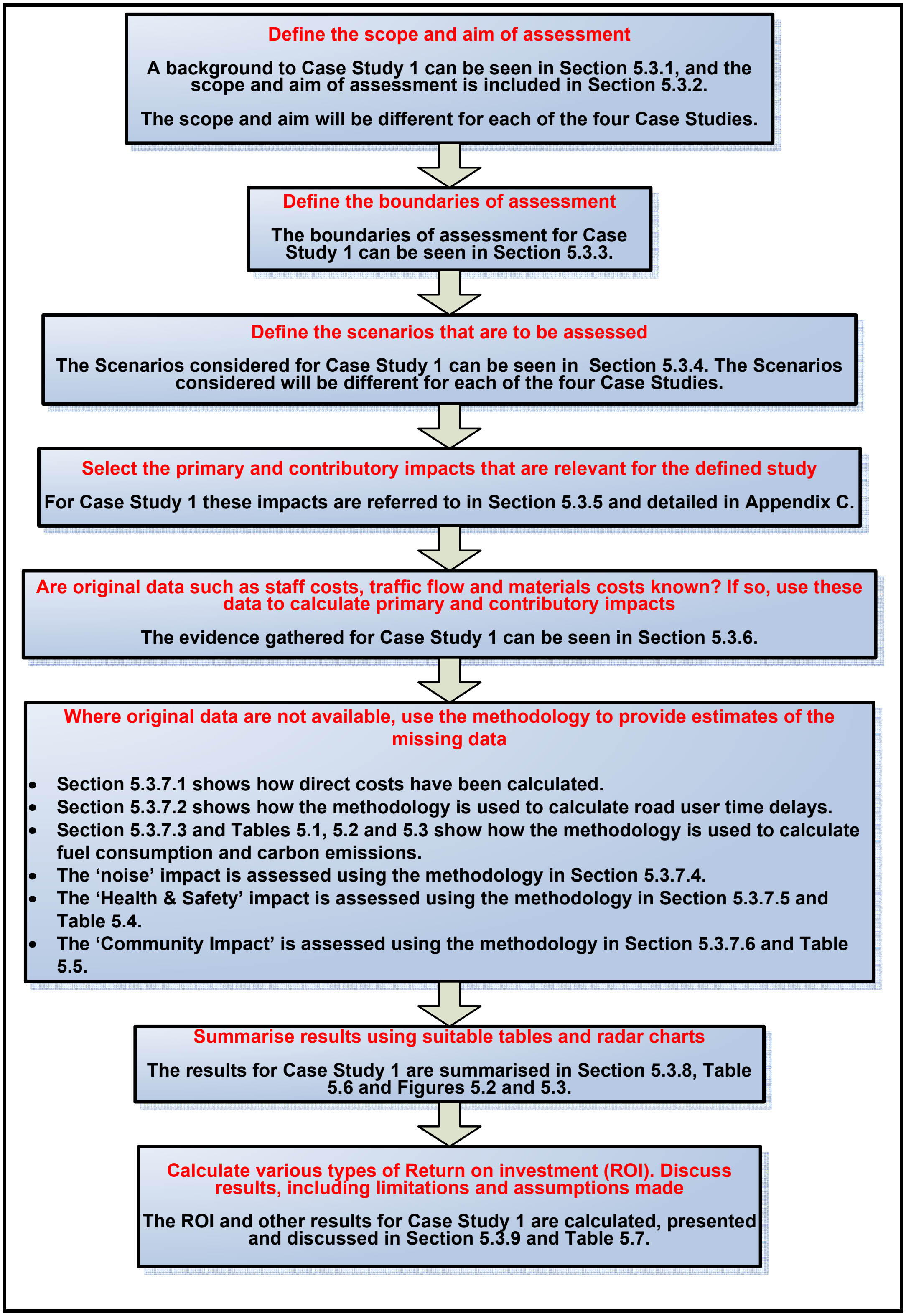

Figure 4-1: Summary of assessment process

5 CASE STUDIES

5.1 Introduction

The methodology will now be validated by being applied to four Case Studies. This will reveal how easy it is to use, as well as the sensitivity and importance of each result. The Case Studies are all located in the UK, and hence the UK's dense urban areas, regulations and legislation provide the context, but the methodology can be applied to any country (the relevant impacts will be context specific).

- Case Study 1 compares two different working methods – one slightly more expensive than the other, but with an associated reduction in road user delays.
- Case Study 2 highlights the far-reaching impacts that can derive from decisions made when streetworks are being planned – an apparently suitable working method led to problems occurring on site. It assesses the full impacts created by this event.
- Case Study 3 identifies some of the problems that can occur when only historic, inaccurate and incomplete, records of utility service locations are available to those working in the street.
- Case Study 4 examines a highway scheme (as opposed to a utility scheme) and tests the advantages of using one particular engineering solution, which was used to obtain more accurate information about buried utilities prior to planning the works.

Each Case Study has a different scope and aim and attempts to use different parts of the methodology; it is hoped this will provide an incremental illustration of different applications.

5.2 Discussion

5.2.1 Data Supplied

Data for the Case Studies were provided by industry partners and included costs and estimates, as well as other confidential information. Often these data were supplied on the condition that the case studies were made anonymous, and therefore the case studies refer to different stakeholders simply as 'Highway Authority A', Utility Company A' etc.

Case Studies 1, 3 and 4 were suggested by highway authorities, whereas the second Case Study was suggested by a utility company; perhaps unsurprisingly all of these stakeholders suggested Case Studies where others were 'at fault'. This Chapter has been written retrospectively, and reflects certain decisions that were made as the Case Studies were carried out. When other project stakeholders were approached their version of events differed to the original party so these discrepancies were questioned, but not to the point of confrontation. The arguments for this are as follows.

Firstly the aim of the research is to develop an assessment methodology, and the Case Studies aim to validate and review that methodology. This validation process requires data to be obtained so that the impacts from different outcomes can be compared. This interrogation of data is more rigorous if it is based around a project where problems have occurred, otherwise it would be necessary to predict what would have gone wrong, rather than compare what actually went wrong with what should have happened. However, it is not the aim of the research to act in the capacity of a Public Inquiry, searching out answers as to why projects went wrong. The final methodology is intended to assess and mitigate problems that may occur in the future, not dissect problems of the past, so the conclusions from the research must assist in this aim; it is not fair or productive to focus on one project or one organisation.

Another decision made was to only select one Scenario to compare with the 'what actually happened' Scenario, and the argument for this is as follows. For each Case Study there are dozens, perhaps even hundreds of different Scenarios that could be developed, but the aim of the research is to develop an assessment methodology, not promote particular solutions. If two or three other Scenarios were developed, this would suggest that there are only two or three Scenarios worth testing, but this is almost certainly not the case. There is some logic behind the following simple choice: test one 'other' Scenario in each case and focus on different elements of the methodology, or test dozens of 'other' Scenarios and define the best solution for each Case Study. The methodology is the novel (untested) element of this research, and therefore the first option has been chosen; this also demonstrates the process by which a greater number of Scenarios might be compared.

5.2.2 Scenarios

Chapter 2 highlighted the disparate nature of the utility streetworks industry and identified a lack of focus on the 'one customer' who pays various utility bills and taxes. This demonstrates that the methodology must be able to consider many different Scenarios if the best interests of this 'one customer' are to be identified. For comparison of two Scenarios to be fair and objective, the scope and aim of assessment needs to be the same for each Scenario. Therefore the Scenarios compare identical situations in which a single change is made, with consequential knock-on effects (such as a change from an open trench working method to a no-dig solution), so that the sustainability of true alternatives can be assessed.

5.2.3 Output from the Assessment Tool

The outputs from the assessment tool could be communicated in various ways, and several different options were considered, but perhaps the simplest approach would be to prepare a narrative of the results as straight text. This approach has been adopted within the assessment tool because different working methods are described as scenarios and the results are then discussed. The advantage of this approach is the flexibility of what can be included within such a discussion (as well as what scenarios can be considered), but it is argued that more must be done to easily and quickly communicate the results of the assessment.

The assessment tool captures the negative impacts created during streetworks projects, and these individual impacts might be considered as 'criteria' or 'performance indicators' against which each option is being assessed. If so, there are various ways in which these multiple criteria can be displayed, and Odds (2012) notes that a tabulated set of results including each criterion or indicator is one option. This would avoid the need for graphical charts, and for each of the Case Studies the negative impacts are tabulated in this way, but it is argued that some type of graphical display is also useful in order to compare options. As Hurley et al. (2008) note, including a visual output within a sustainability assessment framework is an advantage.

Odds (2012) suggests that bar charts are often an effective way to display such data, and Hurley et al. (2008) reflect this approach by using a scoring system for different criteria, before grouping them together under broad categories and aggregating their scores, and then displaying the results in a bar chart. Their scoring system ranges from 0 (the status quo) to +3 or -3, but it is difficult to see how negative impacts can be effectively captured using this scoring system, and it will be difficult to describe what 'the status quo' is for each Case Study. Therefore their approach is rejected because it is not an easy way to assess the value of different options for streetworks projects.

Jefferson et al. (2007) note that judgements about value can be provided graphically by the use of rose diagrams. Their 'radar chart' style of output has been selected for the assessment tool because it provides an immediately visual appreciation of the relevant situation (e.g. see Arup, 2011). Garnåsjordet et al. (2012) note that radar charts are a practical way to express the interdependence and trade-offs between sustainability indicators because they display multi-dimensional information and clarify causal relationships between indicators. Holt (2010) states that this 'dart board' style of output allows an easy understanding of the weaknesses and strengths of a project, and is ideal for aiding progressive assessment at the early stages of decision-making design.

Capturing the impacts associated with different Scenarios as a radar chart permits flexibility: if a particular contributory impact is important for the project being assessed it can appear on the radar chart, while primary impacts that are not relevant can be omitted. Braithwaite (2007) notes that an output that easily highlights and compares the strengths and weaknesses of an option will help decisions makers to demonstrate its overall performance in terms of sustainability. The assessment tool uses the term 'benefit' to describe a reduction in one particular negative impact and this fits with a radar chart - a mixture of positives and negatives would make the output of the assessment more difficult to comprehend, because a negative impact is 'better' the smaller it is, whereas the opposite is true for a positive impact.

Pearce at al. (2012) describe the Halstar sustainability rating system, which uses a 3 dimensional version of the rose diagram. This sustainability decision tool for projects includes an additional vertical axis so that project stakeholders can examine the situation over short, medium and long term timeframes. However this 3 dimensional approach has been dismissed because the assessment tool is used to assess different working methods for short term, small scale construction activities in the street – the long term impact of the works is not questioned; the assessment tool is designed to assess what working method should be used to carry out the work. The focus is different, so the approach used by Pearce at al. (2012) is rejected.

Odds (2012) identifies several negatives from the use of radar charts. If gridlines and labels are shown on the axes it can be difficult to make out a value, but if they are too far away it is difficult to see what axis relates to what label. It is difficult to understand the meaning of the shape of a series. The axes of radar charts represent independent scales for each of the quantitative variables under consideration, but a radar chart encourages a user to compare values across different axes.

Given these comments, it is necessary to consider whether impacts that do share a common unit of measurement should also use a common scale on the radar chart, because these values may vary a great deal. For example, if wasted fuel as well as carbon emissions are both monetised and feature as spikes in the radar chart the 'cost' of carbon emissions may be far smaller than the cost of wasted fuel, so if the same scale is used for all axes it will difficult to compare options with respect to carbon emissions. This issue will be tested for Case Studies 1, 3 and 4 by including two radar charts, one using the same scale for monetised costs and the other using a different scale. Case Study 2 is displayed as 3 different outputs that are compared in different ways. A decision about which approach is 'best' will be difficult to answer, because it will depend on the scope and aim of each assessment. One assessment may require an understanding of the cost of mitigation in terms of the overall project cost (when the same scale bar would be more appropriate), but another assessment may need to understand how air emissions vary between two Scenarios because the site is sensitive to this impact; in this case the monetised carbon emission should be presented using an independent scale from other monetised costs.

A wide range of impacts are being considered in the radar chart and they do not all share a common unit of measurement, so a decision must be made as to how these different results will be presented. Chapter 3 identified a wide range of social, environmental and economic impact assessment techniques, but the literature demonstrated how important it is to go beyond the consideration of monetary costs alone. In particular, personal opinions, social and environmental impacts are not well measured in terms of a cost because they are valued differently by different people, so it is argued that monetising all impacts would be inappropriate – the assessment tool must be able to feature units of measurement other than cost, so these 'other units' will feature alongside monetised impacts. It is difficult to see a practical way around this problem given the fact that social impacts in particular are difficult to both predict and monetise.

The purpose of the methodology is to assess the value of different solutions by comparing the negative impacts created, and an example is shown in Figure 5.1. In this case the additional cost of Scenario 2 might be considered worthwhile in terms of company brand, reducing social costs and/or reducing environmental damage. The impacts that appear on the radar chart are those most relevant to the aim and scope of assessment, they may be one of the 8 primary impacts or one of the contributory impacts. If outputs from different projects are compared then the spikes will necessarily vary a great deal, because each case is unique. The assessment process will always begin with a review of the 8 impact categories and the contributory impacts defined therein, but the spikes shown on the radar charts will be those most relevant to each assessment.

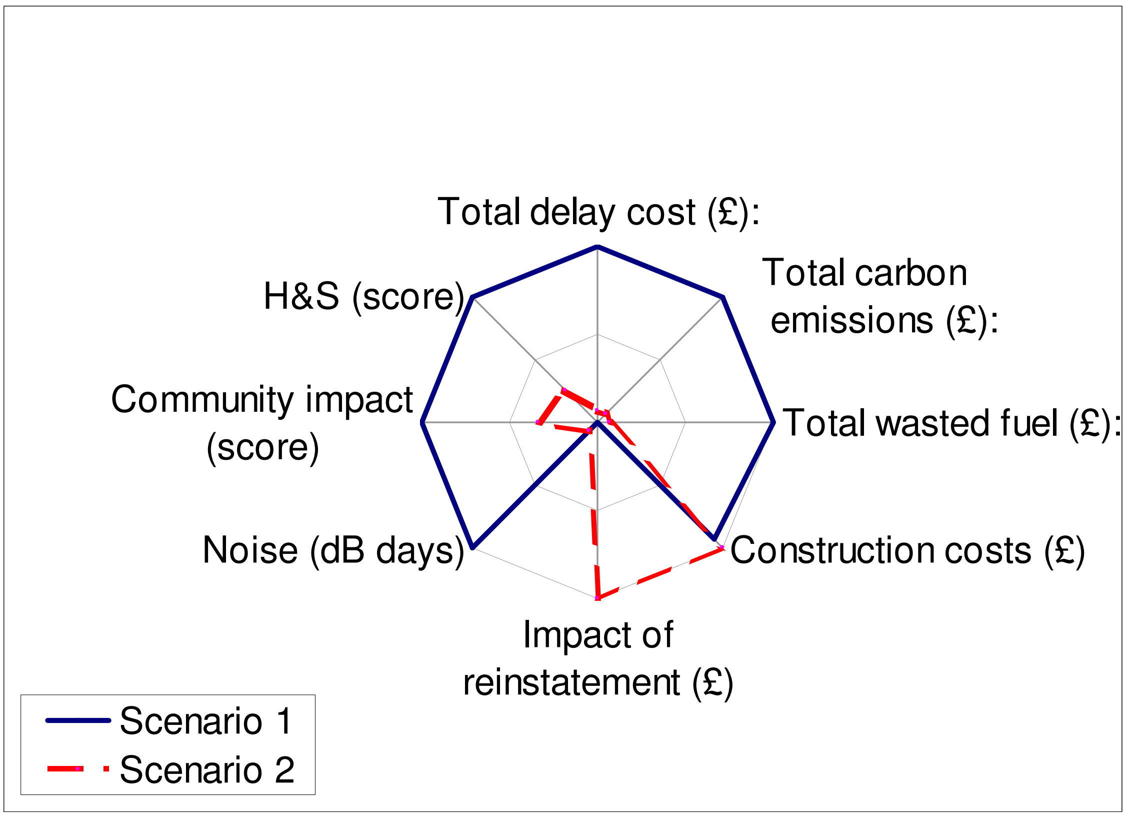

Figure 5-1: An example of the output from the methodology.

5.2.4 Validation and Comparison of Results with an Existing Tool (CEEQUAL)

The primary goal of the assessment tool is to identify solutions that provide real benefits and improvements to 'the one customer' (by minimising negative impacts), so an alternative approach to the use of radar charts might involve a points based scoring system such as that used in GreenRoads (2012) or CEEQUAL (2011), but this has been rejected for the following reasons. Firstly it is argued that the approach will require a large number of prescriptive criteria to be developed, but it is unlikely that these criteria will be able to include all relevant issues for all Scenarios. Secondly, a simple 'points score' such as that used in GreenRoads does not allow for an easy interpretation of results or comparison between different scenarios. Nevertheless, it is important to validate the assessment tool by means external to the main approach, and therefore to contrast the output from the methodology with the most relevant existing assessment method (i.e. best current practice), Case Study 1 is assessed using the CEEQUAL process. This is explored in more detail in Section 5.3.11.

5.2.5 Selection of Impacts and Limits of Applicability

Once a clear and unequivocal aim and objective for an assessment has been established, the primary and contributory impacts are each examined in turn. At this stage, a number of primary and contributory impacts can be removed because they are not relevant to the scope and aim of assessment. For example, if an assessment is only focused on road user delays, and this aim and objective is clearly written down, then it may be appropriate to remove issues regarding the impact of reinstatement, but this will need to be clearly stated. A narrow scope of assessment may miss out other impacts that vary a great deal between Scenarios, but these other impacts are not 'important' in the sense that they are outside of the boundaries of assessment.

For the purposes of this research the term 'streetworks' is used to refer to minor, short term projects and construction activities associated with the repair, maintenance and installation of utility services, as well as any type of road surface reinstatement. However, the limits of applicability for the assessment tool are defined as any type of work carried out in the street, but the broader the aim and objectives become, the greater the number of considerations and potential impacts, and therefore the more difficult it will be to compare results.

5.3 Case Study 1

This scheme was initiated by Utility Company 'A' (UCA), and involves the replacement of a metallic gas main using both open trench, and no dig working methods (pipe insertion). UCA is a gas distribution company regulated by Ofgem. Highway Authority 'A' is herein referred to as HAA.

5.3.1 Background to the Scheme

This scheme has been assessed because it demonstrates some of the more mundane and simple problems that can be created when utility streetworks are carried out (such as resident complaints about excessive delays). This is useful, because it is the accumulation of these simple issues (and the low level of annoyance that they cause) that can create such a negative view of 'roadworks' in the public's mind:

- When the NRSWA streetworks Notice for this scheme was first submitted as 'forward planning' the proposed start date was 9th May 2011. However by 26th May, HAA was informed by members of the public that work had not actually started. On 29th June, HAA stated that a Fixed Penalty Notice may be applicable, but work did not start until July 4th.

- HAA stated that manually controlled Portable Traffic Signals (PTS) would be required during peak periods. On 15th September, HAA received complaints about traffic queues during the morning peak hours, and observed during a drive past that no one was manually managing the PTS at the time. This was in contravention of a NRSWA (Section 60) request for cooperation regarding the use of PTS.
- Finally on 3rd October, HAA again contacted UCA because the work appeared to have finished, but the streetworks notice had not yet been closed on the NSG.

5.3.2 Scope and Aim of Assessment

Huang et al. (2009a) developed a life cycle assessment tool for the construction and maintenance of asphalt pavements, and applied it to a case study. In so doing, they defined their 'project background, goal and scope definition' as follows…

> *"Previous LCA studies have questioned the environmental benefits of using waste glass for construction aggregates in terms of carbon footprint… especially when the recycling involves a transportation of waste glass of more than 30–40 km… This case study investigated the life cycle environmental impacts of asphalt paving at* (a Heathrow*) access road in which natural aggregates were partially replaced with waste glass, incinerator bottom ash (IBA) and reclaimed asphalt pavement (RAP), and compared the results to the pavement of the same size and function but made using virgin aggregates only. This is followed by a discussion and data analysis referring to the most significant variables in this project. This case study is to test and calibrate*

the LCA model described above. The findings…can be beneficial to road engineers or researchers dealing with recycling in roads."

The current research aims to develop an assessment tool for streetworks projects, and its basic principles are based around the generic stages of an LCA, but it is not a true LCA. This adapted approach is necessary because Chapters 3 and 4 identified a wide range of social, economic and environmental impacts that are created by streetworks, but not all of these will be captured effectively in an LCA, because this focuses mainly on environmental impacts. Nevertheless, it is argued that the approach taken by Huang et al. (2009a) is sensible in terms of their description for a scope and aim of assessment, and therefore this approach will be adapted for the current research. The scope and aim for Case Study 1 is worded as follows.

Highway Authorities can impose certain obligations on those carrying out work in the street, but these decisions must be reasonable (HMSO, 1991a). This Case Study is based on a project carried out by UCA to replace a metallic gas main. In this case, the highway authority imposed the need to use manually controlled traffic signals because this allows a site operative to monitor and partially control queuing times in either direction. This Case Study investigates the environmental, social and economic impacts that are created when automatic traffic signals are used on the scheme, whereby no manual labour is required to operate the signals; and compares these results with the impacts that are created when manually controlled traffic signals are used. This is followed by a discussion and data analysis referring to the most significant variables in the project. This Case Study is designed to test and calibrate the results that are generated from the sustainability assessment tool itself. The findings can be beneficial to engineers and other technical staff when they are considering what traffic management is required at future road schemes. The results can also be used to partially justify any fines that are levied on utility companies if they do not follow the requirements of the highway authority in this respect, because the results demonstrate the avoidable or unnecessary impacts that are created when automatic traffic signals are used.

A similar approach will now be used to define the scope and aim of the remaining three Case Studies.

5.3.3 Boundaries of Assessment

Huang et al. (2009a) define the boundaries of their assessment in terms of a ‘product system’ (which in their case study refers to the constituent parts of asphalt), and that…

> *“This is a comparative LCA study. It is assumed that using those recycled materials has no measurable effects on the asphalt layers’ life expectancy or technical constraints on reuse or recycling when these layers are replaced. The upstream boundary for recycled materials is set at the collection point* (for each material)… *The transport of bitumen and emulsifier to emulsion plant is not included in this study”.*

The assessment tool being developed will use the term ‘boundaries of assessment’ for this stage in the assessment process, but the general approach taken by Huang et al. (2009a) will be adapted for the Case Studies. For Case Study 1, the boundaries of assessment are as follows.

This Case Study defines ‘the project’ as all works carried out by UCA to replace the section of gas main in question. This is a comparative sustainability assessment of two different

Scenarios, each based around a different working method. The upstream and downstream timeline boundaries for ‘the project’ are defined as the erection and dismantling of traffic management (TM) within the highway boundary. The physical boundaries of assessment are defined as the extent of the TM plus the queuing traffic. It is assumed that all environmental and social impacts not included within the assessment remain the same for both Scenarios. It is also assumed that there are no additional effects caused after traffic has exited the works site, and that the only difference in direct cost is the cost of labour.

5.3.4 Scenarios

Two Scenarios will be developed:

- Scenario 1: PTS was used without manual control. Complaints from the public occurred.
- Scenario 2: Manually controlled PTS was used. Complaints from the public occurred less frequently than in Scenario 1.

5.3.5 Selection of Primary and Contributory Impacts

The primary and contributory impacts included within this Case Study are shown in Appendix C.

5.3.6 Evidence Gathered for Case Study 1

HAA has supplied the following evidence:

- Information from the National Streets Gazetteer for this scheme which shows the transfer of NRSWA Notices and comments between HAA and UCA.
- An estimation of the amount of time spent on this scheme that is ‘over and above’ what would have happened if the scheme had not created any problems.

- The reinstatement category for the road in question (Type 3), which specifies how any resurfacing should be carried out.

Additional information on these can be found in Appendix C.

UCA engaged with the Case Study, and supplied information about the duration of the work and the length of road affected by the works (approximately 50m). Neither HAA nor UCA could confirm the exact amount of time that TM was on site. A duration of 28 days has been assumed, and this is based on the communications sent between HAA and UCA. This is considered to be a reasonable approach because although there were some ‘fixed costs’ (damage repair costs, impact of reinstatement and HAA additional time spent), most of the additional costs and reduced delays are directly proportional to each other, for each day of work.

5.3.7 Assessment of Primary and Contributory Impacts

This Section will discuss all of the relevant impacts for this Case Study, explain and justify how each impact has been assessed, and state which impacts might not be relevant.

5.3.7.1 Direct Costs of Design and Construction

<u>HAA labour costs</u>

This cost is classified under the contributory impact called ‘supervision during construction’. HAA has estimated the time spent on the scheme as follows:

- Streetworks manager’s time spent telephoning and e-mailing UCA, and local engineer’s time spent dealing with complaints = 4 hours

- HAA local engineer's time spent discussing issues with UCA / HAA streetworks manager, and having meetings on site and inspecting site = 7 hours.

Of course, including these costs at a project level is to an extent misleading. These labour costs would have been payable by the council without any problems occurring at this particular project, and tax payers money is spent on HAA staff so that they can sort out the problems that arise from streetworks. Conversely, there is an 'opportunity cost' argument (council staff could be dealing with other issues), and if a utility project causes unnecessary problems then all costs associated with it should be clearly calculated because this will help to demonstrate the value of a solution that avoids these problems in the future. For this reason, these costs will be included, and should appear as a contributory impact under the 'direct costs' primary impact.

If the assessment tool is being used by an organisation carrying out streetworks in real life, the direct payroll costs of individual staff members can be used in this part of the methodology. However, pay rates for different members of staff were not sought from HAA due to commercial sensitivity, and it is not known how many years of experience each member of staff has, and therefore estimation using the methodology is required in this case.

The methodology allows the use of a daily rate for a 'skilled construction and building trades' worker which equals £150 per day (£20 per hour) excluding National Insurance and tax. However, it is likely that engineers will be more qualified than a trade's worker; therefore it is considered reasonable to double this value to take account of these extra costs (although the actual cost may be higher still). These rates will now be used in all other Case Studies - all council engineers will be valued at £40 per hour, and construction workers will be valued at £20 per hour. It is assumed that these rates include overhead or agency fees. Hence, HAA labour costs for Scenario 1 are £40 * 11h = £440.

Portable Traffic Signal issues

Only the additional costs of employing one person to manage the PTS need to be considered for this contributory impact, defined as 'labour and plant'. These labour costs for UCA in Scenario 1 will therefore be valued at zero. In Scenario 2 UCA needs to pay for the labour required to manually control the PTS, but this was only required during peak hours. Therefore a total of 4 hours per day is used and the cost is £20 * 4 = £80 per day, and assuming weekend working the total cost is 28 days * £80 = £2,240.

5.3.7.2 Road User Time Delays

The primary impact calculated in this Section estimates the time delays that are created when vehicles queue at streetworks. This time delay is measured as a monetary cost, based on the cost of time. As stated in Section 5.3.6, a duration of 28 days has been assumed for this scheme.

In accordance with Section 4.3, road user delays are based on the Reinstatement Category (RC) of the road, and are estimated using the conclusions from DfT (2004b). HAA confirmed that the road in question has a RC of '3', and Tables 4.1 and 4.2 show the typical cost of delays at streetworks projects in 'rural' and 'urban' areas for roads with this reinstatement category, as well as typical traffic flows (AADT) along different the categories of road. Therefore the average delay per vehicle in seconds is based on the following calculation.

The area in question is generally rural in nature but it is considered that the road passing through the works area has characteristics similar to an urban road, thus using Table 4.2:

- for an 'urban' RC3 road with a 50m excavation and typical flow of 10,000 vehicles, the average daily cost of delay is = £535

The delay costs included in Tables 4.1 and 4.2 (taken from DfT, 2004b) are based on a value of time of £11.28, thus:

- average delay per vehicle (seconds) = £535 / £11.28 * 60 * 60 / 10,000 vehicles = 17 seconds per vehicle

The average delay per vehicle used in Scenario 2 will therefore be taken as 17 seconds per vehicle, and it is used to calculate the overall time delay. The actual delays caused at the site were not recorded, so it will never be known how accurate this predicted value is. The worst delays at the site only occurred during peak hours, so at other times of the day the delay per vehicle may well be the same for Scenarios 1 and 2. Nevertheless, an average delay for Scenario 1 is required, and Wiering et al. (2004) state that the optimisation of traffic signals can reduce average delays by 25%. Since manually controlled PTS would be optimally efficient, the average delay per vehicle in Scenario 1 = 12.8 seconds.

Now that this average delay per vehicle has been calculated it is necessary to calculate the total time delay created in each Scenario. This time delay is measured as a cost, and WebTAG Unit 3.5.4 (DfT, 2011b) states that the DfT bases its economic appraisal of transport projects on 2002 values and prices. The case studies base all costs on 2011 values, and therefore the cost of time used for ‘all vehicles’ in the DfT study (£11.28 per hour) will be increased to 2011 values (£15.05, BoE 2011). The general approach outlined in this Section to calculate road user delays will now be used for all Case Studies. Therefore the delay per vehicle will be multiplied by the daily traffic flow and duration of the work to calculate a total delay cost (i.e. the time delay measured as monetised cost of time).

5.3.7.3 Fuel Consumption, Carbon and Other Air Emissions

The primary impacts included in this Section estimate the cost of fuel that is wasted when vehicles queue at streetworks, as well as the carbon emissions associated with burning this amount of fuel. The use of PTS reduces the average waiting time, so this primary impact is relevant as it varies between Scenarios.

The AADT traffic flow stated in Tables 4.1 and 4.2 is made up of different types of vehicles, and when these vehicles queue at streetworks they consume different amounts of fuel. DfT (1994a) states that the average breakdown of traffic on UK roads is as shown in Table 5.1. In the methodology, the percentages shown for the ‘Average All Roads’ category will be used in all Case Studies to pro rate the total AADT traffic flow in to a traffic flow for different vehicle types.

Table 5-1: Average breakdown of traffic by vehicle type, after DfT (1994a).

CLASS OF ROAD	CARS (1)	LGV (2)	OGV1 (3)	OGV2 (4)	PSV (5)
Motorways	0.762	0.107	0.041	0.085	0.005
Built-up Trunk	0.825	0.112	0.030	0.024	0.009
Built-up Principal	0.848	0.103	0.022	0.010	0.017
Non Built-up Trunk	0.787	0.110	0.038	0.059	0.006
Non Built-up Principal	0.826	0.113	0.031	0.022	0.008
Average All Roads (Includes Minor Roads)	0.816	0.114	0.028	0.031	0.011

The fuel consumption rate for each of these types of vehicle is included in Table 4.3 (which expresses fuel consumption in litres) and Table 4.4 (which expresses fuel consumption in terms of a monetary cost). As discussed in Section 4.3.2, the parameter ‘a’ in these Tables estimates fuel consumption per hour when a vehicle is stationary, and this value will be used to calculate fuel consumption for an amount of time equal to the delay calculated in Section 5.3.7.2. First of all the cost of wasted fuel is estimated using the average delay and relevant parameter ‘a’ for each vehicle type, as shown in Table 5.2. This monetary cost of wasted fuel will then appear in the radar chart, having been updated to 2011 costs.

Table 5-2: Example calculation for the cost of fuel that is wasted when traffic is queuing at streetworks.

A	B	C	D	E	F	G
Vehicle Type	**Average percentage of vehicle type from DfT (1994a) (%)**	**Factor ‘a’ from Table 4.4**	**Delay (seconds)**	**Fuel consumption (£) = C*D/3600**	**No. vehicles = AADT * B**	**Total fuel consumption (£) = E*F**
Cars	81.60%	16.24	17	£0.08	8,160	£626
LGV	11.40%	21.10	17	£0.10	1,140	£114
OGV1	2.80%	28.79	17	£0.14	280	£38
OGV2	3.10%	66.49	17	£0.31	310	£97
PSV	1.10%	75.73	17	£0.36	110	£39
			H: Total cost per day (£):			£914
			I: Total cost for 28 day duration (£)= H*28			£25,592
			J: Update cost to 2011 values using a factor of 1.33 (BoE, 2011)			£34,036

Next, a similar calculation is made to estimate fuel consumption in litres as shown in Table 5.3, which goes on to calculate the monetary cost of the associated carbon emission in the following way.

Section 4.4.2 states that the carbon emission associated with burning one litre of fuel can be estimated from Table 4.5, but this includes values for petrol and diesel fuel. Because the exact breakdown of fuel type is not known for each vehicle, an average value has been used. For 2011 values, 614.73 + 693.82 = 654.28 grammes of carbon is emitted for each litre of fuel burnt. This carbon emission can then be expressed as a cost using the process outlined in DECC (2010), which is summarised within a separate table of WebTAG unit 3.3.5 (DfT, 2011b). As the emission is not created by electricity generation or an energy-intensive industry, it is 'non-traded', and using the 'central' estimate for 2011, the cost of one tonne of carbon emissions is taken to be £158.87 (Table 5.3). When this carbon emission has been calculated as a cost, it appears in the radar chart.

Table 5-3: Example calculation for the volume of fuel that is wasted when traffic is queuing at streetworks.

A	B	C	D	E	F	G
Vehicle Type	Average percentage of vehicle type from DfT (1994a) (%)	Factor 'a' from Table 4.3	Delay (seconds)	Fuel consumption (litres) = C*D/3600	No. vehicles = AADT * B	Total fuel consumption (litres) = E*F
Cars	81.60%	0.96	17	0.0045	8160	36.89
LGV	11.40%	1.16	17	0.0055	1140	6.26
OGV1	2.80%	1.56	17	0.0074	280	2.07
OGV2	3.10%	3.61	17	0.0171	310	5.29
PSV	1.10%	4.12	17	0.0194	110	2.14
Tonnes of carbon calculation			H: Total fuel in litres:			52.65
			From Table 4.5, carbon emitted from 1 litre of fuel:			654.28
			I: Total tonnes of carbon per day = H * 654.28 / 10^6			0.034
			Total tonnes of carbon emission for 28 day duration (£) = I*28			0.965
Cost of carbon calculation						
			Cost of carbon taken from DECC (2010):			158.9
			J: Total cost of carbon per day (£) = I*158.87			5.5
			Total cost of carbon emission for 28 day duration (£) = J*28			£154

The general approach outlined in this Section to calculate the monetary cost of wasted fuel and its associated carbon emission will now be used for all Case Studies.

5.3.7.4 Noise

Following the methodology, because the duration of both Scenarios is equal, it is assumed that the noise created (a primary impact) is proportional to the total delay. This reflects the accumulation of noise impacts over time: if traffic is delayed for a longer then the accumulative noise impact is greater. Therefore, the total overall delay in seconds for each Scenario will be used as a proxy measurement for noise.

5.3.7.5 Health and Safety Impact

There will be a difference between Scenarios for the health and safety impact, because an increased average delay will create additional stress and annoyance for road users and residents. Therefore the H&S risk assessment will consider and score both Scenarios using this observation, as shown in Table 5.4. The worst case H&S impact is considered to be when no additional mitigation is used to reduce traffic queues, and driver stress increases to such a point that a traffic accident occurs. If vehicles collide they will be travelling slowly through the works, so a lost time injury is considered to be likely than a life threatening injury. The initial likelihood is scored as a '2' because it is not certain to happen. In Scenario 1, automatic traffic signals score the same as this 'initial risk level', because driver stress is the same. In scenario 2 the likelihood is reduced because mitigation has been carried out. The final scores are '2' (medium) in Scenario 1, and '1' (low) in Scenario 2.

Table 5-4: H&S risk assessment for Case Study 1.

Worst case	Consequence / Impact	Persons at risk	Initial risk level			Scenarios being tested	Residual risk level		
			Severity	Likelihood	Risk Level		Severity	Likelihood	Risk Level
Excessive queues form at the works. Driver stress and road rage caused by delays and travelling through / beyond the works.	Collision between vehicles drivers, construction workers or pedestrians	Vehicle drivers, construction workers or pedestrians	2	2	M	Scenario 1: Use of automatic traffic control signals throughout the work. Same as worst case.	2	2	M
Excessive queues form at the works. Driver stress and road rage caused by delays and travelling through / beyond the works.	Collision between vehicles drivers, construction workers or pedestrians	Vehicle drivers, construction workers or pedestrians	2	2	M	Scenario 2: Use of manually controlled traffic control signals is used after complaints are made and the council intervenes. There is a lower likelihood that an accident will occur because the average delay is lower and driver stress should therefore be lower	2	1	L

5.3.7.6 Impact on the Community and Business

The community impact spreadsheet focuses on the stress caused to drivers by excessive delays, and the fact that local residents suffer noise and blocked access to their properties during the works. A negative brand image was created for UCA as well as HAA as a result of these problems. The methodology attempts to present a business case for the organisations involved, and it is hoped that when these wider impacts are considered it will be recognised that additional money is sometimes worth spending on improved communication, stakeholder involvement, or specific engineering solutions, if this reduces these qualitative impacts.

The worst case impact (scoring '3' initially) is defined as the use of automatic traffic signals throughout the project. Scenario 1 is the same as the worst case, whereas Scenario 2 reduces the severity of the impact to a '2'. All of the likelihoods are felt to be equal and therefore score '2'. This results in a 'medium' and 'low' residual impact as shown in Table 5.5. Therefore the final scores for community impact are '3' and '2' respectively.

Table 5-5: Community impact assessment for Case Study 1.

Worst case community impact	Consequence / Impact	Persons affected	Initial level of impact			Scenarios being tested	Residual impact level		
			Severity	Likelihood	Risk Level		Severity	Likelihood	Risk Level
Excessive delays cause driver stress and road rage. Local residents suffer noise and blocked access to their properties due to delayed traffic.	Members of the public feel powerless and frustrated. The 'brand image' of the local authority and utility company are negatively affected. Complaints are made to UCA as well as HAA.	Drivers, local residents	3	2	H	Scenario 1: Automatic traffic signals are used to minimise delays throughout the work. Same as worst case.	3	2	H
Excessive delays cause driver stress and road rage. Local residents suffer noise and blocked access to their properties due to delayed traffic.	Members of the public feel powerless and frustrated. The 'brand image' of the local authority and utility company are negatively affected. Complaints are made to UCA as well as HAA.	Drivers, local residents	3	2	H	Scenario 2: Manually controlled traffic signals are used to minimise delays. Community impact is reduced and local residents feel they have some control over the situation.	2	2	M

5.3.8 Summary of Results

The results based on a 28 day duration are shown in Table 5.6. This Table summarises the impacts that are created in Scenario 1 where manually controlled PTS are not used, and

Scenario 2 where they are used. In terms of impacts measured in a monetary unit, road user delays, wasted fuel and carbon emissions feature in the table of results. The labour cost of using manually controlled signals features individually because the Case Study focuses on the value of spending this extra money during construction, and the time spent by HAA also appears in the table of results. In terms of non monetary impacts, the community impact, H&S and noise are the impacts that appear.

Table 5-6: Results of Assessment for Case Study 1, comparing Scenario 1 ('automatic traffic signals used') with Scenario 2 ('manually controlled signals used').

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used
Traffic flow (taken from DfT 2004b based on reinstatement catagory)	10,000	10,000
No. days (estimated from NRSWA records)	28	28
Cost of time per hour used (2011 value)	£15.05	£15.05
Cost of time per second	£0.004	£0.004
Delay per vehicle taken (seconds, estimated from DfT 2004b)	17.0	12.8
Total delay cost (£, estimated from DfT 2004b)	£19,899	£14,983
Total fuel consumption (£, estimated using Table 4.4 taken from DfT 2011, updated to 2011 costs from 2002 values stated)	£34,036	£25,627
Total fuel consumption (Litres, estimated using Table 4.3 taken from DfT 2011)	1,474	1,110
Total carbon emissions (tonnes of carbon, estimated using the unit carbon emissions from burning fuel, contained within WebTAG unit 3.3.5)	0.96	0.73
Total carbon emissions (£, estimated using the unit cost of carbon contained within WebTAG unit 3.3.5)	£153	£115
Hourly rate for labour required to manually control signals (estimated from methodology)	0	£20.00
UCA costs for labour required to manually control signals (based on four hours per day of labour)	£0	£2,240
HAA additional time spent on scheme (estimate provided by highway authority)	£440	£0
Community Impact (using the scoring spreadsheet)	3	2
H&S (using the H&S scoring spreadsheet)	2	1
Noise (using total traffic delay as proxy)	170,000	128,000

The outputs for this Case Study are shown in Figures 5.2 and 5.3:

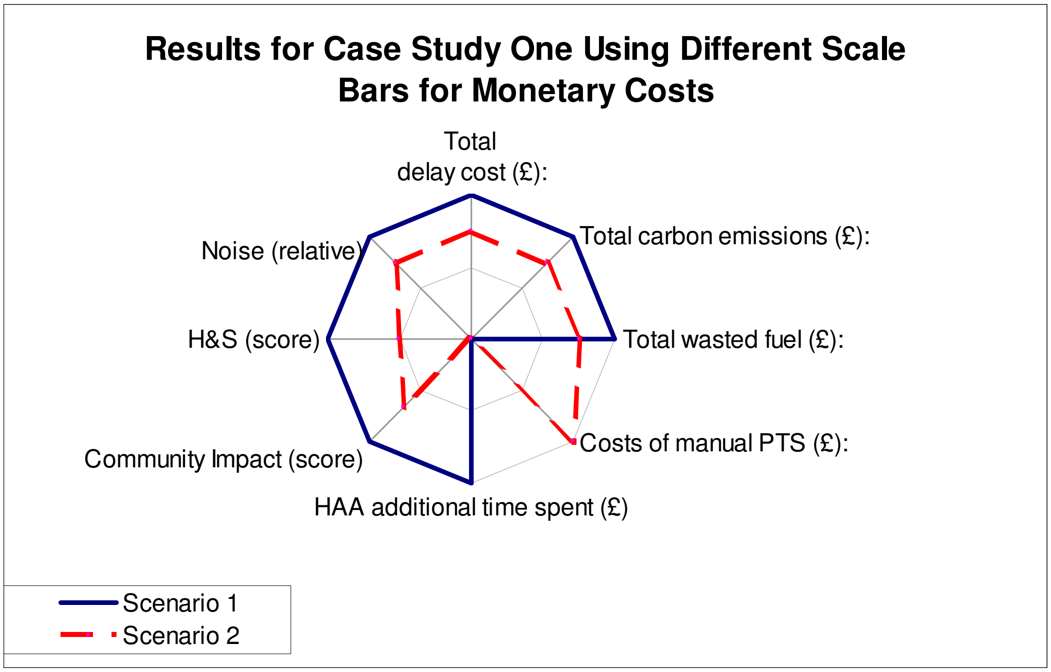

Figure 5-2: Output from the Methodology for Case Study 1, comparing Scenario 1 ('automatic traffic signals used') with Scenario 2 ('manually controlled signals used') using different scale bars for monetised impacts.

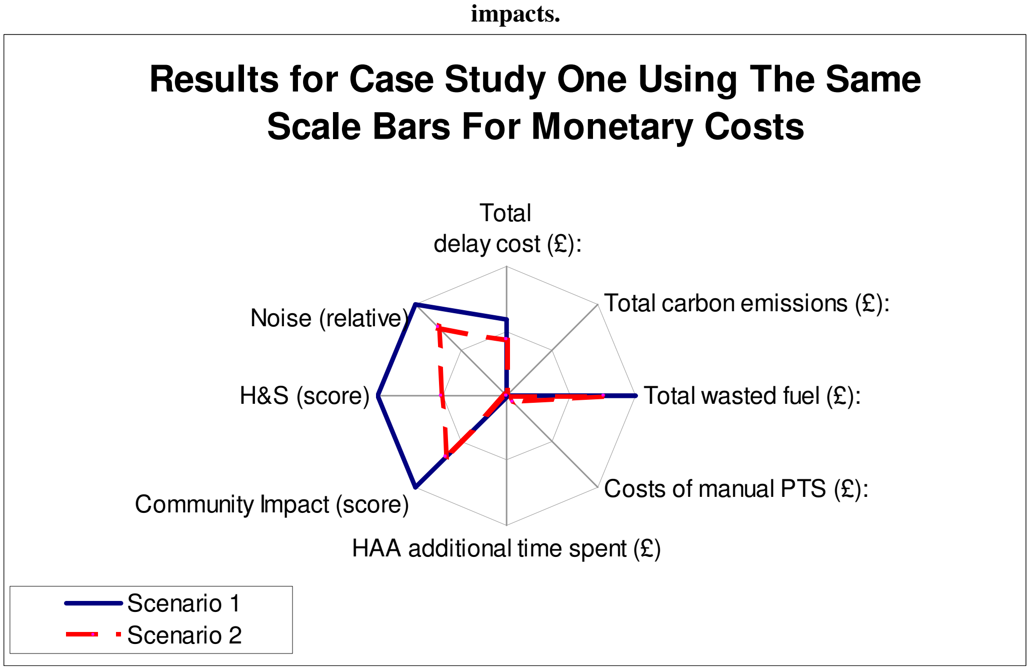

Figure 5-3: Output from the Methodology for Case Study 1, comparing Scenario 1 ('automatic traffic signals used') with Scenario 2 ('manually controlled signals used') using the same scale bars for monetised impacts.

When the same scale is used for all axes it is more difficult to compare labour costs and HAA staff costs between Scenarios, but this in itself proves that these costs are small compared with the overall wasted fuel costs. Both outputs are therefore useful, depending on what information is required.

In Figures 5.2 and 5.3, manually controlled traffic lights reduce the length of a queue at a streetworks project when compared with automatic traffic lights, because the operative can adjust the green time. These outputs define the benefits of a more expensive working method: Scenario 2 is more expensive than Scenario 1 but it creates less road user delays, and therefore less carbon emissions and fuel consumption. Because less disruption is caused, the negative brand image for the utility company carrying out the work is reduced, as are resident complaints. It is possible to calculate a Return on Investment (ROI) for this Case Study because many of the impacts being considered can be easily measured as ‘costs’.

5.3.9 Discussion and Calculation of ROI

Utility streetworks are usually assessed in terms of their direct costs, but it is argued that to be more sustainable, engineering projects must be socially, environmentally and economically accountable. This means that direct cost is only one impact that needs to be considered, and this Case Study calculates a ROI with respect to some of the wider impacts (Table 5.7). For example, spending slightly more money during construction will reduce road user delays, and therefore a ROI with respect to road user delays, fuel and carbon emissions is calculated. Because the methodology is being explored incrementally, this Case Study will only calculate a ROI for the impacts that can be easily monetised, but the principle of embracing the value of both quantitative and qualitative assessments in any rigorous analysis remains.

The ‘investment’ being considered is the cost of the labour required to manually control the traffic lights – £2,240 – and four different ROIs have been calculated. For example, the difference in fuel consumption between Scenario 1 and 2 is £34,036 - £25,627 = £8,409, which is ‘the return’ used in the ROI (fuel) calculation of Table 5.7. This saving in fuel consumption is facilitated by the utility company spending an extra £2,240 in labour costs to operate the traffic signals. Therefore, the ROI with respect to fuel consumption is £8,409 / £2,240 = 1 : 3.75, or a return of £3.75 for every £1 spent. Similar calculations are carried out for each of the Case Studies that follow.

Table 5-7: Different types of a Return on Investment for Case Study 1.

ROI (road user delays valued as a cost)	£2.19	for each £1 spent
ROI (cost of fuel)	£3.75	for each £1 spent
ROI (tonnes of carbon)	0.0001	tonnes of carbon for each £1 spent
ROI (cost of carbon)	£0.0169	for each £1 spent
ROI (all monetised impacts)	£5.97	for each £1 spent
ROI (community impact)	£2,240	to reduce impact score from '3' to '2'
ROI (H&S)	£2,240	to reduce impact score from '2' to '1'

These results show that there are some impacts that can be significantly reduced by spending slightly more money during construction. The results from Case Study 1 could be used to justify the use of manually controlled PTS in the future, due to the benefits accrued from spending slightly more money during construction, which has resulted in a positive ROI, so arguably the additional costs associated with PTS are worthwhile. Of course, this extra cost is spent by a commercial utility company, but the benefit is enjoyed by society at large, and therefore it will be important to consider how such a decision might be incentivised by industry regulators.

Case Study 1 has performed well in terms of demonstrating the principle of a ROI that features wider impacts, but some problems have been highlighted as well. Applying the methodology retrospectively has indicated that not all of the parameters required to evaluate all impacts were routinely measured, and this resulted in assumptions having to be made. However, these assumptions were based on approaches suggested in the literature, and as long as they are made transparent this seems to be a valid approach. Clearly, when more Case Studies are analysed this will allow a database to be developed that includes impacts from different situations. If the methodology is applied at the beginning of a project then there is a greater opportunity to record the correct data.

5.3.10 Sensitivity Check

ISO (2006a and b) state that an important part of an LCA assessment is to test the sensitivity of the results with respect to the data used. Huang et al. (2009a) reflect this approach, and test the sensitivity of their results by using a variation of 10% for their input data; they consider 10% to be 'significant' and it is argued that this represents a sensible approach that is couched within existing literature. Therefore all quantitative input data were tested using a + / - 10% variation, and the background information for this can be seen in Appendix D.

Firstly specific inputs (such as traffic flow and hourly rate) were changed in both Scenarios, and the sensitivity of the output was tested. Secondly, the sensitivity check demonstrated how changes to inputs affect the same Scenario. Hence, specific inputs were changed in Scenario 1 only, so that the 'before' and 'after' values for Scenario 1 could be tested when different input values were used. A graphical representation of the same was also produced. Finally, the sensitivity check demonstrated how the ROI changed when input values for both Scenarios were altered. Details can be seen in Appendix D.

This sensitivity check revealed that quantitative results are particularly sensitive to the average road user delay per vehicle, because the assessment tool is partly made up of mathematical equations where directly proportional relationships exist between road user delays and the following impacts:

- Total delay cost
- Total fuel consumption
- Total carbon emissions
- Noise (if the duration of each Scenario is the same)

The 10% change reflects the approach taken by Huang et al. (2009a), but in actual fact it should reflect the uncertainty associated with the input data. However, this uncertainty is not known, and as many of the impacts are directly related to road user delays, it is recommended that this specific parameter is measured on site so that the uncertainty of the value predicted by DfT (2004b) can start to be established. Nevertheless, the 10% variation check still provides an indication about what parameters are the most sensitive.

Another type of data uncertainty was also revealed, created by commercial sensitivity. A value taken from the methodology is used to calculate staff costs at UCA and HAA, but the accuracy of this figure is not known, and is unlikely to be easily revealed by the organisations involved. Nevertheless, different Scenarios can still be compared if the same staff cost is used throughout an assessment.

Some impacts are scored using proxy measurements, and this creates a third type of data uncertainty. In particular, Case Study 1 uses traffic delay as a proxy measurement for noise, so one way to address this uncertainty could be to use more accurate local traffic flow data. However, this does not really address the issue – if site measurements were taken for noise, the estimation technique used in the methodology could be replaced with more realistic site based measurements, and the uncertainty of the site data themselves could start to be investigated. However, in the absence of such data, the noise assessment techniques included within the methodology will continue to be used, because it is important that 'noise' features in the assessment process.

The H&S and community impact score sheets cannot be so easily tested as part of a sensitivity check. The final scores, associated with a 'low' 'medium' or 'high' value, are created from the severity and likelihood of an event occurring, and so cannot easily be adjusted by a simple 10%. There is uncertainty here in the sense that another user may consider it to be more likely that an incident will result in a fatality rather than a time-loss injury (for example), but a transparent process to reach this conclusion has been established nonetheless.

The sensitivity check allowed the following observations to be made for the ROI when individual input values were altered in both Scenarios.

- Traffic flow: the ROI for road user delays, fuel, carbon and therefore 'all' monetised impacts are affected when traffic flow is changed, because a directly proportional relationship exists in the formula for ROI. For example if the traffic flow is greater, the savings in vehicle delays are therefore greater, and hence a greater return on investment is achieved.
- Days worked: the ROI for 'all' monetised impacts does not alter, reflecting the fact that daily savings in delays / carbon emissions are proportional to the duration of the work, as is the 'investment' being made (labour costs), thereby cancelling each other out in the formula for ROI.
- Cost of time: as expected, if the cost of time increases the ROI with respect to time saved also increases. This also has the effect of increasing the ROI for 'all' monetised impacts.
- Delay per vehicle: if the delay per vehicle is changed this has the effect that all monetised impacts are changed by a similar amount, because a directly proportional relationship exists in the formula for the ROI in each case.
- UCA rate: all ROI values are altered when the UCA hourly rate changes. This is because in Case Study 1 the investment being considered is the cost of the UCA additional labour required to operate the traffic signals, and therefore all formulas for a ROI are changed when the cost of this investment changes.
- HAA costs: HAA labour costs do not feature in the formula for any ROI and therefore the ROI results are not affected. This suggests that it will be useful to calculate a separate ROI based solely on these staff costs incurred.
- In terms of a ROI, noise does not feature specifically in any of the formulas and therefore the ROI results are not affected when a change in the value of noise is made.

However, the reduction in noise created by queuing traffic is taken in to account by reducing the community impact score from '3' to '2'.

- The community impact and safety scores only change if the total UCA labour costs are altered, however it is argued that the scale of difference between Scenario 1 and Scenario 2 still justifies the reduction in score for these qualitative criteria

5.3.11 Validation of Case Study 1 Using CEEQUAL

As stated in Section 5.2.4, it is important to validate the assessment tool by means external to the main approach. Therefore to contrast the output from the methodology with an existing method, Case Study 1 was assessed using the CEEQUAL process (background data are included in Appendix E). This assessment was carried out by a fully qualified CEEQUAL Assessor who works for Mott MacDonald. CEEQUAL was chosen because it is a widely recognised sustainability assessment tool used for civil engineering projects in the UK, and because it uses a criterion based approach that will contrast with the LCA style of assessment that has been adopted.

The validation process began with the Assessor deciding what form of CEEQUAL assessment should be chosen. The 'international' option was dismissed because the project was in the UK, and the standard 'project' type assessment was not used because it was assumed that the repair work would form part of a term maintenance contract (UCA owns the gas network and will therefore need to maintain it over a period of time). Therefore the Term Contracts (maintenance) option was used, which is based on Version 4 of the CEEQUAL methodology, the spreadsheet for which is included in Appendix E. The CEEQUAL for Term Contracts document (CEEQUAL, 2011) has been created for…

> *"The assessment of civil engineering and public realm works that are undertaken through contracts covering work in a geographical or operational area over a number of years. Examples include highway, rail or sewer maintenance, regular interventions in rivers or drainage channels to maintain channel capacity, and a series of minor new works such as road junction remodelling, track maintenance and minor realignments, all undertaken through what we are calling 'Term Contracts'…By 'term contracts', we mean those where a civil engineering or public realm works activity – such as road, sewer or water-main maintenance or a series of minor improvements – is undertaken in a geographical area over a term of often 3, 4, 5 or more years, and with multiple works orders for the individual jobs".*

The boundaries of assessment were defined in exactly the same way as Section 5.3.3. Next, it was assumed that the assessment tool was used at the planning stages of the project, before any construction work was carried out. Two options would have been considered by the designer (the use of manually controlled and automatic traffic signals), and the new assessment tool was used to compare these options in the same way as Case Study 1. Once this was complete, the CEEQUAL Assessor would have begun their assessment of the project. It was assumed that standard industry procedures were followed regarding information management, project management and quality assurance, and that all of the necessary assessments and site surveys were carried out, with specialist advice sought when required.

Once this background was established the Assessor scored each criterion, thereby establishing an overall CEEQUAL score for the project; various comments were also added by the Assessor to the spreadsheet. These observations (gathered during an interview process) and criterion scores, were then collectively considered to be ‘the results’ that were used to validate (i.e. directly compare in terms of outcomes) the new assessment tool when used alone. This comparison allowed the following conclusions to be drawn:

1. CEEQUAL is a criterion-based approach and this is different to the assessment tool, which considers different Scenarios and then quantifies the negative impacts that are created under each Scenario.
2. The ‘CEEQUAL for Term Contracts’ document is not primarily intended to be used for one off project assessments – it would normally be used as a guiding document when setting up a long term contract.
3. Before a CEEQUAL assessment can be carried out it is necessary to define who is involved in the assessment. The conclusions from Chapter 2 and 3 indicate that a wide number of stakeholders are affected by streetworks, but they would not necessarily form part of the team being assessed using CEEQUAL. Therefore the new assessment tool has advantages through its focus on the ‘one customer’.
4. It would be time consuming and therefore costly to carry out a CEEQUAL assessment for every streetworks project; indeed the aim of CEEQUAL (2012) is that the overall maintenance contract is assessed.
5. If one CEEQUAL assessment were carried out by a utility company for a large geographical area, it would need to include several different highway authorities, because their areas of interest are all different.
6. Other utility companies operating in one particular area would also need to be involved in this CEEQUAL assessment if it were to promote solutions such as joint working, but such ideas are not specifically outlined in the criteria.

7. CEEQUAL concentrates on social and environmental impacts, but the assessment tool attempts to consider the triple bottom line, which also includes economic impacts.
8. Because the team involved with CEEQUAL may not be affected by all of the impacts created by a streetworks project, the developed assessment tool has an advantage through its broader focus, its ability to consider the triple bottom line, and its focus specifically on short term maintenance work carried out by a number of different organisations within the street.

It was also found that the new assessment tool could be used as part of a CEEQUAL assessment to help achieve the following CEEQUAL criteria:

Project Management:

- Is there clear evidence that the client and the design team have adopted a whole-life approach to environmental aspects of the project?
- Did the whole-life approach include consideration of the potential effects of predicted climate change scenarios, leading to appropriate adaptation strategies?
- Is there evidence that the design team has addressed the environmental and social implications of different construction methods and materials (including their whole life cycle) for the project (for example, through workshops, briefing papers or an environmental statement)?
- Have specific targets been set during the design process for the environmental and social performance of the project during construction and is progress towards them monitored?

- Have specific targets been set during the design process for the environmental and social performance of the project during operation or once in use, and is there a monitoring programme in place for the operational phase?

Transport:

- Have local traffic movements been reviewed or considered by the project team prior to the construction stage commencing?
- Is there evidence that transport impacts during the construction stage have been considered at the design stage? And that steps have been taken to minimise these?
- Has a Construction Traffic Management Plan or a transport section in the Site Environmental Management Plan or Integrated Project Management Plan been drawn up to outline measures for minimising disruption caused by construction traffic; and has this plan been implemented during construction?
- Have the measures outlined been monitored during construction and successful in reducing disruption caused by construction traffic?
- Has the project team assessed possible use of other, more sustainable transport routes (other than road), such as rail, water etc, for the movement of construction materials and/or waste?

Effects on neighbours

- Were the policy and its implementation independently assessed and judged to be at least satisfactory?
- Has a SEMP or equivalent section in a Project Environmental Management Plan considered the effects of the construction process on neighbours and has this been implemented and monitored?

Relations with the local community and other stakeholders

- Has a community consultation exercise been carried out at each stage of the project and the results been passed to appropriate members of the project team and, as and where appropriate, the results fed back to consultees?
- Is there evidence that due consideration has been given, during the project's feasibility stage and during design, to wider social impacts of the project during construction and operation, and to the effects of the completed project on the human environment?
- Is there evidence that the needs of all different user groups have been considered and respected in the design solution (for example, car drivers, cyclists, pedestrians, disabled people etc) and the specification achieved in the completed project?
- Is there evidence that the project has been designed to be sympathetic to its human users and in scale with its surrounding environment?

It is likely that both CEEQUAL and the new assessment tool would 'point towards' the same conclusion (i.e. manually controlled traffic signals would be chosen in either case), but arguably it is more likely that this decision will be made if the new assessment tool is used. This is because the new technique has been developed, via the conclusions of the literature review, to address two specific needs: a need to focus on small scale streetworks projects, and a need to focus on the 'one customer'. Although the result from each approach would be the same (if they were actually used), the new assessment tool makes the 'most sustainable outcome' more likely to happen because it is focussed specifically on streetworks projects and is less time consuming to use.

In conclusion, the assessment tool was validated by using the CEEQUAL process to assess Case Study 1 so that the result from the two methods can be compared. It was found that the assessment tool can play a useful part within a CEEQUAL assessment, and can be used to score criteria within the categories called project management, transport, effects on neighbours, and relations with the local community. As such, the validation process has demonstrated how the assessment tool can be incorporated within an existing sustainability based assessment process.

5.4 Case Study 2

This scheme was initiated by an electricity distribution network operator referred to as Utility Company ‘B’ (UCB) but the work was carried out by their contractor (Contractor ‘A’, CA). The highway authority is herein referred to Highway Authority ‘B’ (HAB).

5.4.1 Background to the Scheme

The scheme involved the installation of a 33 kV underground cable which needed to cross the entry and exit lanes of a roundabout along a major ‘A’ road. UCB designed and specified the route and construction method for the cable, engaged with the council at the early stages of planning, and submitted all NRSWA streetworks notices. CA followed the specified plans, and any changes to the route could only be made if engineering difficulties were encountered during construction; these changes would need to be authorised by UCB and HAB.

UCB originally requested that the cable should be installed using an open trench working method, but HAB declined permission and instructed that the works be carried out using a ‘no dig’ technique. Several reasons for this decision were given by a highway engineer at HAB, who stated that gas and water companies had both recently carried out work at this roundabout using a trenchless technique without any problems occurring. In addition it is a busy roundabout, and the council were keen to avoid traffic delays wherever possible. Finally, an open trench working method would have an impact on the structural condition of the existing road surface due to reinstatement. There is no embargo against open trench methods at this roundabout; instead individual cases are considered on their own merit. In this particular case, the council felt on balance that open trench was not appropriate.

Utility plans showing the location of existing services were made available, but CA did not obtain geotechnical data or borehole records, or carry out a ground radar survey, noting that this is a relatively new technology currently being trialled within their organisation. Some trial holes were dug but not to any significant depths, and services were located using existing plans, but unfortunately this meant that their exact depth was not known. When horizontal directional drilling (HDD) started between the intended locations (referred to as A and B) no traffic management was required because both of the launch pits were outside of the highway boundary, but a water main was struck because it was buried much deeper than was anticipated. Staff from the local water company (UCC) were contacted regarding this damage to the water pipe, and highlighted the following issues.

The directional drilling head severed the top section of a 350mm asbestos cement water main, which feeds 2,000 customers. Fortunately supplies were rezoned around the damaged pipe, and this meant that only a handful of customers were directly affected. Asbestos cement pipes are very fragile and if the whole pipe had been damaged rather than just the top part, a 5m section would have had to be replaced, resulting in the full closure of the road. If this resulted in water supplies being affected for over 12 hours, a compensation payment of £30 per customer would also become payable. The subcontractor employed by UCC can only carry out work on pipes up to 8 inches (200mm) in diameter, and therefore the 'Trunk Mains Team' from UCC carried out the work. The repairs involved installing a clamp around the mains pipe to seal the hole, and the repair work was carried out on the same day.

The original route for the directional drilling was abandoned and a new route was initiated ('D' and 'C'). Location 'C' was within the highway boundary and required traffic management to protect the area. When drilling started, unexpected ground conditions meant that the drilling head kept getting stuck, and was unable to drill through the rock that was encountered. The subcontractor working for CA (herein called CB) had originally quoted for drilling in soft cohesive ground, so their charges started to increase. Staff from CA, CB and UCB attended meetings with HAB, as it became obvious that the costs and duration of the scheme would increase significantly. HAB stated that full rock drilling would be required, and this meant that a different drilling head had to be imported from Holland.

All of these problems collectively meant that the original 3 days of work without traffic management eventually affected traffic along the main 'A' road for a total of 46 days.

5.4.2 Scope and Aim of Assessment

There is a broad research agenda centred around the need to accurately locate buried utilities (Boukhelifa and Duke, 2007; Beck et al., 2009; Metje et al., 2011; Royal et al., 2011), as this lack of accuracy can lead to damage being caused to underground utilities during construction (HSE, 2001). The aim of this Case Study is to estimate many of the wider impacts that can be created when such damage occurs, such as road user delays, carbon emissions and noise. In this case, the highway authority imposed the need to use a trenchless technique to install a new 33 kV underground cable because this will potentially reduce the duration of the works. However the site was very congested, and during construction damage occurred to buried assets and this led to delays to the project overall, thereby creating environmental, social and economic impacts. The Case Study models a Scenario where no damage occurs, and compares the results with the impacts created in a ‘with damage’ Scenario. The findings can be beneficial to engineers and other technical staff when they are planning streetworks projects that require excavation along busy roads, and / or where there is a crowded underground networks of buried pipes, because the results demonstrate the value of carrying out additional mitigation to locate buried pipes and cables before work commences.

5.4.3 Boundaries of Assessment

This Case Study defines ‘the project’ as all works carried out by CA to install a new 33 kV underground cable across the entry and exit lanes of the southern arm of the roundabout. This is a comparative sustainability assessment of three different Scenarios, each based around a different outcome. The upstream and downstream timeline boundaries for ‘the project’ are defined as the commencement and completion of the work within the highway boundary of the southern arm of the roundabout. The physical boundaries of assessment are defined as the extent of the highway boundary on the southern arm of the roundabout. It is assumed that all environmental and social impacts not included within the assessment remain the same for both Scenarios. It is also assumed that there are no additional effects caused after traffic has exited the works site.

5.4.4 Scenarios

Scenario 1 represents what actually happened, whereas Scenario 2 represents what would have happened if open trenching was used and no problems occurred. Making this simple comparison with the benefit of hindsight it is obvious that an open trench working method would have been the best option, but no one can predict the future at the planning stages of a project. When the matter was discussed with the council, rational and logical reasons were given as to why a trenchless technique might be the best approach to take. Therefore to contrast these two outputs, a third Scenario has been developed – ‘HDD with no damage’.

5.4.5 Selection of Primary and Contributory Impacts

The primary and contributory impacts included within this Case Study are shown in Appendix F.

5.4.6 Evidence Gathered for Case Study 2

CA has supplied the following evidence:

- Cost estimates for the scheme including standard rates for labour, standard volume rates for drilling through rock, and rates for extra width or depth of trench if unexpected buried obstacles are encountered
- Schedule of work for cable route
- Streetworks notice for excavation work

UCB supplied scheme drawings. Staff from HAB and UCC also supplied information over the phone. Further information can be found in Appendix F.

5.4.7 Assessment of Impacts

This Section will discuss all of the relevant impacts for this Case Study, explain and justify how each impact has been assessed, and state which impacts might not be relevant.

5.4.7.1 Direct Costs of Design and Construction

Construction Costs

The following costs have been obtained from the data supplied and are classified under the 'labour and plant' contributory impact:

- Quote to carry out directional drilling across the roundabout arm (Scenario 1 and 3) = £14,993.
- Quote to carry out open trench working methods across the roundabout arm (Scenario 2) = £15,932.

These costs were created just a few months before the Case Study was carried out and have therefore not been adjusted for inflation.

Cost of additional traffic management

This is classified under the 'labour and plant' contributory impact. The original proposed route for the directional drilling would not have required any traffic management because the launch pits were outside of the highway boundary so it will score zero. This original route was abandoned after the water main was struck, and two new launch pits were dug, one of which encroached on the highway boundary and therefore required traffic management. However, unexpected problems meant that traffic was affected for a total of 46 days.

An invoice for traffic management costs this work at £30,723. Therefore this cost will be included in Scenario 1 (not adjusted for inflation because it was obtained in 2011 values already).

A time schedule for the works has been created based on evidence provided by CA and an anonymous extract can be seen in Appendix F. CA has confirmed that Scenario 2 (open trench with no problems between A and B) would have been carried out over 3 Sundays, and traffic management would have been required for these three days. CA data state the total cost of this open trench working method is £15,932 and confirmed that this price includes the TM (not adjusted for inflation). In any case, data that specifically state the cost of TM for 3 days is not available so it is estimated using a daily rate calculated from the traffic management invoice that was supplied, thus:

Average cost of TM for 3 days = £30,723 / 46 days * 3 days = £2,003.67.

Therefore Scenario 2 will use a value of £2,000 to measure this impact, which will then reduce the construction costs calculated above for Scenario 2 to £13,932.

<u>Cost of repairing damaged water main</u>

This contributory impact is defined under 'repair costs due to damage caused to underground utilities'. The water main cost £3,165 to repair and this will be the value used in the assessment for Scenario 1 (not adjusted for inflation). It is interesting to note that the methodology costs any type of utility damage at £2,900 in the absence of site specific cost data; a value that is reassuringly close. However as discussed previously, the repair costs could have been much higher than this.

5.4.7.2 Road User Time Delays

This road user time delay (monetised as a cost) is calculated using a similar method to that outlined in Section 5.3.7.2.

The data supplied by CA state that the Reinstatement Category for the road in question is '1', and the area is generally 'urban'. Table 4.2 lists typical delays for different lengths of streetworks project, but this length refers to the distance along the road. In this case, the works were perpendicular to the road, so 'the length' is relatively short (consisting of the width of the trench plus safety working zones either side. Therefore, the shortest length of works was selected (10m). Thus:

- for an 'urban', RC1 road with a 10m excavation and typical flow of 24,000 vehicles, the average daily cost of delay is = £9,000
- average delay (seconds) = £9,000 / £11.28 * 60 * 60 / 24,000 vehicles = 120 seconds per vehicle

Therefore an average delay of 120s will be used. Using the time schedule that was created from CA evidence, it was concluded that traffic was affected by traffic management operations on 46 days, and open trench working would have been carried out over 3 Sundays. Therefore 3 days of road user delays occur in Scenario 2. The duration of Scenario 3 is also 3 days, but it has been assumed that traffic was not affected at any time, because no traffic management was required if a trenchless technique was used between A and B and no problems occurred. These durations will be used to calculate total road user delays.

5.4.7.3 Fuel Consumption, Carbon and Other Air Emissions

An average delay of 120s per vehicle was used to calculate this impact by using a similar approach to that outlined in Section 5.3.7.3.

5.4.7.4 Noise

The methodology stipulates a value of 78dB multiplied by the duration of the works. Therefore Scenario 1 will score 78 * 46 = 3,588 'dB days' and Scenarios 2 and 3 will each score 78 * 3 = 234 'dB days'.

5.4.7.5 Highway Reinstatement

This primary impact is relevant for this Case Study because open trench methods are being compared with a trenchless technique. The standard details included in the site data confirm that a typical width of open trench excavation is 450mm, and the CA schedule states that the length across the road is 35m. Therefore the area in question measures 0.45m * 35m in length = 15.8 m^2. Using a rate of £183 per m^2 as defined in Section 4.6, the cost associated with the impact of reinstatement for Scenario 2 will be £2,882. Scenarios 1 and 3 do not involve excavation, and therefore score zero for his impact.

5.4.7.6 The Health and Safety Impact

The H&S impact spreadsheet is shown in Table 5.8. Potentially a utility strike could have caused a severe or life threatening injury and this is why the 'severity' scores a '3'. Because in actual fact a utility strike did happen, it is difficult to score the 'likelihood' as anything other than '3', although if this scheme was being planned in the future the same 'likelihood' or 'severity' score may not be used. The likelihood of a strike slowly reduces in the three Scenarios, with Scenario 1 being scored in the same way as the worst case. Therefore the final scores for all three Scenarios are 3, 3 and 2 respectively.

Table 5-8: H&S risk assessment for Case Study 2.

Worst case	Consequence / Impact	Persons at risk	Initial risk level			Scenarios being tested	Residual risk level		
			Severity	Likelihood	Risk Level		Severity	Likelihood	Risk Level
Utility strike, causing damage to a buried pipe or cable	Injury to construction workers or members of the public	Vehicle drivers, construction workers or pedestrians	3	3	H	Scenario 1: Use of a trenchless technique without any geotechnical or utility survey carried out before work commences. Luckily no harm actually occurred but there was certainly the potential for it to happen when the utility was struck. Therefore it is defined as the worst case.	3	3	H
Utility strike, causing damage to a buried pipe or cable	Injury to construction workers or members of the public	Vehicle drivers, construction workers or pedestrians	3	3	H	Scenario 2: Use of an open trench working method, with careful hand digging around buried pipes and cables. The likelihood of a utility strike is reduced because it is easier to located and avoid cables than 'blind' underground drilling	3	2	H
Utility strike, causing damage to a buried pipe or cable	Injury to construction workers or members of the public	Vehicle drivers, construction workers or pedestrians	3	3	H	Scenario 3: Use of a trenchless technique in construction, following a full geotechnical and utility survey. SUE process followed wherever possible. The likelihood of as utility strike is reduced still further.	3	1	M

5.4.7.7 Impact on the Community and Business

Due to the shear scale of the disruption that was actually caused, it is difficult to score the worst case community impact as anything other than '3'. Scenario 1 is defined as being the same as the worst case Scenario, and the likelihood of this community impact is reduced in Scenario 2, and greater still in Scenario 3. Therefore the final scores for all three Scenarios are 3, 3 and 2 respectively, as shown in Table 5.9:

Table 5-9: Community impact assessment for Case Study 2.

Worst case community impact	Consequence / Impact	Persons affected	Initial level of impact			Scenarios being tested	Residual impact level		
			Severity	Likelihood	Risk Level		Severity	Likelihood	Risk Level
A utility strike creates excessive and unplanned delays, driver stress and road rage. Local residents suffer ongoing noise and disruption.	Members of the public feel powerless and frustrated. The 'brand image' of the local authority and utility company are negatively affected. Complaints are made to UCA as well as HAA. The water company also suffers, even though they were not responsible.	Drivers, local residents	3	3	H	Scenario 1: Use of a trenchless technique without any geotechnical or utility survey carried out before work commences. Same as worst case.	3	3	H
A utility strike creates excessive and unplanned delays, driver stress and road rage. Local residents suffer ongoing noise and disruption.	Members of the public feel powerless and frustrated. The 'brand image' of the local authority and utility company are negatively affected. Complaints are made to UCA as well as HAA. The water company also suffers, even though they were not responsible.	Drivers, local residents	3	3	H	Scenario 2: Use of an open trench working method, with careful hand digging around buried pipes and cables. The likelihood of the same level of community impact is reduced to the fact that the cables can be carefully revealed.	3	2	H
A utility strike creates excessive and unplanned delays, driver stress and road rage. Local residents suffer ongoing noise and disruption.	Members of the public feel powerless and frustrated. The 'brand image' of the local authority and utility company are negatively affected. Complaints are made to UCA as well as HAA. The water company also suffers, even though they were not responsible.	Drivers, local residents	3	3	H	Scenario 3: Use of a trenchless technique in construction, following a full geotechnical and utility survey. SUE process followed wherever possible. Likelihood of a utility strike reduced further.	3	1	M

5.4.8 Summary of Results

The results from this Case Study for all three Scenarios are summarised in Table 5.10. In terms of impacts measured in a monetary unit this table is similar to Case Study 1, because road user delays, wasted fuel and carbon emissions appear again. Construction costs, traffic management, repairing the water main and the impact of reinstatement are also measured in a monetary unit because they are relevant to the aim and objective of the Case Study. In terms of non monetary impacts, the community impact, H&S and noise appear in the table of results.

Table 5-10: Results of Assessment for Case Study 2, comparing Scenario 1 ('actual impacts created') with Scenario 2 ('open trench used with no problems') and Scenario 3 ('horizontal directional drilling used with no problems').

	Scenario 1: Actual impacts created	Scenario 2: Open trench with no problems	Scenario 3: HDD with no problems
Traffic flow (taken from DfT 2004b based on reinstatement category)	24,000	24,000	24,000
No. days (estimated from NRSWA records)	46	3	0
Cost of time per hour used (2011 value)	£15.05	£15.05	£15.05
Cost of time per second	£0.004	£0.004	£0.004
Delay per vehicle taken (seconds, estimated from DfT 2004b)	120	120	120
Total delay cost (£, estimated from DfT 2004b)	£553,840	£36,120	£0
Total fuel consumption (£, estimated using Table 4.4 taken from DfT 2011, updated to 2011 costs from 2002 values stated)	£947,291	£61,780	£0
Total fuel consumption (Litres, estimated using Table 4.3 taken from DfT 2011)	41,029	2,676	0
Total carbon emissions (tonnes of carbon, estimated using the unit carbon emissions from burning fuel, contained within WebTAG unit 3.3.5)	26.84	1.75	0.00
Total carbon emissions (£, estimated using the unit cost of carbon contained within WebTAG unit 3.3.5)	£4,265	£278	£0
Construction costs (taken from CA quotes)	£14,993	£13,932	£14,993
Additional TM (taken from quotes)	£30,723	£2,000	£0
Cost of repairing water main (taken from evidence supplied by CA)	£3,165	£0.00	£0.00

	Scenario 1: Actual impacts created	Scenario 2: Open trench with no problems	Scenario 3: HDD with no problems
Impact of reinstatement (using methodology)	£0	£2,882	£0
Noise (dB days, using methodology)	3,588	234	234
Community Impact (using the scoring spreadsheet)	3	3	2
H&S (using the H&S scoring spreadsheet)	3	3	2

Three radar charts have been produced for this Case Study (Figures 5.4, 5.5 and 5.6). Figure 5.4 shows all three Scenarios on one graph and seeks to demonstrate the shear scale of difference in impacts between Scenarios. Figures 5.5 and 5.6 drill down from these high level data by comparing Scenarios in pairs.

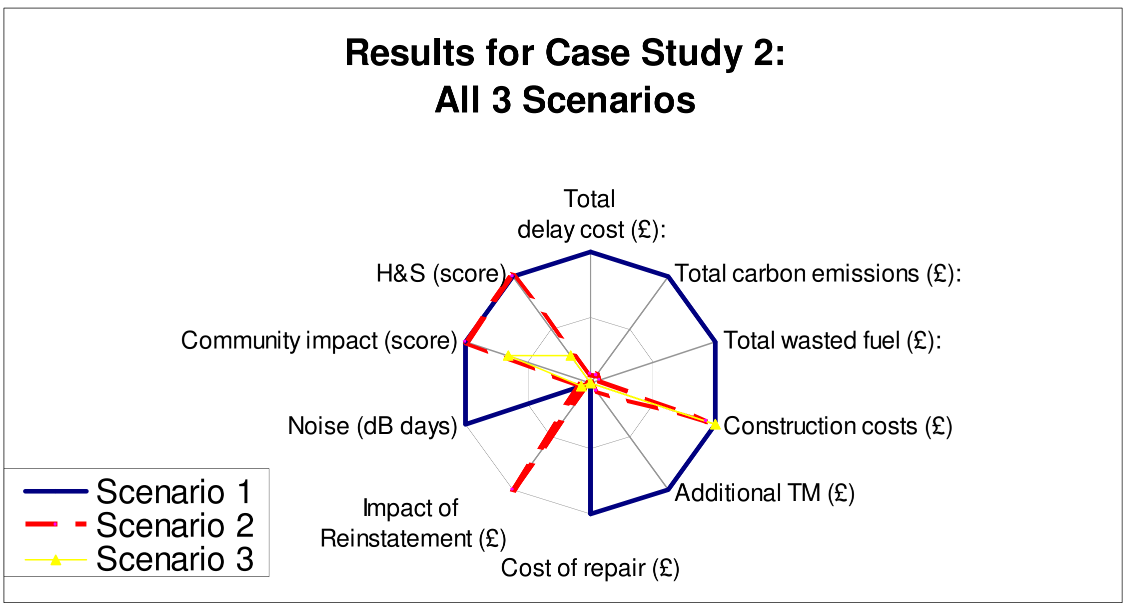

Figure 5-4: Output A for Case Study 2, comparing Scenario 1 ('actual impacts created') with Scenario 2 ('open trench used with no problems') and Scenario 3 ('horizontal directional drilling used with no problems')

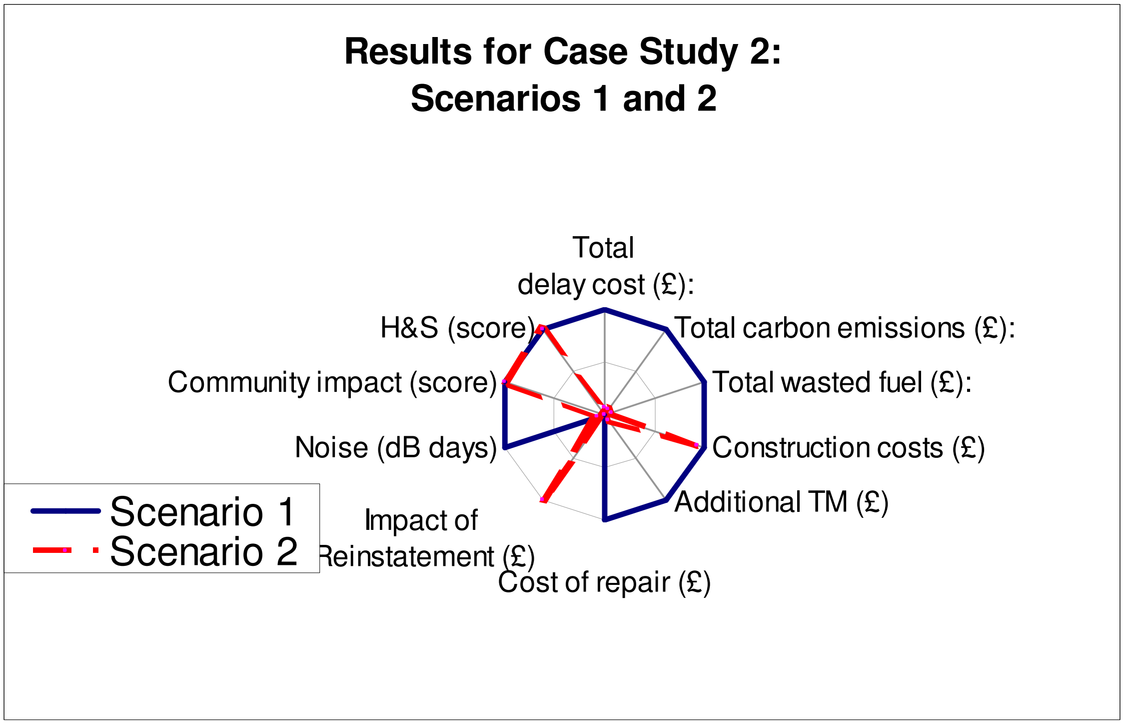

Figure 5-5: Output B for Case Study 2, comparing Scenario 1 ('actual impacts created') with Scenario 2 ('open trench used with no problems')

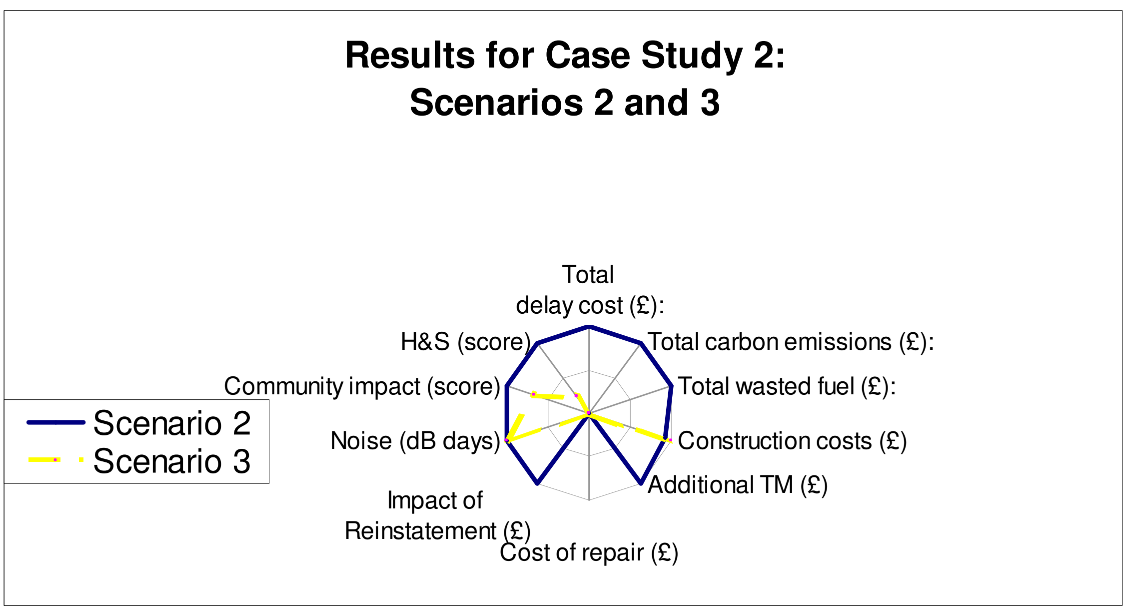

Figure 5-6: Output C for Case Study 2, comparing Scenario 2 ('open trench used with no problems') and Scenario 3 ('horizontal directional drilling used with no problems')

Figure 5.5 conceptualises the impacts that were actually created (Scenario 1) and compares them with the open trenching working method that was originally suggested by UCB (Scenario 2). The council has stated that the main issues being considered when they declined an open trench technique were traffic delays and the impact of reinstatement, and this thought process is reflected fairly well in Figure 5.6. In any case, it is somewhat unfair to combine these two graphs, because they conceptualise two very different situations. Figure 5.5 is an analysis carried out with hindsight, whereas Figure 5.6 conceptualises a decision made during the planning of the project.

5.4.9 Discussion

The aim of this Case Study was to estimate the wider impacts that can be created when problems occur at streetworks, and as a result no ROI has been calculated. The Case Study can be used to assess a scheme being carried out at this location in the future, and would justify a much more careful examination of ground conditions and utility locations before work starts. A radar survey was not carried out to detect underground utilities, and geotechnical information and borehole records were not obtained, but these might have indicated the depth of the water pipe and the presence of hard rock.

In their review of this Case Study, CA noted that they had to take on risks during construction, because UCB designed the route and construction method for the cable. They also highlighted that a ground radar survey may not have detected the water pipe because it was made of asbestos cement. In addition, the use of HDD meant that the 33 kV cable is now buried below the standard depth required by UCB, which results in future maintenance work being made more difficult and time consuming. It would be possible to model this type of future maintenance work as two Scenarios in a new assessment, as long as the assumptions are clearly stated. Ideally, the results would have been introduced at the planning stages of the project, and presented to the council as part of a broad ranging sustainability assessment of the scheme.

5.5 Case Study 3

This scheme was initiated by a water company (UCD), and the highway authority is herein referred to as HAC.

5.5.1 Background to the Scheme

This scheme has been assessed because it demonstrates some of the problems that can occur with historic records. UCD carried out emergency repairs to a burst water main which was located at the bottom of an embankment (Figures 5.7 and 5.8):

Figure 5-7: Photo A for Case Study 3, showing the location of the embankment where the burst water pipe was located

Figure 5-8: Photo B for Case Study 3, showing the embankment from the opposite angle

UCD records did not clearly indicate the location of the pipe, and when their own contractors started to dig in to the side of the embankment around the flow of water (Figures 5.7 and 5.8) they were unable to locate the damaged pipe. UCD contractors continued to dig into the side of the embankment, and eventually the structural integrity of the road at the top began to be affected and the excavations were halted. The work was carried out near to Christmas, so UCD installed an overland main to bypass the burst water main under the embankment. UCD claims that its contractors worked closely with HAC to reinstate the embankment before Christmas, which meant that the main road above the embankment could have its traffic management removed and be opened prior to Christmas. HAC state that officers had to visit the site over the Christmas holidays because the embankment remained structurally suspect. UCD state that the burying of the overland main was not completed until the New Year due to negotiations with the land owner, but no resident supplies were directly affected by the burst pipe. HAC designed a retaining wall on behalf of UCD in order to restore the structural integrity of the road at the top of the embankment (Figure 5.9).

Figure 5-9: Photo C for Case Study 3, showing the retaining wall designed by the council

UCD published an announcement in all local media explaining what was happening and how long it would take, and also worked closely with the local Parish Council. UCD state that this removed a great deal of the negative calls and queries received by UCD and HAC. Because of UCD's cooperation with HAC, no Section 74 charges were applied.

When a site visit was carried out on 17th November 2011, the mains water pipe was still left unburied on the opposite side of the embankment (Figure 5.10). This was a surprise to both the council officers as well as the representative of UCD:

Figure 5-10: Photo D for Case Study 3, showing the unburied replacement water pipe

If the location of the pipe had been known then this event could have been avoided, but the deployment of sophisticated utility location surveying techniques for such an emergency repair would not have been standard practice. Accurate and up-to-date records would similarly have avoided the problem occurring, but such records have yet to be created that are fully comprehensive for each water companies' assets. Therefore, this Case Study will accept that the event itself was unavoidable given the specific circumstances: the water pipe was more than 60 years old, and the records available to UCD did not show the position of the buried pipe accurately enough for it to be located.

5.5.2 Scope and Aim of Assessment

There is a broad research agenda centred around the need to accurately locate buried utilities (Boukhelifa and Duke, 2007; Beck et al., 2009; Metje et al., 2011; Royal et al., 2011), as this lack of accuracy can lead to damage being caused to underground utilities during construction

(HSE, 2001). The aim of this Case Study is to demonstrate how intangible ‘social’ impacts can be captured and featured as part of a sustainability assessment for streetworks projects. In this case, the water company could not easily detect their buried pipe when they carried out emergency work on a water leak. The Case Study assumes this damage was unavoidable, however, additional mitigation could have been carried out when the new pipe was installed in order to make it easier to detect in the future (using tags), thereby avoiding unnecessary environmental, social and economic impacts at some point in the future. The findings can be beneficial to consumer groups, engineers and company directors responsible for allocating construction budgets, because the results show how an assessment of value can include intangible ‘social impacts’ that cannot easily be captured using a monetary unit.

5.5.3 Boundaries of Assessment

This Case Study defines ‘the project’ as all works carried out by UCD to repair the damaged water main in question. This is a comparative sustainability assessment of two different Scenarios, each based around a different level of mitigation. The upstream and downstream timeline boundaries for ‘the project’ are defined as the commencement and completion of the repair work within the highway boundary at the site. The physical boundaries of assessment are defined as the extent of the works carried out as part of the repair work, both within and outside the highway boundary. It is assumed that all environmental and social impacts not included within the assessment remain the same for both Scenarios.

5.5.4 Scenarios

It is argued that if this mitigation was promoted properly it could reduce the negative brand image associated with UCD, and could be presented to the industry regulator Ofwat as evidence that UCD tries to minimise its impact on the community. Therefore, two Scenarios will be developed:

- Scenario 1 (what actually happened): The water pipe burst, and damage was caused. A new water main was installed, but no special mitigation took place.
- Scenario 2 (additional mitigation carried out): The water pipe burst, and damage was caused. A new water main was installed, but tagging technologies were used and the location of the pipe was accurately recorded using a new tagging technology developed at the University of Oxford, and delivered through 'Oxford Electromagnetic Solutions' (Oxems). This enables buried utility pipes to be found and identified via the use of tags and Ground Penetrating Radar (Oxems, 2011), and has an associated subscription database that records information such as type of pipe, the utility company responsible and where the nearest stop valve is located. In this Scenario, the use of Oxems technology was widely publicised by UCD because it demonstrates a customer focus, and a willingness to prevent problems occurring in the future.

It was decided to focus on how a 'social impact' can be assessed, because this type of impact is difficult to quantify and it is therefore useful to test how such an impact could be considered. Given the aim of the research, this concept is more important than defining the benefits of 'Oxems' tagging per se. Indeed, it should not be concluded that this Case Study promotes the use of 'Oxems' technology at all, or that this is the best or only solution – the technology is simply a way to test how a social impact can be measured.

5.5.5 Selection of Primary and Contributory Impacts

The primary and contributory impacts included within this Case Study are shown in Appendix G.

5.5.6 Evidence Gathered for Case Study 3

HAC has supplied the following evidence:

- Traffic flow and traffic speed data for the main road above the embankment
- Section 74 charges that could have been applied for 47 days of over run (£117,500). In reality, no charges were applied
- Estimation of time spent in meetings and additional inspections on site (60 hours)
- RC of road (RC 2, verbally confirmed during site visit)

UCD has supplied the following:

- Cost estimate for advertising the repair work in local media (£3,000)
- Cost of embankment work (£40,000). Cost of installing new supply across the road, installing an overland mains bypass and subsequent burial of the bypass (£40,000). Because these figures are rough estimates they have not been adjusted for inflation.

Additional information can be found in Appendix G.

5.5.7 Assessment of Impacts

5.5.7.1 Direct Costs of Design and Construction

Cost of installing new water pipe

This 'labour and plant' cost is the same for each Scenario so it is removed from the output, because only the additional cost of mitigation should be compared between Scenarios. However, it is interesting to compare the additional cost of mitigation with the actual costs associated with the repair work, and therefore using the data supplied by UCD, a value of £40,000 is noted in this Section, but will not appear in the output.

Cost of embankment work

Using the data supplied by UCD which estimate the cost of construction, a value of £40,000 might be used for both Scenarios (this is a separate amount to the cost of installing a new water main). However, because this value is the same for both Scenarios it will be removed.

Unnecessary time associated with HAC staff (meetings and site visits)

This 'supervision during construction' contributory impact will use a rate of £40 per hour for the HAC engineers involved, which for a total of 60 hours equates to £40 * 60 hours = £2,400.

Cost of tagging and recording new pipe

This is defined as a 'labour and plant' contributory impact. The Oxems system consists of tags that are placed on buried pipes, a surface detector and a subscription database that stores location information. The cost of the tags can be considered at a project level, but it is difficult to allocate a cost of the database and detector device at a project level because they will be used on many other projects if they were to be purchased. Therefore a nominal cost of £500 will be used as the cost of tags at this site. This nominal cost is used because the purpose of the Case Study is to demonstrate the process through which the value of such a solution may be demonstrated, not actually prove the benefits of the Oxems technology itself.

<u>Cost of advertising repair works in local media</u>

This is defined under the 'cost of restoring brand / image' contributory impact, and using the data supplied by UCD is valued at £3,000.

5.5.7.2 Road User Time Delays

This road user time delay (monetised as a cost) is calculated using a similar method to that outlined in Section 5.3.7.2.

The actual duration of the work is not clear from the available evidence from UCD and a duration of 14 days will be used. Traffic count data are available from HAC for the main road above the embankment and the two way annual average daily traffic (AADT) calculated from these results is 12,171 vehicles. In DfT (2004b), the limiting flow for an RC2 road in a 'rural' setting is 12,000 vehicles. Because the average flow calculated is so close to the limiting flow stated in DfT (2004b), the average cost of delay for a RC2 'rural' road will be used.

Tables 4.1 and 4.2 contain road user delays for different lengths of excavation, but this length refers to the direction of travel along the road. Similar to Case Study 2, the opening required to install the new water pipe is perpendicular to the road, so the 'length' of the excavation in this sense will be short. Therefore, the minimum length (10m) has been used in the following calculation, thus:

- for a 'rural', RC2 road with a 10m excavation and typical flow of 12,000 vehicles, the average daily cost of delay is = £1,610
- average delay (seconds) = £1,610 / £11.28 * 60 * 60 / 12,000 vehicles = 43 seconds per vehicle

5.5.7.3 Fuel Consumption, Carbon and Other Air Emissions

An average delay of 43 seconds will be used to calculate this impact by using a similar approach to that outlined in Section 5.3.7.3.

5.5.7.4 Noise

Although it is possible to argue that future work can be completed more quickly (and therefore more quietly) in the future, this is very difficult to quantify and therefore noise will be removed from this Case Study.

5.5.7.5 The Health and Safety Impact

This assessment considers the impacts of striking a water pipe. This is likely to result in a lost time injury and therefore scores '2' (if it was a gas pipe for example it is likely to score higher because of the risk of explosion). Without any mitigation (Scenario 1) the situation is the same as the worst case, but Scenario 2 reduces the likelihood of such an event occurring, and therefore scores '1'. Hence, the final risk scores for both Scenarios are '2' and '1' respectively, as shown in Table 5.11.

Table 5-11: H&S risk assessment for Case Study 3.

Worst case	Consequence / Impact	Persons at risk	Initial risk level			Scenarios being tested	Residual risk level		
			Severity	Likelihood	Risk Level		Severity	Likelihood	Risk Level
Utility strike in the future, due to the fact that the position of the buried pipe is not known.	Injury to construction workers or members of the public	Vehicle drivers, construction workers or pedestrians	2	2	M	Repair of water main without any mitigation that allows it to be detected more easily in the future. This is the same as the worst case.	2	2	M
Utility strike in the future, due to the fact that the position of the buried pipe is not known.	Injury to construction workers or members of the public	Vehicle drivers, construction workers or pedestrians	2	2	M	Repair of water main with the use of 'Oxems' tagging technologies. The likelihood of a utility strike occuring is reduced.	2	1	L

5.5.7.6 Impact on the Community and Business

It is argued that if a buried pipe is more difficult to detect in the future, the work required (and costs involved) will create unnecessary community impacts. This is the worst case and therefore scores ‘3’. The likelihood is also ‘3’ because the assessment is based on what would happen if this event did actually occur. In Scenario 1, no mitigation is carried out and this situation is therefore the same as the worst case. In Scenario 2 mitigation is carried out, the likelihood therefore much reduced to score ‘1’. Hence, the final community impact scores for both Scenarios are ‘3’ and ‘2’ respectively, as shown in Table 5.12.

Table 5-12: Community impact assessment for Case Study 3.

Worst case community impact	Consequence / Impact	Persons affected	Initial level of impact			Scenarios being tested	Residual impact level		
			Severity	Likelihood	Risk Level		Severity	Likelihood	Risk Level
Utility strike in the future, due to the fact that the position of the buried pipe is not known.	Because this event occurs at some time in the future it is difficult to predict what community impacts will occur. However, any repair work required will create unnessary and avoidable impacts such as road user delays or a temporary loss of supply	Drivers, local residents	3	3	H	Scenario 1: Repair of water main without any mitigation that allows it to be detected more easily in the future. Same as worst case.	3	3	H
Utility strike in the future, due to the fact that the position of the buried pipe is not known.	Because this event occurs at some time in the future it is difficult to predict what community impacts will occur. However, any repair work required will create unnessary and avoidable impacts such as road user delays or a temporary loss of supply	Drivers, local residents	3	3	H	Scenario 2: Repair of water main with the use of 'Oxems' tagging technologies. The likelihood of the same level of community impact occuring in the future is reduced	3	1	M

5.5.8 Summary of Results

The results for a 14 day duration are shown in Table 5.13. Once again, road user delays, wasted fuel and carbon emissions appear as monetised impacts. The costs associated with advertising, tagging technologies and HAC staff also appear because they are relevant to the aim and objective of the Case Study. In terms of non monetary impacts, the community impact and H&S both appear in the table of results.

Table 5-13: Case Study 3 results for Scenario 1 ('water pipe burst with no additional mitigation') and Scenario 2 ('water pipe burst and additional mitigation was carried out').

	Scenario 1: Water pipe burst and damage was caused	Scenario 2: The water pipe burst, damage was caused and tagging technologies were used
Traffic flow (taken from DfT 2004b based on reinstatement catagory)	12,000	12,000
Delay per vehicle taken (seconds, estimated from DfT 2004b)	43	43
No. days (estimated from NRSWA records)	14	14
Cost of time per hour used (2011 value)	£15.05	£15.05
Cost of time per second	£0.004	£0.004
Delay per vehicle taken (seconds, estimated from DfT 2004b)	£1,600	£1,600
Total delay cost (£, estimated from DfT 2004b)	£30,200	£30,200
Total fuel consumption (£, estimated using Table 4.4 taken from DfT 2011, updated to 2011 costs from 2002 values stated)	£51,655	£51,655
Total fuel consumption (Litres, estimated using Table 4.3 taken from DfT 2011)	2,237	2,237
Total carbon emissions (tonnes of carbon, estimated using the unit carbon emissions from burning fuel, contained within WebTAG unit 3.3.5)	1.46	1.46
Total carbon emissions (£, estimated using the unit cost of carbon contained within WebTAG unit 3.3.5)	£233	£233
Cost of advertising repair work (£, estimate from UCD)	£3,000	£3,000
Cost of tagging (estimate)	£0	£500
HAC additional time spent on scheme (estimate provided by council)	£2,400	£2,400
H&S (using the H&S scoring spreadsheet)	2	1
Community Impact (using the scoring spreadsheet)	3	2

The output for this Case Study is shown in Figures 5.11 and 5.12.

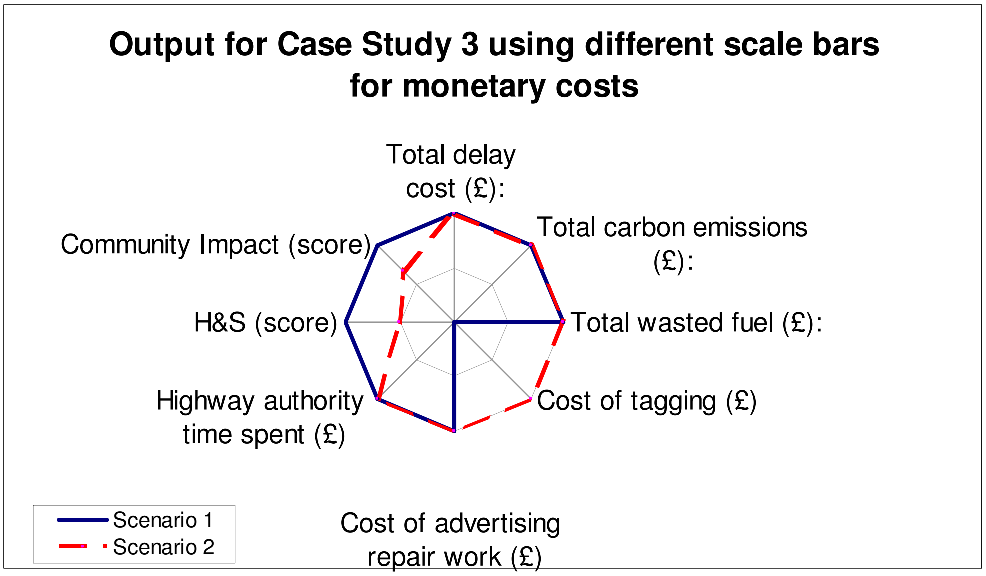

Figure 5-11: Output from the Methodology for Case Study 3, showing Scenario 1 ('water pipe burst with no additional mitigation') and Scenario 2 ('water pipe burst and additional mitigation was carried out') using different scale bars for monetary costs.

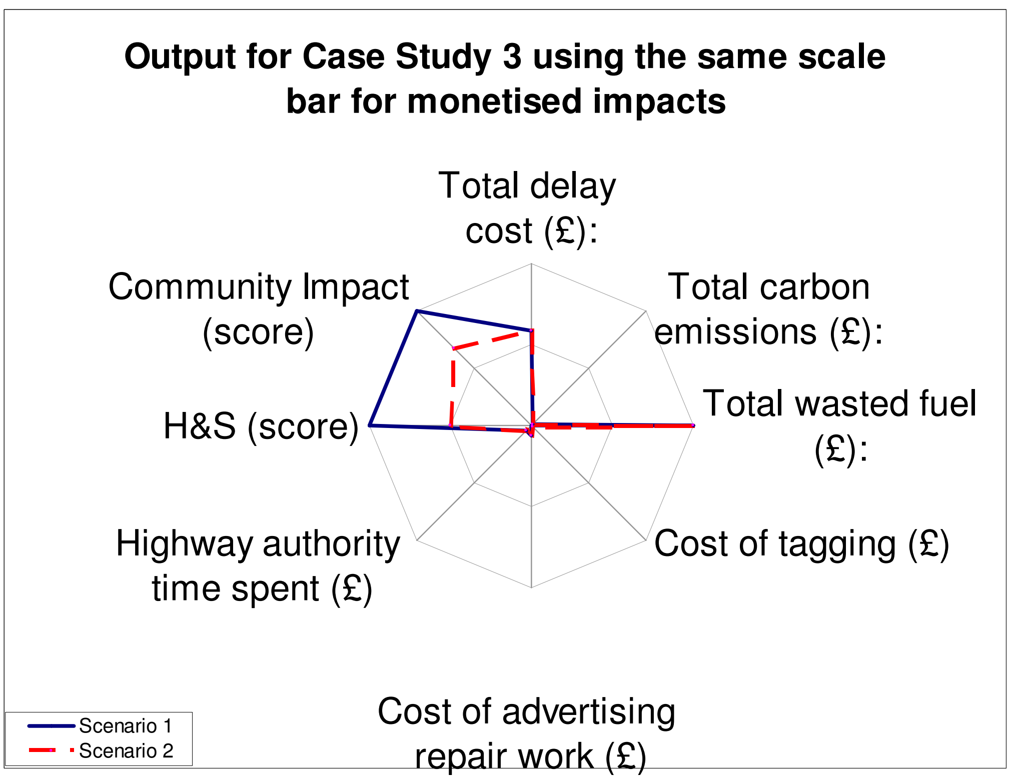

Figure 5-12: Output from the Methodology for Case Study 3, showing Scenario 1 ('water pipe burst with no additional mitigation') and Scenario 2 ('water pipe burst and additional mitigation was carried out') using the same scale bars for monetary costs.

When the same scale bars are used this makes it difficult to compare the cost of the tagging technologies, advertising costs, HAC time spent, and total carbon emissions, because these are dwarfed by the cost of wasted fuel and delay costs. In this case, the use of different scale bars is recommended because the aim of the assessment is to focus on how an intangible social impact is considered, and this is more usefully displayed in Figure 5.11.

5.5.9 Calculation of Return on Investment (ROI)

In this Case Study, a benefit (or 'return') is created when a 'social' impact is reduced, but because this social impact is difficult to measure as a monetary unit it is measured as a score. In Figure 5.11, Scenario 1 has a lower direct cost because tagging is not used but its future impact is greater; therefore this radar chart seeks to emphasise a community impact. A ROI with respect to reducing the score of one particular criterion is then possible, and this might be referred to as 'triple accounting', because the social and environmental impacts are being considered and accounted for in the same way as a monetary cost. This approach is very different to standard practice, but it is arguably essential if utility streetworks are to be carried out in a more sustainable way.

The ROI is simply calculated as £500 to reduce the community impact score from '3' to '2'. This may seem like a small return for the investment, but it is interesting to contrast this with an estimate of the impacts created from of one day of work along the main road above the embankment. If the assessment tool is run separately with a duration of one day, then £1,600 in time delay costs, £2,681 in fuel consumption and £16 in carbon emissions are generated by delayed traffic. Therefore if just one day of road user delays can be prevented in the future by spending £500 today, this is a ROI (with respect to monetised impacts and ignoring inflation) of (£1,600 + £2,681 + £16) / £500 = £8.59 for every £1 spent. However, these road user delays will not be the only 'return', and other benefits are likely to accrue in terms of safety, noise and community severance. This is an alternative measure for reducing the community impact score from '3' to '2', and is fundamentally what the methodology tries to achieve – it can test a number of different scenarios, separate the advantages and tradeoffs, and display the result in different ways.

Finally, it is interesting to compare the additional cost of mitigation (£500) with the actual costs associated with the repair work (£40,000). This equates to 1.25% of the project cost, arguably a justifiable increase on costs.

5.6 Case Study 4

This Case Study is different to the previous three because it is classified as 'roadworks', i.e. it was initiated by a highway authority and involves the improvement of the road itself as opposed to being a 'streetworks' (utility maintenance) project.

5.6.1 Background to the Scheme

The project owner was Highway Authority 'D' (HAD) and the purpose of the scheme was to improve a roundabout located on a major dual carriageway trunk road. Improvements involved the installation of traffic lights on each arm of the roundabout, as well as the addition of a traffic lane on the eastern and western approaches. This scheme was designed by an engineering consultant (ECA) and constructed by a contractor (CC).

By following SUE, designers are able to mitigate the risk of damaging underground pipes and cables during construction because they can obtain detailed information before work starts

(Zembillas, 2002). A quote for the SUE survey that would have been carried out as part of this process was obtained from a specialist contractor (CD). It consisted of a survey of the area using both electromagnetic and ground penetrating radar techniques, as well as a drainage survey to record invert levels and direction of flow. This detected utility information would then be overlaid on to an electronic topographical survey drawing.

5.6.2 Scope and Aim of Assessment

There is a broad research agenda centred around the need to accurately locate buried utilities (Boukhelifa and Duke, 2007; Beck et al., 2009; Metje et al., 2011; Royal et al., 2011), as this lack of accuracy can lead to damage being caused to underground utilities during construction (HSE, 2001). The aim of this Case Study is to assess the value of one particular type of mitigation (the SUE process as outlined in Chapter 2) by estimating many of the wider impacts that can be created when damage to underground utilities occurs, such as road user delays, carbon emissions and noise. In this case, the SUE process was not actually used and fortunately no damage occurred so it models two theoretical Scenarios, one 'with damage' and one 'without damage' occurring. The findings can be beneficial to engineers and other technical staff when they are planning streetworks projects that require excavation along busy roads, and / or where there is a crowded underground networks of buried pipes, because the results demonstrate the value of carrying out additional mitigation to locate buried pipes and cables before work commences.

5.6.3 Boundaries of Assessment

This Case Study defines 'the project' as all works carried out to repair a damaged gas main during highway improvement works carried out along the highway in question. This is a theoretical, comparative sustainability assessment of two different Scenarios, each based around a different outcome. The upstream and downstream timeline boundaries for ‘the project’ are defined as the point in time when the gas pipe was damaged, and the completion of the repair works that were required. The physical boundaries of assessment are defined as the physical extent of the repair works. It is assumed that all environmental and social impacts not included within the assessment remain the same for both Scenarios. It is also assumed that there are no additional effects caused after traffic has exited the works site.

5.6.4 Scenarios

The SUE process was not actually carried out for the scheme and in actual fact no damage occurred here, so a theoretical ‘with SUE’ Scenario will be compared with a theoretical ‘with damage’ Scenario. Therefore the following two Scenarios are developed:

- Scenario 1: the US design process SUE was applied to a UK setting and used on the scheme. A SUE survey was carried out to detect the location of underground pipes and cables. No damage to underground utilities occurred during construction
- Scenario 2: the SUE process was not used, and during construction a mains gas pipe was severed. This event delayed the entire highway scheme by one week and resulted in a fatality.

5.6.5 Selection of Primary and Contributory Impacts

The primary and contributory impacts included within this Case Study are shown in Appendix H.

5.6.6 Evidence Gathered for Case Study 4

The following evidence has been gathered for this Case Study:

- Quotation from CD for a SUE survey (£8,017.12 inc VAT)
- Evidence from an expert in the SUE discipline in the US (Jim Anspach) which outlines how SUE would apply to the scheme
- Environmental Constraints Analysis Report: Pedestrian Count and Non-Motorised Users Context Report.

UCE were asked how long it would typically take to repair the mains gas pipe located along the centre of the roundabout (which they own), and what type of damage and personal injuries are likely to occur. Unfortunately, no response was received so a theoretical Scenario was created where the repair work takes one week, and a fatality occurs to the site operative who struck the gas main.

Extracts of the data supplied can be found in Appendix H.

5.6.7 Assessment of Impacts

5.6.7.1 Direct Costs of Design and Construction

Cost of SUE Survey

The cost for this was obtained from CD, and a value of £8,017.12 including VAT will be used in Scenario 1 (2011 costs so not adjusted for inflation). It is classified as the contributory impact 'site survey to locate existing apparatus, infrastructure, trees etc and to determine the ground conditions'.

Cost of repairing damaged gas pipe in Scenario 2

The cost for this contributory impact ('repair costs due to damage caused to underground utilities') is not known because the Scenario is theoretical and therefore the methodology must be relied upon. Following the methodology, a nominal sum of £2,900 will be added as the cost of repairing damage in Scenario 2, with Scenario 1 scoring zero.

Compensation payments to local business

This contributory impact is defined as 'compensation payments'. There are some highway services located off of the roundabout, and access remained open during the highway scheme. However, it is likely that trade was reduced when compared to the road being fully open, and this means it is likely that HAD paid some kind of compensation to the business owner. However, these costs are difficult to obtain due to commercial sensitivities, and are linked to the highway work, not the effects of the damaged gas pipe. Therefore the methodology is used, which values this impact at £143 per day of compensation, which is £143 * 7 days = £1,005 (rounded to £1,000). Because it is assumed that the entire highway scheme is stalled for one week while the utilities are repaired, Scenario 1 will score zero but Scenario 2 will score £1,000.

5.6.7.2 Road User Time Delays

In Scenario 2, no evidence was presented by UCE and therefore it was assumed that the damage to the gas pipe will take one week to repair. However, this does not prove that the whole project would be delayed by one week, because the utility aspects are only one small part of a much larger highway scheme. This suggests it is not easy to separate out utility work from the highway work for roundabout, but even though this damage did not actually occur it is still the type of question that might be asked for projects being planned in the future - what are the potential impacts of damage, and what is the cost of mitigation? Therefore, Scenario 2 will be based around a nominal 7 day duration where no highway work is carried out, because this is a possible situation for work being planned in the future.

However, this will not account for the road user delays created by the SUE survey itself. If the dual carriageway needs to be closed while this is carried out it should rightfully be included in the assessment, and therefore the duration of Scenario 1 will be 1 day to take account of the SUE survey.

DfT (2004b) estimates delay costs for different lengths of excavation, and in light of the nature of this highways project the maximum length of opening included in DfT (2004b) has been used – 200m. The entire scheme is delayed by one week, so using a similar approach to that outlined in Section 5.3.7.2 using an assumed reinstatement category of 0, the average delay using the methodology is estimated thus:

- Using Table 4.1 for a rural, RC0 road with (an assumed) 200m excavation and annual average delay traffic (AADT) of 32,000 vehicles, the average daily costs of delays = £4,000
- Average delay per vehicle (seconds) = £4000 / £11.28 *60 * 60 / 32,000 vehicles = 40 seconds per vehicle average

Thus an average delay of 40s per vehicle will be used in the calculation of road user delays.

5.6.7.3 Fuel Consumption, Carbon and Other Air Emissions

An average delay of 40s per vehicle was used to calculate this impact by using a similar approach to that outlined in Section 5.3.7.3.

5.6.7.4 Noise

When a SUE survey is carried out, different Quality Levels of information can be obtained. Quality levels B, C and D can be obtained almost silently, because they only require a site detection technique such as a ground penetrating radar device. Quality level 'A' requires vacuum excavation, which is arguably just as noisy as standard utility work because both involve excavation. The SUE survey quote obtained from CD recommends that Quality Level 'B' data should be obtained, and therefore Scenario 1 will score zero.

It has been assumed that the entire highway project is delayed by one week and therefore no highway construction work will be carried out during the time when the gas pipe is being repaired. Therefore, it is assumed that no noise other than that created by utility work will occur during this period. Therefore following the methodology, Scenario 2 will score as 78dB * 7 = 546 dB days.

5.6.7.5 Highway Reinstatement

The entire road surface was resurfaced as part of the scheme, whereas the 'impact of reinstatement' refers to the impact that a utility trench will have if it is reinstated within an existing road surface. Therefore it is removed.

5.6.7.6 The Health and Safety Impact

The H&S spreadsheet is based around an event where a fatality does actually occur, therefore the 'severity' and 'likelihood' are both scored as '3'. With the use of SUE the likelihood is reduced (scoring a '1'), whereas without any special mitigation the situation is the same as the worst case. Hence the final H&S score for both Scenarios is '1' and '3' respectively, as shown in Table 5.14.

Table 5-14: H&S risk assessment for Case Study 4.

Worst case	Consequence / Impact	Persons at risk	Initial risk level			Scenarios being tested	Residual risk level		
			Severity	Likelihood	Risk Level		Severity	Likelihood	Risk Level
Utility strike causing death to a constructio n worker	Injury to construction workers	Construction workers	3	3	H	Scenario 1: The SUE process is followed, allowing the risk of a utility strike to be reduced. Therefore the likelihood of the situation is reduced accordingly.	3	1	L
Utility strike causing death to a constructio n worker	Injury to construction workers	Construction workers	3	3	H	Scenario 2: no special mitigation is carried out to reduce the risk of a utility strike. Same as worst case.	3	3	H

5.6.7.7 Impact on the Community and Business

The emotional consequences of a death cannot easily be appreciated, but the community impact spreadsheet includes family bereavement and loss of income as potential consequences. At a less serious level, utility customers will be disrupted by the repair work. The assessment is based around a situation where this event does actually occur, so the worst case severity and likelihood both score '3'. With mitigation (SUE) the likelihood of the event is much reduced and therefore scores a '1'. Hence the final H&S score for both Scenarios is '2' and '3' respectively, as shown in Table 5.15.

Table 5-15: Community impact assessment for Case Study 4.

Worst case community impact	Consequence / Impact	Persons affected	Initial level of impact			Scenarios being tested	Residual impact level		
			Severity	Likelihood	Risk Level		Severity	Likelihood	Risk Level
Utility strike causing death to a construction worker	Loss of life. Family bereavement and loss of income. At a less serious level, annoyance and disruption for utility customers.	Construction workers, family members and utility customers	3	2	H	Scenario 1: The SUE process is followed, allowing the risk of a utility strike to be reduced. The potential severity is the same, but the likelihood is reduced.	3	1	M
Utility strike causing death to a construction worker	Loss of life. Family bereavement and loss of income. At a less serious level, annoyance and disruption for utility customers.	Construction workers, family members and utility customers	3	3	H	Scenario 2: no special mitigation is carried out to reduce the risk of a utility strike. Same as worst case.	3	3	H

5.6.8 Summary of Results

The results from this Case Study can be seen in Table 5.16. As with the previous three Case Studies, road user delays, wasted fuel and carbon emissions appear as monetised impacts. This indicates that three 'Core Impacts' can be usefully defined for future use: road user delays, wasted fuel whilst queuing and carbon emissions associated with this wasted fuel. Although H&S and community impact also appear in each Case Study it is arguably important to note the three 'Core Impacts' for each assessment, because they provide a quick and simple indication of whether a solution provides value for money, and are presented in a unit that is widely accepted (that is the monetary unit). However, it must be clearly understood that this type of quick assessment will not include the wider, intangible impacts of a scheme and is therefore limited.

Other monetised impacts for this Case Study are the costs associated with a SUE survey, compensation to local business and damage repair costs, because they are relevant to the aim and objective of the Case Study. In terms of non monetary impacts, the community impact, H&S and noise all appear in the table of results.

Table 5-16: Results of Assessment for Case Study 4 showing Scenario 1 ('SUE was used and no damage occurred during construction') and Scenario 2 ('SUE was not used and damage did occur during construction').

	Scenario 1: With SUE / no damage	Scenario 2: No SUE / with damage
Traffic flow (taken from DfT 2004b based on reinstatement catagory)	32,000	32,000
No. days (estimated from NRSWA records)	1	7
Cost of time per hour used (2011 value)	£15.05	£15.05
Cost of time per second	£0.004	£0.004
Delay per vehicle taken (seconds, estimated from DfT 2004b)	40	40
Total delay cost (£, estimated from DfT 2004b)	£5,351	£37,458
Total fuel consumption (£, estimated using Table 4.4 taken from DfT 2011, updated to 2011 costs from 2002 values stated)	£9,153	£64,068
Total fuel consumption (Litres, estimated using Table 4.3 taken from DfT 2011)	396	2,775
Total carbon emissions (tonnes of carbon, estimated using the unit carbon emissions from burning fuel, contained within WebTAG unit 3.3.5)	0.26	1.82
Total carbon emissions (tonnes of of carbon, estimated using the unit carbon emissions from burning fuel, contained within WebTAG unit 3.3.5)	£41	£288
SUE Survey (from estimate)	£8,017	£0
Compensation to Business (nominal score using methodology)	£0	£1,000
Cost of repairing damage (estimated following methodology)	£0	£2,900
Noise ('dB days', using methodology)	0	546
H&S (using the H&S scoring spreadsheet)	1	3
Community Impact (using the scoring spreadsheet)	2	3

The radar chart is shown in Figures 5.13 and 5.14.

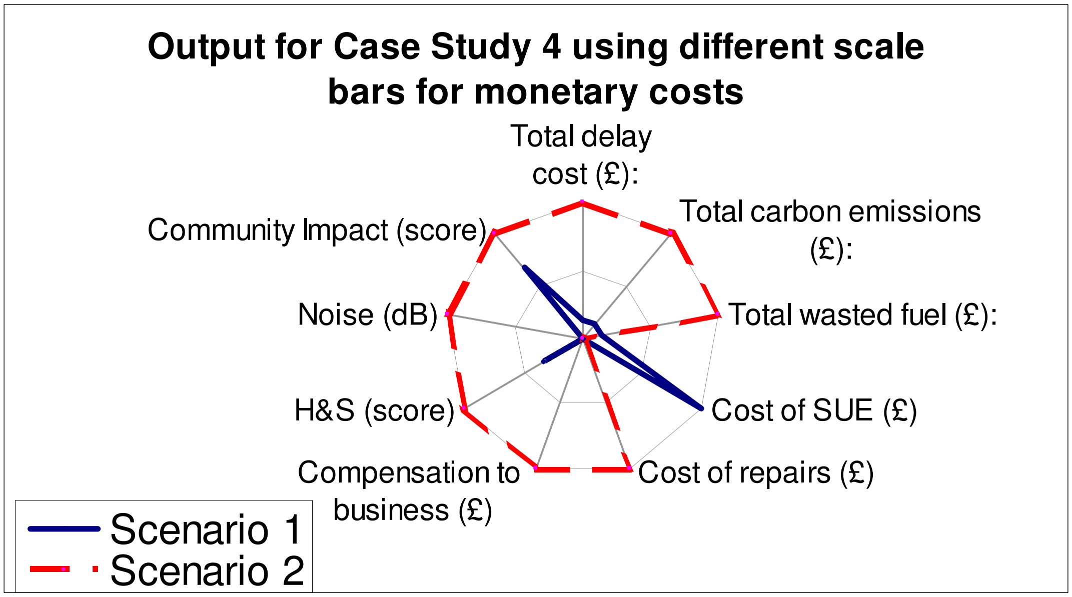

Figure 5-13: Output from the Methodology for Case Study 4 showing Scenario 1 ('SUE was used and no damage occurred during construction') and Scenario 2 ('SUE was not used and damage did occur during construction') using different scale bars for monetary costs.

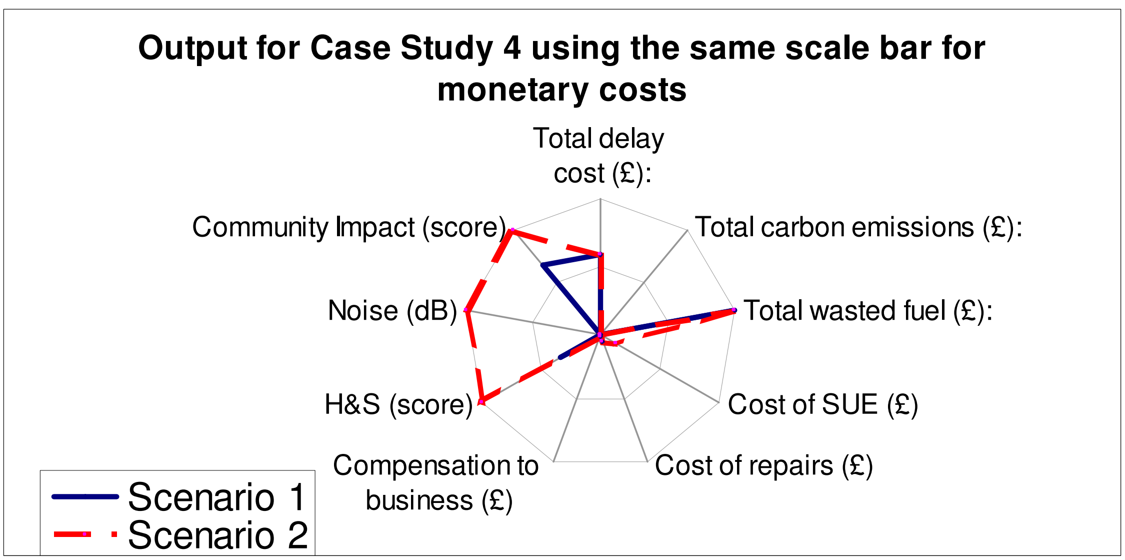

Figure 5-14: Output from the Methodology for Case Study 4 showing Scenario 1 ('SUE was used and no damage occurred during construction') and Scenario 2 ('SUE was not used and damage did occur during construction') using the same scale bar for monetary costs.

If the same scale bars are used it is difficult to appreciate the cost of compensation, repairs, SUE and carbon emissions because they are dwarfed by the cost of wasted fuel. This is because the A303 is a busy road, so any delays will create significant monetised delay impacts. In this case it is argued that a separate scale bars should be used because the aim of the assessment is to understand whether the cost of SUE is worthwhile, and it is felt that this is more usefully displayed in Figure 5.14. However, both options should be available within the assessment tool.

5.6.9 Discussion and Calculation of ROI

Both Scenarios in Case Study 4 are theoretical, and this made the results more questionable than those obtained in the previous Case Studies. For example, in Scenario 2 it was assumed that the entire highway project would be delayed by one week, but in reality that is unlikely to be the case because other work can still continue around the utility repair. If a different type of utility was damaged, the impact would be different. When multiple assumptions are made in this way the result becomes less clear than when one evidence based Scenario is compared with a second.

The main shortfalls are the types of data that were available and the assumptions that were made, but this will be less of an issue if the methodology is used by a project owner who is actually planning the work, as there will be more relevant information to hand. However, it is argued that some positive points remain. The methodology is intended to scope out different solutions for projects being planned in the future, and therefore the Scenarios developed here conceptualise exactly the type of situation that might occur – is the cost of mitigation (SUE) a justified expense? If it is accepted that the two Scenarios developed for Case Study 4 are at least possible, then the ROIs shown in Table 5.17 are useful and meaningful.

In Figure 5.13 Scenario 1 includes mitigation and no damage occurs. In Scenario 2, no mitigation is used and damage occurs. However, the reality is that the highway scheme was constructed, no SUE survey was carried out, and no damage to underground utilities occurred. Therefore, a third Scenario should be added ('no SUE / no damage'). In this sense the cost of any mitigation would have been wasted, as it did not prevent any damage. Figure 5.13 should be seen as the potential risk that is being mitigated against when such a scheme is planned.

Table 5-17: Different types of a Return on Investment for Case Study 4.

ROI (road user delays valued as a cost)	£4.00	for each £1 spent
ROI (cost of fuel)	£6.85	for each £1 spent
ROI (tonnes of carbon)	0.0002	tonnes of carbon for each £1 spent
ROI (cost of carbon)	£0.0308	for each £1 spent
ROI (all monetised impacts)	£11	for each £1 spent
ROI (community impact)	£8,017	to reduce impact score from '3' to '2'
ROI (H&S)	£8,017	to reduce impact score from '3' to '1'

Table 5.17 is based on two main assumptions – if the SUE process is followed, no damage to underground utilities occurs. Secondly, if damage does occur it will delay the roundabout scheme for a total of one week. By carrying out a SUE survey, the traffic delays that would have been caused from repairing the gas main have been prevented. The monetary value of this time delay is £3 for each £1 spent on the SUE survey. Queuing traffic would have wasted fuel during this delay, and over £5 of fuel has been saved for every £1 spent on the SUE survey. A small saving in carbon emission also results.

6 RESULTS AND DISCUSSION

The Case Studies have performed well in demonstrating the principle behind a Return on Investment (ROI) that features wider impacts, but some problems have been highlighted as well. The key findings are as follows.

6.1 Triple Accounting

In order to assess the value of different working methods in terms of sustainability, direct cost is only one impact that needs to be considered. The case studies were based on the principle of 'triple accounting' where the social, environmental and economic impacts of a project are assessed.

6.2 A ROI With Respect to 'Wider Impacts'

In Case Studies 1, 3 and 4 a slightly more expensive working method was assessed, and this had a positive ROI when road user delays and fuel consumption were considered. The results from the case studies allow this type of calculation to be made, but it works best when impacts can be easily monetised, for example road user delays, fuel consumption and impact of reinstatement or carbon emissions. The return becomes less clear when qualitative criteria are used, because the return is simply a reduction in the score of one criterion.

6.3 Core Impacts

Because they appear in the output tables for all four Case Studies, three 'Core Impacts' were defined for future use: road user delays, wasted fuel whilst queuing and carbon emissions associated with this wasted fuel.

6.4 Radar Charts

The case studies were presented through the use of tables and radar charts. When the same scale bars were used in the radar charts it was found that the cost of wasted fuel and delays dwarfed other costs, such as those associated with labour.

6.5 Sensitivity of Results

All quantitative input data for Case Study 1 were tested using a 10% variation for input data. This revealed that delay costs, fuel consumption, carbon emissions and noise are particularly sensitive to the average road user delay per vehicle, so it is important to test the uncertainty in this parameter further. Commercial sensitivities created further uncertainties for staff costs, and impacts measured by proxy (such as noise) would be understood better through direct site measurement. The H&S and community impact score sheets cannot be so easily tested as part of a sensitivity check; uncertainty here might exist in predicting the exact outcome of an event such as a utility strike.

6.6 Validation Through the Use of an Existing Assessment Method

Case Study 1 was assessed using the CEEQUAL process. This revealed that the assessment tool can play a useful part within a CEEQUAL assessment by helping to score criteria within the following categories: project management, transport, effects on neighbours, and relations with the local community. The assessment tool has advantages over CEEQUAL through its focus on streetworks projects specifically, and its ability to consider the best interests of the 'one customer'.

6.7 Data Availability

Applying the methodology retrospectively to the case studies revealed that not all of the parameters required to evaluate all impacts are routinely measured, and this resulted in assumptions having to be made, but these assumptions were based on approaches suggested in the literature. The methodology was best validated by being applied to problem projects, and Case Study 4 suggests this can only be done effectively for historical schemes where something has gone wrong: Scenarios in Case Study 4 were theoretical, but it was found that many assumptions had to be made and this could be argued to bring into question whether the results are valuable.

6.8 Defining Each Assessment

Care needs to be taken when setting out the scope and aim of each assessment, as well as the Scenarios that are to be included. The methodology works best when only one single change is made (with consequential knock-on effects), because this allows the sustainability of true alternatives to be assessed.

6.9 Bespoke Assessment

If an organisation were to adopt the methodology to assess their own projects then some of their original data (staff costs for example) might be embedded within the assessment process.

6.10 Case Studies Suggested

Sometimes there were conflicting versions of events. When highway authorities and utility companies were approached for data they naturally chose Case Studies where they were clearly not at fault. For this reason it would be helpful if prior agreement were reached to monitor complex projects, where delays to traffic and other disruptions are inevitable, because the assessment tool can be used to test these 'what ifs'.

6.11 The H&S Impact

The H&S risk of different options was scored using an approach adapted from industry and couched within existing literature. This worked well, and allows a rigorous approach to be used to score a wide number of possible outcomes.

6.12 The Community Impact

The community impact was scored using a similar approach to H&S, and this allowed many of the wider, intangible impacts of a scheme to be usefully defined and compared between Scenarios.

6.13 Potential Impacts from Damaging Underground Assets

Case Study 2 highlighted the true impacts that can be created when damage occurs to underground pipes and cables. Apart from the direct costs of repair and compensation payments it was found that many of the other impacts were very much dependent on traffic flow, as this creates a significant amount of traffic delays, wasted fuel and carbon emissions.

6.14 Specific Solutions

Case Study 1 expressed the potential benefits of manually controlled traffic signals, whereas Case Study 3 examined the benefits of using resonant tags which allow for an easy location of pipes using a surface scanner; Case Study 4 identified advantages in carrying out a SUE survey. Case Study 2 suggests that it cannot be assumed that trenchless technologies are always the best solution. However, none of these Case Studies should be used as a justification or rejection of any working method – that is not the aim of the research. Local conditions and priorities should be allowed to dictate how decisions are made, but they must be transparent and justified by those doing and presenting the analysis.

6.15 Lack of Research for Specific Impacts

Some areas are well researched (e.g. noise), but care must be taken to capture the relevant noise, and indeed move to a measure of the distress caused. Therefore, even in the case of noise, the most appropriate means of assessment are far from clear. Some areas are poorly bounded (e.g. CO_2 or carbon emissions), so in the assessment it is necessary to question how wide the boundaries of the study should be made. Nevertheless, it is worth reiterating that simply introducing such considerations in to an engineer's decision making will change behaviours and yield more sustainable working practices.

6.16 Acting on the Results of the Methodology

The four Case Studies prove the concept of the methodology, but its value is reduced unless it recognised more widely. Ideally the methodology will be used during the planning stages of a future streetworks projects and then the results will be tested by site measurements. If it can be proved that a more expensive working method has advantages then utility companies need to be incentivised to make such a choice.

7 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORK

7.1 Conclusions

This research has focused on developing an understanding of the utility streetworks industry with a focus of identifying the relevant stakeholders and their role in utility streetworks. It soon became apparent that this is a disparate industry with a number of different stakeholders, all with different motivations. This was followed up with a review of the relevant guidelines and regulations. When reviewing the literature it was apparent that, in order to assess value with regard to different working practices for utility streetworks, it was necessary to develop a sustainability assessment tool. This tool was tested on four Case Studies. These Case Studies revealed a need to carefully consider the aim of assessment, which in turn requires a careful assessment of the impacts that should be included. Overall, the methodology performed well in terms of capturing the advantages of working methods in terms of their wider impacts, but further research is required to understand the uncertainty of specific impacts, notably average vehicle delay. The methodology should now be used as a focus for highway authorities and utility regulators in order to assess the value of different solutions for streetworks projects.

The key conclusions for this research are:

- There are currently two different types of organisations involved with streetworks, each with very different interests. Highways are controlled by highway authorities who operate in the public interest and are funded through tax. Utility companies are often commercial organisations who operate to make a profit. This is a different situation to the railways where Network Rail owns the track and the land on which the track sits. Being aware of these interests is important.

- Utility companies are regulated by consumer groups like Ofgem and Ofwat, but these authorities only consider the needs of a particular type of consumer (i.e. someone who pays a water bill, or an electricity bill), and focus on ‘efficiencies’, which will almost certainly mean cutting costs. Highway authorities focus mainly on the needs of road users.
- It was shown that it is important to consider the needs of the ‘one customer’ who benefits from access to roads and utilities every day, but also pays the price through tax, utility bills, road user delays, noise and wasted fuel. In this sense, the best value solution for the ‘one customer’ overall may not be the lowest direct cost solution.
- The ‘one customer’ may not own a car or even travel on public transport, but they still use products or services that rely on well maintained roads and utility infrastructure. Therefore these assets always need to be maintained in the most efficient and cost effective way possible, but this does not mean always choosing the cheapest option.
- Streetworks solutions may have positive and negative aspects, and an ‘advantage’ such as a reduced duration can always be viewed in a different way – a negative impact (road user delays) has been reduced. The research defined a ‘benefit’ as a reduction in any negative impact associated with streetworks, but it is recognised this approach is somewhat subjective, and that the arguments on both sides are valid and finely balanced.
- To assess the benefits for the one customer of different working practices, and after reviewing the literature, it was concluded that a new sustainability assessment tool is

required as utility streetworks create a 'footprint' that includes social, environmental and economic impacts, rather than simply the direct costs of a scheme

- Different sustainability assessment tools were reviewed including both qualitative and quantitative methods. It was shown that the generic four stage LCA process offers a sensible reference point, starting with the identification of the scope of assessment, and then choosing a suitable list of primary and contributory impacts. When identifying the relevant impacts, it was shown that some impacts need to be assessed using a qualitative approach, while others require a quantitative approach.
- Previous studies such as Huang et al. (2009a and b) and Boyce and Bried (1994) only considered a limited number of social, economic and environmental impacts. Therefore it seemed prudent to develop a list of primary and contributory impacts. The list of primary and contributory impacts was developed following a review of relevant literature, beginning with the potential impacts identified in McMahon et al. (2006). However this list is not exhaustive and it is important that industry stakeholders now become involved with the assessment tool so that this list can be expanded usefully.
- When the methodology was tested on four Case Studies, it turned out that not all of the data required to assess different impacts get routinely collected during most utility streetworks projects, so assumptions had to be made. Some impact types are well researched (e.g. noise), but care must be taken to capture the relevant noise, and indeed move to a measure of the distress cause.
- The methodology allows a user to define the Return On Investment from different working methods. This is a key strength of the methodology because it allows the benefits of a more expensive working method to be realised. The concept of a Return On Investment is somewhat limited because the 'investment' (say, deciding to use a

site operative to manually control traffic signals) may be made by a commercial utility company, but the 'return' (perhaps a reduction in road user delays, fuel consumption, carbon emissions or resident complaints) is enjoyed by society at large. Utility companies will need to be incentivised by their regulator if they are to make such decisions, but provision of the necessary information lies at the heart of this discussion.

- A Return On Investment works best when impacts can be easily monetised – road user delays, fuel consumption, impact of reinstatement and carbon emissions are all good examples – and the return becomes less clear when qualitative criteria are used, because the return is simply a reduction in the score of one criterion. Nevertheless, sustainable engineering is about social, environmental and economic accountability so it is necessary to 'triple account' for all of these impacts when streetworks are carried out.
- Three monetised impacts were defined as the 'Core Impacts' of streetworks: road user delays, wasted fuel whilst queuing and carbon emissions associated with this wasted fuel. Focussing on these three 'Core Impacts' allows for a quick assessment of the best value solution in terms of monetised impacts only, whereas a full assessment allows a designer to consider the wider, intangible, non-monetised impacts of a scheme.
- If an organisation were to adopt the methodology then a partly automated system could be developed (for example staff costs could be pre set), and this will allow a larger number of assessments to be quickly carried out.
- It was decided that a radar chart should be used to graphically display the output from the assessment tool rather than using a points based (criterion) approach because this provides an immediately visual appreciation of the relevant situation. Given the fact

that social impacts are difficult to predict and monetise, different units of measurement do appear as spikes on the same radar chart.

- When the same scale bars were used for the radar charts it was found that the cost of wasted fuel and the delay costs dwarf other costs. When different scale bars were used the Scenarios was easier to compare in terms of all impacts. However, it cannot easily be stated whether one approach is better than another because it depends on the scope and aim of assessment. In the case studies it was more appropriate to use different scale bars, because the advantages of a particular solution were being tested, but both options should be available.
- It would be possible to separate the methodology into two levels of assessment. Estimating the three 'Core Impacts' could be carried out automatically, but a more complex assessment could be carried out by the scheme designer to include non monetised impacts. If the second option is chosen, the comparison is more usefully carried out through the use of a radar chart. This might become 'economically unsustainable' if carried out for every project in the street, but this would become clearer with experience of using the method. It might be argued in turn that the methodology seeks to initiate a change in the thinking of engineers, and the fact that such considerations are being weighed for any project is likely to yield more sustainable solutions.
- It is always necessary to consider what might be the 'status quo' Scenario, for example, 'what if no mitigation was carried out, but no damage was caused anyway?' This is likely to represent the thought process of those who pay the direct costs associated with streetworks projects.

- The methodology works best when only one single change is made between Scenarios, because this allows the sustainability of true alternatives to be assessed. This does mean that a larger number of Scenarios might be required to assess different outcomes, but the assessment tool is flexible enough to allow this to happen.
- The CEEQUAL criterion-based approach is different to that taken in the assessment tool, which considers different Scenarios and then quantifies the negative impacts that are created under each Scenario. When the CEEQUAL process was used to validate the results of Case Study 1 it was revealed that the assessment tool has advantages over CEEQUAL due to its focus on streetworks and its ability to consider the needs of the 'one customer'. However, the results from the assessment can also help to score a CEEQUAL assessment in the future, so this demonstrates how the assessment tool might fit in with existing procedures.
- A 10% sensitivity check for all quantitative data revealed that delay costs, fuel consumption, carbon emissions and noise are particularly sensitive to the average road user delay per vehicle. However, the uncertainty in this parameter (average road user delay per vehicle) is not known, so it is recommended that site measurements are taken to better understand how the value predicted by DfT (2004b) might differ to site measurements. Nevertheless, the 10% variation check has provided an indication of the most suitable parameters to test further.
- To assess the Health & Safety risk of different Scenarios, an adaptive approach was used. A document created by the engineering consultant Mott MacDonald called a 'Health & Safety Risk Assessment' was adapted for use; this industry-best-practice approach was also couched within existing literature (Syachrani et al., 2010). The worst case Health & Safety risk level was compared with the risk level following

mitigation by using a fixed scoring system. The alternative to this approach would be to use one of several 'safety factors', such as the Kolater (1998) factor of '4'. It is argued that the chosen approach is more rigorous in the way that it scores the Health & Safety impact, and a wide range of possible outcomes can be compared.

- The community impact was scored using a similar approach to the Health & Safety impact. Again, this provides a rigorous method of scoring, and allows a wide range of outcomes to be assessed.
- The four Case Studies prove the concept of the methodology. If a more expensive working method has advantages and a clear positive Return On Investment, then the methodology should be used as a justification to encourage that solution to be used.

7.2 Recommendations for Future Work

Some impacts are surprisingly poorly defined (e.g. reinstatement) and yet are of fundamental importance to this debate. For example, McMahon et al. (2006) state that poor compaction of the road surface can lead to water ingress, which can cause premature structural failure and deterioration of the road, but there is an urgent need for further research in this area – it must be accurately determined if streetworks are to be more effectively conceived, designed and costed.

Nevertheless this research has developed a 'Version 1.0' methodology to assess many of the wider impacts that are created by streetworks projects. It is important that the general principles behind this methodology become recognised by those involved with streetworks projects (primarily the idea of 'the one customer'). However, a number of aspects need further work before this methodology can be adopted widely. Therefore, the following recommendations for further work are suggested:

- The assessment tool should be used more widely by industry stakeholders so that the list of primary and contributory impacts can be usefully developed further.
- Site measurements should be collected for the average vehicle delay at different types of streetworks project, so that the uncertainty of the value predicted by DfT (2004b) can start to be established.
- Given more time, individual impacts might be assessed using a technique that did not originally appear in the methodology.
- In three of the four case studies, the amount of time spent by council officers on a scheme was relevant. This suggests that the time spent by council employees on dealing with streetworks problems should be more widely recorded, as this will allow for as wider appreciation of the true costs involved.
- In each Case Study only one project aspect was altered, and the final impact level following mitigation was scored as 1, 2 or 3 for a 'low', 'medium' or 'high' magnitude of impact. In the future it would be possible to develop more than one criterion, and add the scores for each one, so that an overall 'community impact score' can be established for each Scenario.
- The Case Studies highlighted the challenges that are faced when all of the different impacts are assessed with limited data. Therefore, it will be critical to test the methodology while a project is being carried out, so that more of the required data can be collected. Furthermore, different working practices beyond those tested in the Case Studies need to be assessed in order to ensure full robustness of the methodology.

- The methodology should be tested on a small-scale highway resurfacing scheme, as logically this type of project has much in common with a utility repair scheme – it is temporary and has an impact mainly during construction.
- Although sustainability is important in the construction industry, for this methodology to achieve its full potential it is critical to ensure that the industry fully adopts the idea of social and environmental impacts being as important as economic impacts, or at the very least they need to be considered when utility streetworks are planned. It is likely that this will require lobbying, informing the industry and potentially adapting or introducing guidelines and or regulations.

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APPENDIX A: LIST OF PRIMARY AND CONTRIBUTORY IMPACTS

Primary Impact: Direct Costs of Design and Construction (£)

Contributory impacts (Part 1):

- Labour and plant
- Construction materials
- Reinstatement / resurfacing of the trench
- Traffic management
- Supervision during construction
- Cost of diverting existing services
- Additional works along the diversion route
- Costs associated with obtaining network records
- Monetary costs of administration, such as the maintenance and exchange of notices and records
- Design / redesign costs
- Site survey to locate existing apparatus, infrastructure, trees etc and to determine the ground conditions
- Administration costs associated with risk assessment
- Consultation with interested parties
- Engineering and cost assessment of the proposed technique

Assessment Method (Part 1):

- If an organisation is using the assessment tool for its own projects then its own labour and materials costs will be used
- Hourly rate for construction workers will be taken as £20 per hour
- Hourly rate for engineers will be taken as £40 per hour
- For costs that are not known in this way the Spons Manual (Langdon, 2011) will be used wherever possible
- If the specific costs are not included in Langdon (2011) then they will need to be estimated, but the assessor will need to clearly state what assumptions they have made

Contributory impacts (Part 2, if damage to underground utilities occurs):

- Repair costs due to damage caused to underground utilities
- Repair costs due to damage to adjacent property
- Increased insurance premiums / excess
- Compensation payments
- Short term loss of income
- Longer term loss of income (e.g. loosing business to competitors)
- Cost of restoring brand / image
- Lost opportunity cost

- Payments under Section 74 of NRSWA (1991)
- Pavement damage to the diversion route if it is not designed to cope with the additional traffic flow

<u>Assessment Method (Part 2, for scenarios involving damage to underground utilities):</u>

- If an organisation has access to data showing the cost of previous damage it can use this to estimate damage costs in the future
- If a 3rd party is assessing potential damage it can use the default value created in the methodology (direct costs of damage = £2,900 per event)
- Damage to brand image is included within the assessment for 'Impact on Community and Business'

Primary Impact: Road User Delays

<u>Contributory impacts:</u>

- Queuing prior to reaching the works
- Reduced traffic flow through the works
- The need to accelerate/decelerate adjacent to the work area
- Following longer diversion route (if this is assessed individually then road user delays for the whole scheme will need to be modelled separately as well. Alternatively, averaged values for the typical delays that will occur can be estimated from the process below).

<u>Assessment Method Part 1: Cost of Time Delays</u>

- Traffic flow / reinstatement category of road identified for 'rural' and 'urban' locations
- Average cost of daily road user delays estimated from Tables 4.1 and 4.2
- Daily cost from Tables 4.1 and 4.2 divided by £11.28 = delay in hours
- Delay in seconds per vehicle then calculated by dividing by 3,600
- Total delay cost = average delay per vehicle (seconds) multiplied by average daily traffic flow multiplied by inflation-adjusted-cost-of-time
- Average delay should be recorded on site wherever possible

<u>Assessment Method Part 2: Cost of Wasted Fuel</u>

- Assume the average delay per vehicle calculated above is the amount of time that each vehicle is stationary
- Calculate fuel consumption for each vehicle using parameter 'a' in Equation 1, Tables 4.3 and 4.4
- Total wasted fuel calculated by multiplying 'per vehicle' wasted fuel by average daily flow

Primary Impact: Carbon and Other Air Emissions (Measured in £)

Contributory impacts:

- Emissions from delayed traffic
- Emissions associated with manufacture / use of building materials
- Emissions associated with delivery of materials

Assessment Method for Emissions From Delayed Traffic:

- Volume of wasted fuel calculated as above
- Volume of wasted fuel converted to grams of carbon using Table 4.5
- Grams of carbon calculated as an inflation-adjusted cost using Web-TAG Unit 3.3.5 (£158.87 per tonne in 2011 costs)
- Total carbon emission = carbon emission per vehicle multiplied by average daily flow
- Carbon emissions used as a proxy for other air emissions

Assessment Method for Emissions Associated with the Manufacture / Use of Building Materials:

- Estimated using CapIT

Primary Impact: Noise Pollution

Contributory impacts:

- Excavation work
- Reinstatement works
- Queuing traffic

Assessment Method

Option 1: If the Duration of the Work is different in each scenario:

- Worst case noise associated with excavation work during construction is taken to be 78 dB (from Ballesteros et al., 2010)
- Worst case noise multiplied by duration

Option 2: If the Duration of the Work is the same in each scenario:

- Total vehicle delay used as a proxy measurement for noise created

Primary Impact: Impact of Reinstatement (£)

Contributory impacts:

Any type of reinstatement work

Assessment Method:

- Estimate surface area that has been resurfaced
- Impact of reinstatement assumed to be proportional to the cost of resurfacing area of carriageway
- Cost estimated from Spons (Langdon, 2011) at £183 / m^2.

Primary Impact: Safety Impact

Contributory impacts:

Any activity that has implications for H&S

Assessment Method:

The H&S scoring sheet will be used

Primary Impact: Impact on Business and the Community

Contributory impacts:

- Location specific criteria such as…
    - Severance
    - Tree damage
    - Trade lost for local business
    - Reduced income from parking meters
    - Longer pedestrian routes

Assessment Method:

- The 'Community Impact' scoring sheet will be used
- If compensation is paid to locals business, the actual costs of compensation will be used wherever they are known. Otherwise, the default value from the methodology will be used - £143 per day

Primary Impact: Other Environmental Impacts

The following issues are not generally included within an assessment, but in exceptional cases it is possible to develop site specific criteria based around the following issues:

- Land use
- Land contamination by hazardous materials
- Landscape issues
- Ecology and biodiversity
- Flood risk
- The historic environment
- Water resources and the water environment
- Light pollution

APPENDIX B: DISCUSSION OF DfT (2004b) AND GOODWIN (2005)

DfT (2004b) estimates the total annual cost of congestion created by utility streetworks at £4.3 billion. This conclusion was controversial with the utilities industries, who commissioned (through the ‘National Joint Utilities Group, NJUG) a separate report to comment on its findings (Goodwin, 2005), which estimated the cost of congestion at 0.5 to 1 billion. This huge difference needs to be explored in greater detail because it will identify what assumptions and calculation methods were used, why the results are so different, and if these methods can be applied in ways that will predict road user delays and congestion at a project level. This Appendix carries out that examination.

To begin, it is useful to note that Goodwin (2005) defines two generic approaches that can be used to calculate road congestion:

- A ‘top down’ method, where the total cost of all congestion is calculated and then pro rated by the percentage of work carried out by one particular sector. For example, Goodwin (2005) is only examining utility streetworks, so he multiplies the total cost of congestion by the percentage of delays that are caused by utility streetworks projects. In this top down method, the total cost of congestion is equal to *(total time spent travelling in reality) – (total time if everyone could travel at free flow speeds) * number of people * value of time*
- A ‘bottom up’ method, whereby the cost of congestion is calculated for individual projects by observing or modelling queue lengths, and the average delay cost is then multiplied by the total number of similar schemes per year

Goodwin (2005) describes the 'most famous' example of the top down calculation as that published by the Confederation of British Industry in 1989 (CBI, 1989). This report summarises the findings from a survey carried out with 2,000 CBI members from the London region, who were asked to estimate how much extra money they need to spend when working in the capital due to congestion – this is defined as the 'business costs' of congestion in London. Royal Mail for example, estimate that they paid an additional £10.4 million in 1989 through fleet inefficiencies, additional driver time and vehicle costs. These costs appear to be estimations made by the different businesses that were questioned, and therefore it must be assumed that some bias will occur, although if anything this is likely to be an overestimate, not an underestimate of the true cost. CBI (1989) estimates the total annual cost of *all* types of congestion (not just utility streetworks) at £15 billion in 1989 prices, and Goodwin (2005) claims that by 2000 this figure was most often quoted as £20 billion.

This current research must take a rigorous and robust approach if it is to withstand criticism, and therefore it is argued that little credence can be given to CBI (1989) because it was not routed in a robust, numerical approach – it was based on estimates provided by business. Despite this lack of rigour, Goodwin (2005) uses the £20 billion estimate to calculate the cost of congestion due to utility streetworks by pro rating this value by the proportion of work created by utility companies. To do this, he uses a breakdown of congestion types included within a Transport Research Laboratory study (Frith, 1999) to calculate the cost of congestion on non-urban roads, and therefore Frith (1999) needs to be examined in more detail.

Frith (1999) categorised the different types of congestion that can occur on UK motorways and highways. He defined 'recurrent' congestion by identifying locations where congestion occurs in three out of five weeks at the same location at the same time on a particular day of the week. He then calculated congestion ‘due to roadworks’ by using the Highways Agency’s National Lane Closure Bulletin to identify locations where roadworks were happening, and compared congestion at this location with the congestion occurring at the same location a year earlier. Finally, any congestion that was not defined as ‘recurrent’ or ‘due to roadworks’ was identified as congestion due to ‘incidents’. Frith (1999) notes that the accuracy of the result depends on identifying the causes of congestion, and realises this is not always possible: for example congestion may have been caused even if an event had not happened.

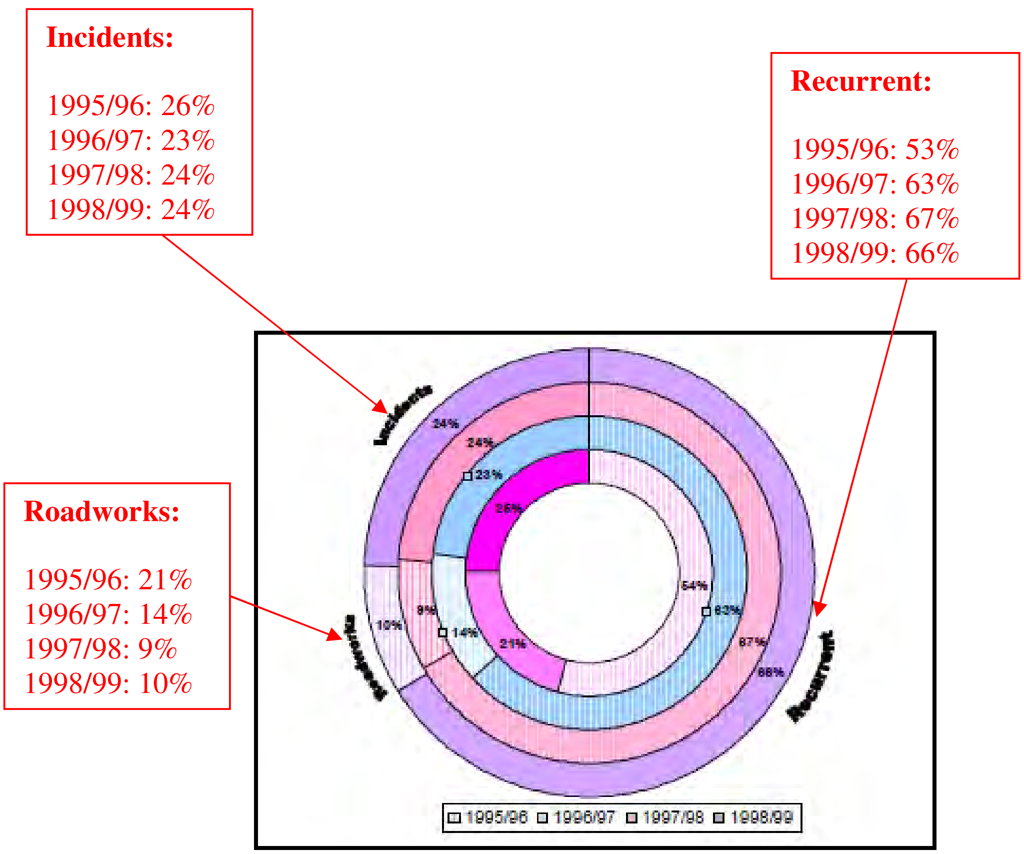

Figure B-1: The estimated percentage of congestion that is defined as ‘recurrent’, due to ‘roadworks’ and due to ‘incidents’, for 1995/96 to 1998/99, after Frith (1999).

As shown in Figure B-1, between 1998 and 1999 the percentage of congestion due to ‘roadworks’ (by which Frith (1999) means highway work *and* utility repairs) was 10%, but this was one of the smallest percentages for all of the four years assessed. Goodwin (2005) only uses this 10% value, and does not explain why only this year was selected – the average of all 4 years is 13.5%. He then splits this percentage 50:50 between highway schemes and utility works (again, without explaining why), and states that ergo, 5% of congestion on trunk roads and motorways is due to utility work.

Goodwin (2005) then seeks out a similar percentage for the congestion caused in urban areas. In his report he includes the results from a TfL conference presentation (Brown, 2004; quoted in Goodwin, 2005), but the original of this report was impossible to find. This TfL study differs to Frith (1999) in the way it categorises congestion – firstly it does not include 'recurrent' congestion at all, and instead categorises the causes of 'slight / moderate' and 'serious / severe' congestion in London, as shown in Figure B-2 and B-3.

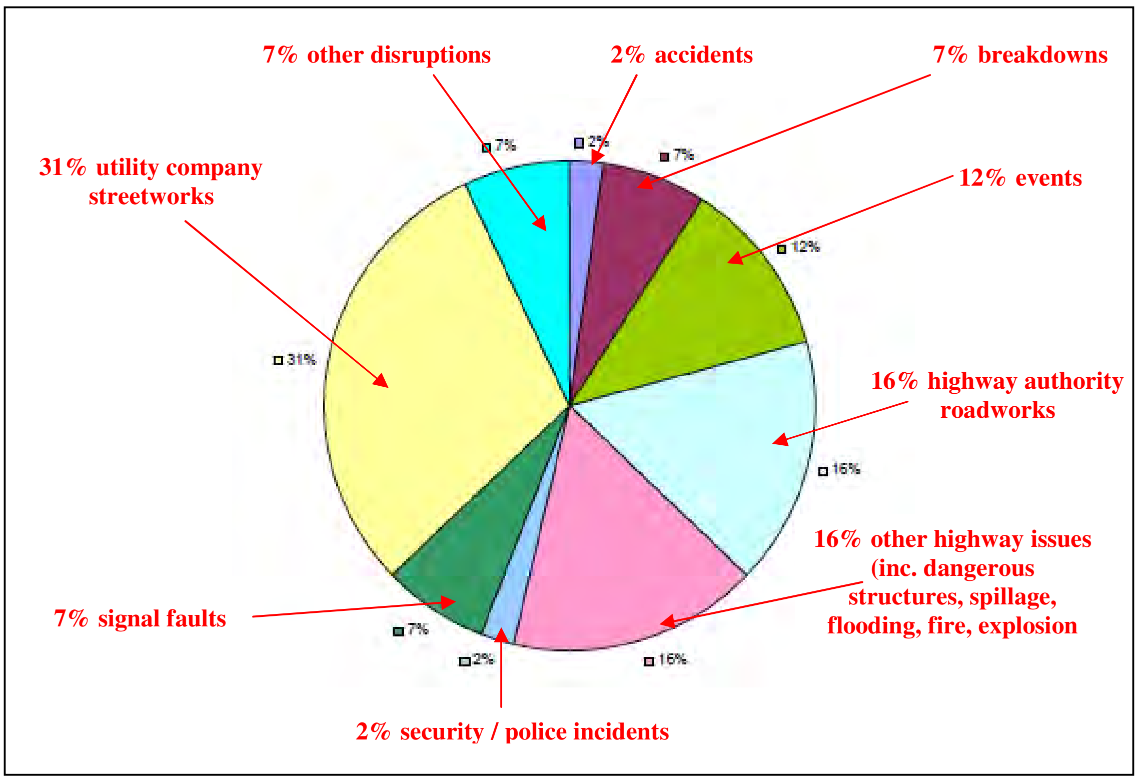

Figure B-2: TfL estimates for causes of 'slight and moderate' congestion in London, after Brown (2004); quoted in Goodwin (2005).

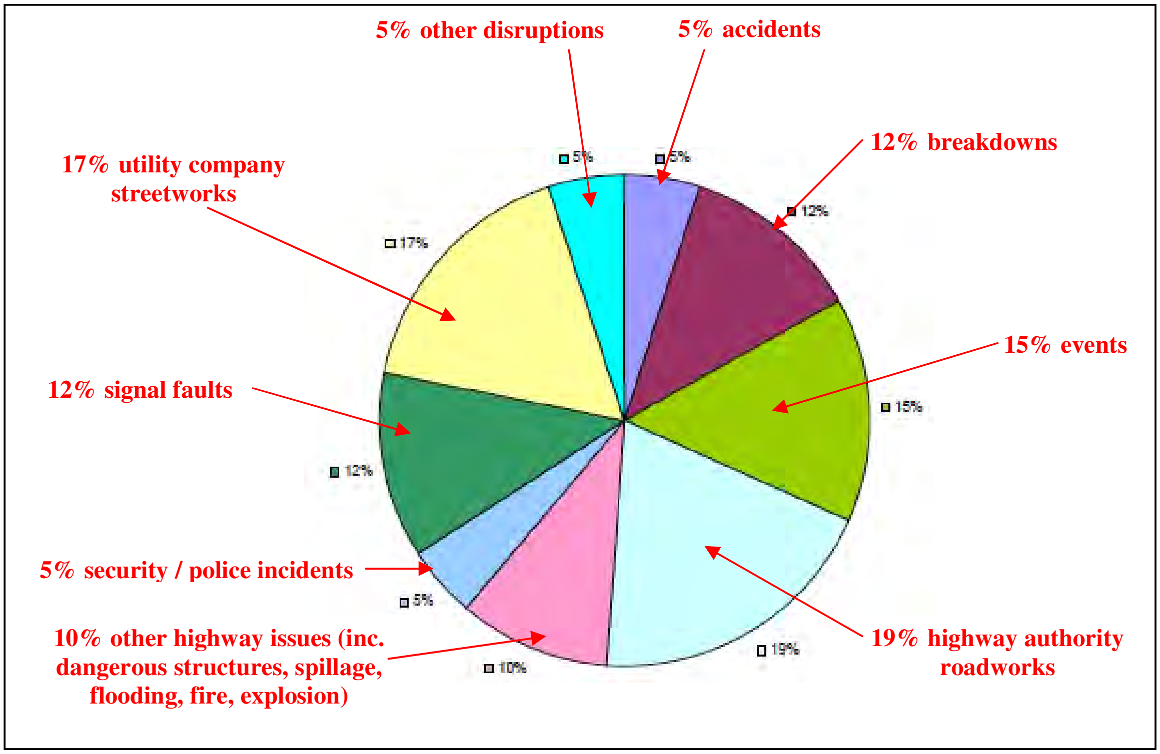

Figure B-3: TfL estimates for causes of 'serious and severe' congestion in London, after Brown (2004); quoted in Goodwin (2005).

Brown (2004) states that 17% of 'serious / severe' and 31% of 'slight / moderate' congestion is caused by utilities, but Goodwin (2005) then reintroduces Frith (1999), and argues that because two thirds of congestion on trunk roads is 'recurrent' (i.e. due to the weight of traffic), the percentages quoted in Brown (2004) should be reduced two thirds – meaning that 6% of 'slight / moderate' and 10% of 'serious / severe' congestion is caused by utilities.

Goodwin (2005) then argues that these percentages should be reduced further, because 'recurrent' congestion is likely to be more of an issue in the capital than along trunk roads, so he uses a value of 80% (not two-thirds) for congestion due to weight of traffic. Without showing his calculation method, he suggests these figures lead to the conclusion that only 5% of 'slight / moderate' and 'serious / severe' congestion is due to utilities in both urban and rural areas, and using the £20 billion annual cost of congestion stated in CBI (1989), he concludes that the overall cost of congestion due to utility streetworks is £1 billion.

The first problem here is that Goodwin (2005) makes no comment about the accuracy of the results generated by Frith (1999), and doesn't explain why he only uses the lowest percentage for delays caused by 'roadworks'. Secondly, he compares two very different studies; Frith (1999) and Brown (2004) evolved from different needs and use different methodologies so their results and are difficult to compare. Thirdly he uses a highly questionable total cost of congestion (i.e. that put forward by CBI, 1989) to calculate the cost of congestion due to utility streetworks. Finally, he does not clearly show his calculation method.

Goodwin (2005) was prepared in response to DfT (2004b), and therefore it is necessary to understand the methodology used in this second study in more detail. DfT (2004b) was prepared on behalf of the DfT by Halcrow, and uses what Goodwin (2005) refers to as a 'bottom up' approach to calculate the annual cost of congestion. This approach began by discretely considering individual streetworks projects to predict the delays that will occur in each case, and then extrapolated the result for the total number of projects occurring each year. These different types of streetworks projects were modelled as a constriction to the carriageway, whereby they reduce traffic speeds and increase delays. In the study, a variety of situations were modelled which were typical of the types of work that commonly occur, along with the dimensions of the work and the type of road. The different models examined urban situations separately to rural situations, and accounted for the assumption that diversionary routes were more likely to be available in urban areas.

Overall, DfT (2004b) suggests that their own approach will underestimate the cost of congestion due to utility streetworks (£4.2 billion) because:

- When no other information was available it was assumed that all roads are RC 4, which is the lowest value. This means that heavily trafficked roads may have been allocated as RC 4.
- The Notices for work involving 'no excavation' have been ignored, even though they may encroach on the highway and therefore cause delays.
- When different traffic models are used for congested urban areas the results produced can vary a great deal, because the algorithms contained within the software are different, and the situation being modelled is complex.

Various modelling techniques were used, and it is worth highlighting the approach taken to understand how thorough the study was. The first type was a queue / delay model (QUADRO), used to model a range of utility streetworks likely to affect county councils, in both rural and urban locations. The second type used assignment models to model congested urban networks, because these can consider situations where congestion is commonplace, and a range of alternatives routes are available. SATURN was used alongside the 'West Inner London Traffic Model'. Finally, micro simulation models (VISSIM and AIMSUN) were used to model the impact of short term and localised utility streetworks for congested urban networks in the centre of towns, as this type of modelling will replicate the interaction of individual vehicles. This allows short term emergency work to be modelled, because a situation can be considered before 'equilibrium' occurs. It was noted that situations modelled using micro simulation only covered a small area, and this will overestimate delays because other potential alternative routes were modelled as being unavailable. The results from VISSIM and SATURN were then compared with the results for QUADRO. In all cases, the aim of the modelling in DfT (2004b) was to develop an estimate for delays at peak and off peak hours, from which a daily profile was developed for a given work type. Goodwin (2005) criticises the DfT (2004b) study in the following way:

1. The reinstatement category has not been established as an accurate proxy measurement for traffic flow.
2. Factors for extrapolating the results nationally have not been verified.
3. The relationship between streetworks, width, length, duration and congestion has not been verified.
4. The size of bias introduced by assuming zero adaptation has not been quantified.

The first three criticisms are accepted as being perfectly valid, and these will now need to be recognised as limitations when the results contained within DfT (2004b) are discussed. In particular, using the limiting commercial vehicle flow and / or reinstatement category as a proxy measurement for average traffic flow is a particularly broad assumption, but one that has been clearly stated in the study. However, the last criticism seems unfounded; it has not been assumed that zero adaptation will occur – a variety of different assignment and micro simulation models were used for this very reason, and therefore this criticism is rejected.

There is a very large difference between the cost of congestion calculated by DfT (2004b) - £4.3 billion – and that calculated by Goodwin (2005) - £1 billion, and Goodwin (2005) puts this difference down to the following factors:

1. The problem of aggregating very small time savings and losses;
2. The implications of defining congestion by comparing it with free flow conditions;

3. The implications of ignoring adaptation of driver behaviour;
4. The effect of general congestion on specific congestion;
5. The reliability of the data base.

Several of these criticisms are valid. Firstly, if a road user is delayed for a few seconds this is unlikely to cause annoyance, but aggregated across the country these small insignificant impacts might be calculated as significant costs. Secondly, he is correct that delays cannot sensibly be compared with free flow conditions, as effectively this rarely occurs for any journey no matter how short. However, his third argument is rejected because the DfT (2004b) modelling specifically takes in to account emergency work before equilibrium conditions are reached (i.e. before traffic is likely to divert), as well as with equilibrium conditions. His fourth argument is also supported by Frith (1999); it is very difficult to state with certainty exactly what impacts an event will have because a complex system is being modelled, and other outside events will have also an impact; this criticism is also accepted. Finally, it is recognised that the reliability of any database can never be assured, and therefore this is also accepted as a limitation of the study. However, the limitations of the modelling in DfT (2004b) are inherent in the modelling software itself, and therefore if the findings were to be rejected in favour of a new type of modelling being carried out, then these limitations would still exist.

Goodwin (2005) states that if the 'top down' and 'bottom up' approaches are valid they will both lead to the same value, and he points out that his top down analysis does not agree with the value obtained from a bottom up approach used in DfT (2004b), but he does not carry out his own bottom up approach to compare the 'like for like' result.

On balance it is argued that DfT (2004b) takes a more rigorous and defendable approach than Goodwin (2005). Therefore, in the methodology the values contained within Tables 4.1 and 4.2 will be used to estimate the cost of road user delays for utility streetworks projects on different types of road. If the *actual* traffic flow is known then the values in Tables 4.1 and 4.2 will be pro rated accordingly.

APPENDIX C: EXTRACTS GATHERED FOR CASE STUDY 1

Primary and Contributory Impacts Selected for Case Study 1

The following contributory impacts were selected as being relevant to the given scope, aim and boundaries of assessment, as well as the scenarios created.

Direct Costs of Design and Construction (£)

- Labour and plant
- Supervision during construction

Primary Impact: Road User Delays

- Queuing prior to reaching the works
- Reduced traffic flow through the works

Primary Impact: Carbon and Other Air Emissions (Measured in £)

- Emissions from delayed traffic

Primary Impact: Noise Pollution

- Queuing traffic

Primary Impact: Impact on Business and the Community

- Location specific criteria used within the score sheet

Primary Impact: H&S

- Location specific criteria used within the score sheet

Phase	Sent / Rec'd	Sender	Notice Type	Notice Date	Notice Comments	Proposed Start	Estimated End	Actual Start	Actual End	Works Description	Location Description
1	R	UCA	Forward planning information	16-Dec-10		01-Apr-11	31-Mar-12			REPLACEMENT OF GAS MAINS	
1	R	UCA	Initial Notice	03-Feb-11		09-May-11	17-Oct-11			REPLACEMENT OF GAS MAINS	
1	R	UCA	Confirmation Notice	21-Apr-11		09-May-11	17-Oct-11			REPLACEMENT OF GAS MAINS	
1	R	UCA	Actual Start Date	11-May-11	Actual Start as per XX			11-May-11			
1	S	HAA	Works Comments	26-May-11	I have been informed that these works are not actually ongoing at this very moment. Please can someone contact me to discuss the continuation of this notice as the public are getting involved.						
1	S	HAA	Works Comments	04-Jul-11	Notice is 'in progress' yet works still not started.						

APPENDIX D: TESTING THE SENSITIVITY OF THE RESULTS

This Appendix provides background data for a sensitivity check of Case Study 1.

Firstly specific inputs (such as traffic flow and hourly rate) are changed in both Scenarios, and the sensitivity of the outputs is tested. Secondly, the sensitivity check demonstrates how changes to inputs affect the same Scenario. Hence, specific inputs are changed in Scenario 1 only, so that the 'before' and 'after' values for Scenario 1 can be tested when different input values have been used. A graphical interpretation of the same is also generated. Finally, the sensitivity check demonstrates how the ROI changes when input values for both Scenarios are altered.

Sensitivity Check

If the value for traffic flow is changed by 10%, the following results are also adjusted by 10% because they are directly proportional:

- Total delay cost
- Total fuel consumption
- Total carbon emissions

In addition, the value for noise increases in this case because traffic flow has been used as a proxy measurement. Therefore if local traffic surveys are available then these data should replace the assumed AADT figures given in DfT (2004b) to reduce uncertainty. This is even more important if traffic flow is being used as a proxy measurement for noise.

Table D-1: Result of Case Study 1 where a +10% variation is used for traffic flow

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	% Variation for Scenario 1	% Variation for Scenario 2
Traffic flow	11,000	11,000	110.0%	110.0%
Total delay cost	£21,889	£16,481	110.0%	110.0%
Total fuel consumption	£0	£0	110.0%	110.0%
Total carbon emissions	£0	£0	110.0%	110.0%
Noise (using total traffic delay as proxy)	187,000	140,800	110.0%	110.0%

Table D-2: Result of Case Study 1 where a -10% variation is used for traffic flow

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	% Variation for Scenario 1	% Variation for Scenario 2
Traffic flow	9,000	9,000	90.0%	90.0%
Total delay cost	£17,910	£13,485	90.0%	90.0%
Total fuel consumption	£0	£0	90.0%	90.0%
Total carbon emissions	£0	£0	90.0%	90.0%
Noise (using total traffic delay as proxy)	153,000	115,200	90.0%	90.0%

Table D-3: Result of Case Study 1 Scenario 1 when traffic flow is changed by 10%

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	Scenario 1: Traffic flow + 10%	Scenario 1: Traffic flow - 10%
Traffic flow	10,000	10,000	110%	90%
Total delay cost	£19,899	£14,983	110%	90%
Total fuel consumption	£34,036	£25,627	110%	90%
Total carbon emissions	£153	£115	110%	90%
Noise (using total traffic delay as proxy)	170,000	128,000	110%	90%

The ROI for road user delays, fuel, carbon (and therefore 'all' monetised impacts) is also altered by 10%, because a directly proportional relationship exists. For example if the traffic flow is greater, the savings in vehicle delays are therefore greater, and hence a greater return on investment is achieved. The ROI for community impact and safety is still a reduction of the score by '1', and the formula for this calculation does not include traffic flow, so these ROIs remain unchanged. However, the scale of different between Scenario 1 and Scenario 2 still justifies the scoring used.

Table D-4: Result for ROI in Case Study 1 when traffic flow is changed by 10%

	Original ROI	Type of Return	ROI when traffic flow varies +10%	ROI when traffic flow varies -10%
ROI (road user delays valued as a cost)	£2.19	for each £1 spent	110%	90%
ROI (cost of fuel)	£3.75	for each £1 spent	110%	90%
ROI (tonnes of carbon)	0.0001	tonnes of carbon for each £1 spent	110%	90%
ROI (cost of carbon)	£0.0169	for each £1 spent	110%	90%
ROI (all monetised impacts)	£5.97	for each £1 spent	110%	90%
ROI (community impact)	£2,240	to reduce impact score from '3' to '2'	100%	100%
ROI (H&S)	£2,240	to reduce impact score from '2' to '1'	100%	100%

If the number of days work is increased by 10%, the following results are increased by 10% because they are directly proportional:

- Total delay cost
- Total fuel consumption
- Total carbon emissions

In addition, UCA costs for labour increase by 10% in Scenario 2 only. This is because the labour costs of manually controlling traffic signals are being tested in the Case Study, and these labour costs are zero in Scenario 1, because the signals are not manually controlled.

This is important input data for this Case Study because the staff costs of controlling traffic signals are central to its aim and objective, but if a future scheme is being assessed there should not be a great deal of uncertainty to its value, as long as the actual duration of the work is recorded.

Table D-5: Result of Case Study 1 where a +10% variation is used for the number of days worked

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	% Variation for Scenario 1	% Variation for Scenario 2
No. days	30.8	30.8	110.0%	110.0%
Total delay cost	£21,889	£16,481	110.0%	110.0%
Total fuel consumption	£0	£0	110.0%	110.0%
Total carbon emissions	£0	£0	110.0%	110.0%
UCA costs for labour	£0	£2,464	100.0%	110.0%

Table D-6: Result of Case Study 1 where a -10% variation is used for the number of days worked

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	% Variation for Scenario 1	% Variation for Scenario 2
No. days	25.2	25.2	90.0%	90.0%
Total delay cost	£17,910	£13,485	90.0%	90.0%
Total fuel consumption	£0	£0	90.0%	90.0%
Total carbon emissions	£0	£0	90.0%	90.0%
UCA costs for labour	£0	£2,016	100.0%	90.0%

Table D-7: Result of Case Study 1 Scenario 1 when the number of days worked is changed by 10%

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	Scenario 1: Days worked + 10%	Scenario 1: Days worked - 10%
No. days	28	28	110%	90%
Total delay cost	£19,899	£14,983	110%	90%
Total fuel consumption	£34,036	£25,627	110%	90%
Total carbon emissions	£153	£115	110%	90%

The ROI for 'all' monetised impacts does not alter, because the numerator and denominator in each case are both changed by 10%, thereby cancelling each other out. This reflects the fact that the returns (savings in delays, fuel consumption and carbon emissions) are all proportional to the duration of the work, as is the 'investment' being made in each case (labour costs). The 'return' for the community impact and safety ROIs is still a reduction in the scoring of 1, and this reduction in score is independent of the duration of the work. However, the 'investment' has increased in each case, because labour costs are proportional to the duration of the work, and therefore these two ROIs are reduced.

Table D-8: Result for ROI in Case Study 1 when the number of days worked is changed by 10%

	Type of Return	Original ROI	ROI when number of days worked varies + 10%	ROI when number of days worked varies - 10%
ROI (road user delays valued as a cost)	for each £1 spent	£2.19	100%	100%
ROI (cost of fuel)	for each £1 spent	£3.75	100%	100%
ROI (tonnes of carbon)	tonnes of carbon for each £1 spent	0.0001	100%	100%
ROI (cost of carbon)	for each £1 spent	£0.0169	100%	100%
ROI (all monetised impacts)	for each £1 spent	£5.97	100%	100%
ROI (community impact)	to reduce impact score from '3' to '2'	£2,240	90%	110%
ROI (H&S)	to reduce impact score from '2' to '1'	£2,240	90%	110%

If the cost of time for road user delays is increased by 10%, the following results are increased by 10% because they are directly proportional:

- Cost of time per second
- Total delay cost

This is a standard cost-of-time value used in traffic appraisals (DfT, 2011b) so there is not uncertainty in the same way that exists for other input data.

Table D-9: Result of Case Study 1 where a +10% variation is used for the cost of time

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	% Variation for Scenario 1	% Variation for Scenario 2
Cost of time per hour (2011 values)	£16.56	£16.56	110.0%	110.0%
Cost of time per second	£0.005	£0.005	110.0%	110.0%
Total delay cost	£21,889	£16,481	110.0%	110.0%

Table D-10: Result of Case Study 1 where a -10% variation is used for the cost of time

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	% Variation for Scenario 1	% Variation for Scenario 2
Cost of time per hour (2011 values)	£13.55	£13.55	90.0%	90.0%
Cost of time per second	£0.004	£0.004	90.0%	90.0%
Total delay cost	£17,910	£13,485	90.0%	90.0%

Table D-11: Result of Case Study 1 Scenario 1 when cost of time is changed by 10%

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	Scenario 1: Cost of time + 10%	Scenario 1: Cost of time - 10%
Cost of time per hour used	£16.56	£15.05	110%	90%
Cost of time per second	£0.004	£0.004	110%	90%
Total delay cost	£19,899	£14,983	110%	90%

As expected if the cost of time increases, the ROI with respect to time saved also increases. This also has the effect of increasing the ROI for 'all' monetised impacts.

Table D-12: Result for ROI in Case Study 1 when the cost of time is changed by 10%

	Type of Return	Original ROI	ROI when cost of time varies +10%	ROI when cost of time varies - 10%
ROI (road user delays valued as a cost)	for each £1 spent	£2.19	110%	90%
ROI (cost of fuel)	for each £1 spent	£3.75	100%	100%
ROI (tonnes of carbon)	tonnes of carbon for each £1 spent	0.0001	100%	100%
ROI (cost of carbon)	for each £1 spent	£0.0169	100%	100%
ROI (all monetised impacts)	for each £1 spent	£5.97	104%	96%
ROI (community impact)	to reduce impact score from '3' to '2'	£2,240	100%	100%
ROI (H&S)	to reduce impact score from '2' to '1'	£2,240	100%	100%

If the delay per vehicle is increased by 10%, the following results are increased by 10% because they are directly proportional:

- Total delay cost
- Total fuel consumption
- Total carbon emissions

The total delay cost, fuel consumption and carbon emissions make up the monetised costs used in the ROI tables, so clearly this particular input parameter is especially important because there is uncertainty regarding its accuracy, and small changes will affect several impacts measured as costs. These cost-based measures of a ROI are likely to grab the attention more than criterion scores. Therefore it is recommended that average delay per vehicle is measured on site so that these data can be compared with the value predicted by DfT (2004b). This is important because there is an uncertainty inherent within the value.

In addition, noise increases by 10% because in this Case Study, traffic flow has been used as a proxy measurement. In other cases, noise is proportional to the duration of the work and so would not change if delay per vehicle was changed.

Table D-13: Result of Case Study 1 where a +10% variation is used for delay per vehicle

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	% Variation for Scenario 1	% Variation for Scenario 2
Delay per vehicle	18.7	14.1	110.0%	110.0%
Total delay cost	£21,889	£16,481	110.0%	110.0%
Total fuel consumption	£0	£0	110.0%	110.0%
Total carbon emissions	£0	£0	110.0%	110.0%
Noise (using total traffic delay as proxy)	187,000	140,800	110.0%	110.0%

Table D-14: Result of Case Study 1 where a -10% variation is used for delay per vehicle

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	% Variation for Scenario 1	% Variation for Scenario 2
Delay per vehicle	15.3	11.5	90.0%	90.0%
Total delay cost	£17,910	£13,485	90.0%	90.0%
Total fuel consumption	£0	£0	90.0%	90.0%
Total carbon emissions	£0	£0	90.0%	90.0%
Noise (using total traffic delay as proxy)	153,000	115,200	90.0%	90.0%

Table D-15: Result of Case Study 1 Scenario 1 when the delay per vehicle is changed by 10%

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	Scenario 1: Delay per vehicle + 10%	Scenario 1: Delay per vehicle - 10%
Delay per vehicle (seconds)	17.0	12.8	110%	90%
Total delay cost	£19,899	£14,983	110%	90%
Total fuel consumption	£34,036	£25,627	110%	90%
Total carbon emissions	£153	£115	110%	90%
Noise (using total traffic delay as proxy)	170,000	128,000	110%	90%

If the delay per vehicle is changed this has the effect that all monetised impacts are also changed by a similar amount, because a directly proportional relationship exists in the formula for ROI in each case. The community impact and safety scores are not dependent on the average delay in the same way, and because the UCA labour costs do not change, neither ROI is affected. However, it is argued that the difference between both Scenarios still justifies this reduction in scoring of ‘1’.

Table D-16: Result for ROI in Case Study 1 when the delay per vehicle is changed by 10%

	Type of Return	Original ROI	ROI when delay per vehicle varies + 10%	ROI when delay per vehicle varies - 10%
ROI (road user delays valued as a cost)	for each £1 spent	£2.19	110%	90%
ROI (cost of fuel)	for each £1 spent	£3.75	110%	90%
ROI (tonnes of carbon)	tonnes of carbon for each £1 spent	0.0001	110%	90%
ROI (cost of carbon)	for each £1 spent	£0.0169	110%	90%
ROI (all monetised impacts)	for each £1 spent	£5.97	110%	90%
ROI (community impact)	to reduce impact score from '3' to '2'	£2,240	100%	100%
ROI (H&S)	to reduce impact score from '2' to '1'	£2,240	100%	100%

If the hourly labour rate for UCA is increased by 10%, the following results are increased by 10% because they are directly proportional:

- UCA total labour costs (only applicable to Scenario 2)

Table D-17: Result of Case Study 1 where a +10% variation is used for UCA hourly labour rates

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	% Variation for Scenario 1	% Variation for Scenario 2
Hourly rate for labour	0	£22.00	100.0%	110.0%
UCA costs for labour	£0	£2,464	100.0%	110.0%

Table D-18: Result of Case Study 1 where a -10% variation is used for UCA hourly labour rates

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	% Variation for Scenario 1	% Variation for Scenario 2
Hourly rate for labour	0	£18.00	100.0%	90.0%
UCA costs for labour	£0	£2,016	100.0%	90.0%

In terms of a ROI, all values are altered when the UCA hourly rate changes. This is to be expected, because in Case Study 1 the investment being considered is the cost of UCA additional labour required to operate the traffic signals, and therefore all formulas for a ROI are changed when this investment changes.

Table D-19: Result for ROI in Case Study 1 when the UCA hourly rate is changed by 10%

	Type of Return	Original ROI	ROI when UCA rate varies + 10%	ROI when UCA rate varies - 10%
ROI (road user delays valued as a cost)	for each £1 spent	£2.19	91%	110%
ROI (cost of fuel)	for each £1 spent	£3.75	91%	110%
ROI (tonnes of carbon)	tonnes of carbon for each £1 spent	0.0001	91%	110%
ROI (cost of carbon)	for each £1 spent	£0.0169	91%	110%
ROI (all monetised impacts)	for each £1 spent	£5.97	91%	110%
ROI (community impact)	to reduce impact score from '3' to '2'	£2,240	91%	110%
ROI (H&S)	to reduce impact score from '2' to '1'	£2,240	91%	110%

There is uncertainty to these data (UCA hourly rates), but the original data are commercially sensitive. However, it is hoped that original data will replace these estimates wherever possible (i.e. actual pay rates), but the methodology will still need to be used if these data are not available. In any case, it is still possible to compare different scenarios if one hourly rate is used.

If the costs associated with HAA staff costs are increased by 10% then this is the only impact to be increased. Again, there is uncertainty to these data, but this is because the original data are commercially sensitive.

Table D-20: Result of Case Study 1 where a +10% variation is used for HAA staff costs

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	% Variation for Scenario 1	% Variation for Scenario 2
HAA additional time spent	£484	£0	110.0%	100.0%

Table D-21: Result of Case Study 1 where a -10% variation is used for HAA staff costs

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	% Variation for Scenario 1	% Variation for Scenario 2
HAA additional time spent	£396	£0	90.0%	100.0%

Table D-22: Result of Case Study 1 Scenario 1 when the HAA hourly rate is changed by 10%

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	Scenario 1: HAA rate + 10%	Scenario 1: HAA rate - 10%
HAA additional time spent on scheme	£440	£0	110%	90%

In terms of a ROI, the HAA labour costs do not feature in the formula for any ROI and therefore the ROI results are not affected. There is some justification for this, as these council staff costs would still have accrued without any problems during the project, so they are not specifically a 'return' on the investment made.

Table D-23: Result for ROI in Case Study 1 when the HAA hourly rate is changed by 10%

	Type of Return	Original ROI	ROI when HAA rate varies +10%	ROI when HAA rate varies -10%
ROI (road user delays valued as a cost)	for each £1 spent	£2.19	100%	100%
ROI (cost of fuel)	for each £1 spent	£3.75	100%	100%
ROI (tonnes of carbon)	tonnes of carbon for each £1 spent	0.0001	100%	100%
ROI (cost of carbon)	for each £1 spent	£0.0169	100%	100%
ROI (all monetised impacts)	for each £1 spent	£5.97	100%	100%
ROI (community impact)	to reduce impact score from '3' to '2'	£2,240	100%	100%
ROI (H&S)	to reduce impact score from '2' to '1'	£2,240	100%	100%

If the noise measurement is increased by 10% then this is the only impact to be increased.

Table D-24: Result of Case Study 1 where a +10% variation is used for noise

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	% Variation for Scenario 1	% Variation for Scenario 2
Noise (using total traffic delay as proxy)	187,000 vehicles	140,800 vehicles	110.0%	110.0%

Table D-25: Result of Case Study 1 where a -10% variation is used for noise

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	% Variation for Scenario 1	% Variation for Scenario 2
Noise (using total traffic delay as proxy)	153,000 vehicles	115,200 vehicles	90.0%	90.0%

Table D-26: Result of Case Study 1 Scenario 1 when noise is changed by 10%

	Scenario 1: Automatic traffic signals used	Scenario 2: Manually controlled traffic signals used	Scenario 1: Noise + 10%	Scenario 1: Noise - 10%
Noise (using total traffic delay as proxy)	170,000	128,000	110%	90%

In terms of a ROI, noise does not feature specifically in any of the ROI formulas and therefore the ROI results are not affected. However, the reduction in noise created by queuing traffic is partly taken in to account by reducing the community impact score from ‘3’ to ‘2’.

It should be noted that in this Case Study noise is measured by proxy through traffic flow. In other case studies noise is measured as the duration of the work multiplied by a constant. Therefore, the true uncertainty lies in the values used for traffic flow, duration of the work and the average noise created by streetworks (the methodology uses a value of 78dB). Alternatively, a more structured approach would be to simply record noise at several different types of site, so that these measurements can replace the predicted value. If sufficient site measurements were taken, the uncertainty in the site data themselves could become established, rather than relying on a predicted or proxy value.

Table D-27: Result for ROI in Case Study 1 when noise is changed by 10%

	Type of Return	Original ROI	ROI when noise varies + 10%	ROI when noise varies - 10%
ROI (road user delays valued as a cost)	for each £1 spent	£2.19	100%	100%
ROI (cost of fuel)	for each £1 spent	£3.75	100%	100%
ROI (tonnes of carbon)	tonnes of carbon for each £1 spent	0.0001	100%	100%
ROI (cost of carbon)	for each £1 spent	£0.0169	100%	100%
ROI (all monetised impacts)	for each £1 spent	£5.97	100%	100%
ROI (community impact)	to reduce impact score from '3' to '2'	£2,240	100%	100%
ROI (H&S)	to reduce impact score from '2' to '1'	£2,240	100%	100%

Finally, it is important to show a graphical interpretation of one Case Study both ‘before’ and ‘after’ different input values have been used. This is illustrated in Figures D-1 to D-4 by adjusting the duration of the work in Scenario 1 by 10%. As reflected in Tables D-5, D-6 and D-7 this has the effect that delay cost, fuel consumption and carbon emissions are increased by 10% in the ‘after’ graph because they are directly proportional to the duration of the work. UCA labour costs are not increased in Scenario 2 because the duration remains the same – only the duration of Scenario 1 is changed between the ‘before’ and ‘after’ situation.

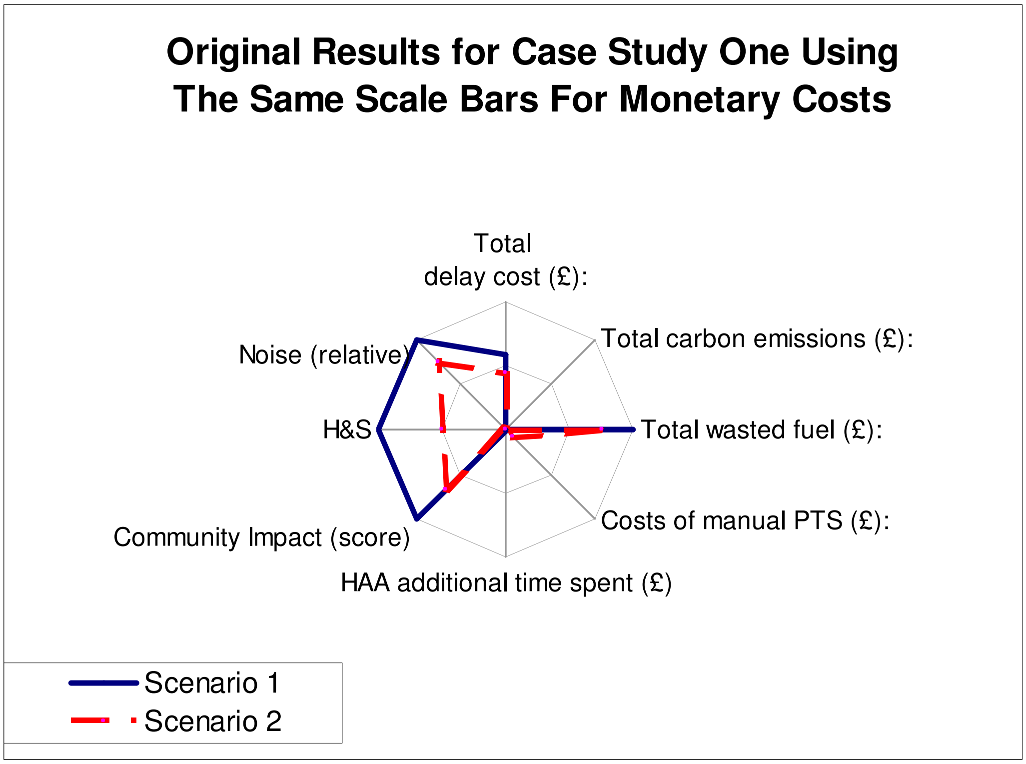

Figure D-1: Original Results for Case Study One using the same scale bars for monetary costs; Scenario 2 figures included for comparison.

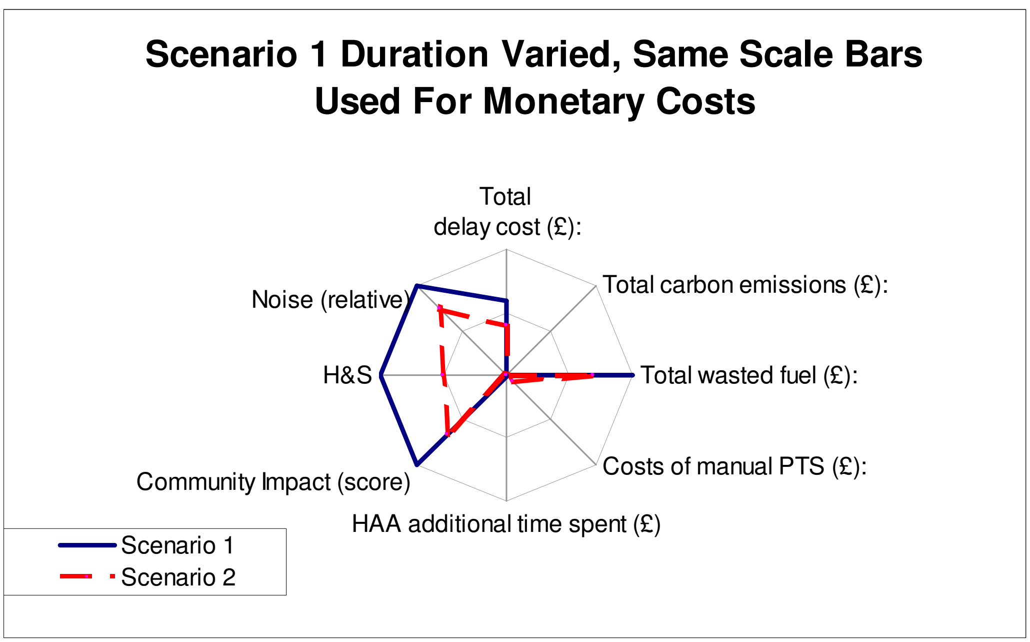

Figure D-2: Results when the duration is varied for Scenario 1, using the same scale bars for monetary costs; Scenario 2 figures included for comparison.

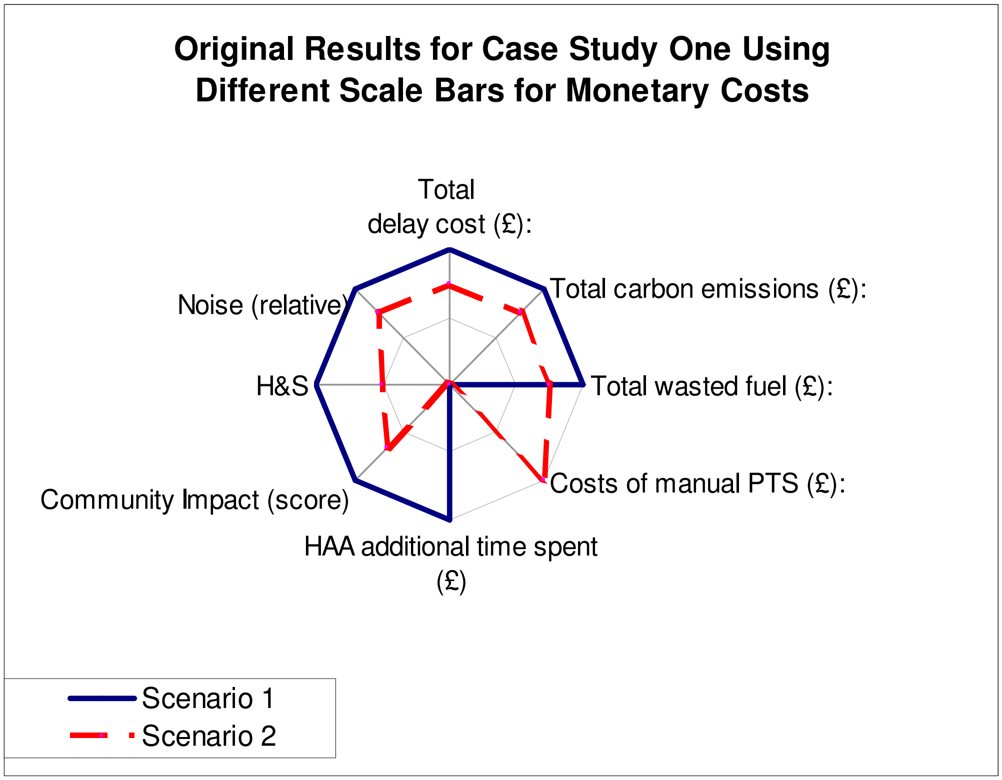

Figure D-3: Original Results for Case Study One using different scale bars for monetary costs; Scenario 2 figures included for comparison.

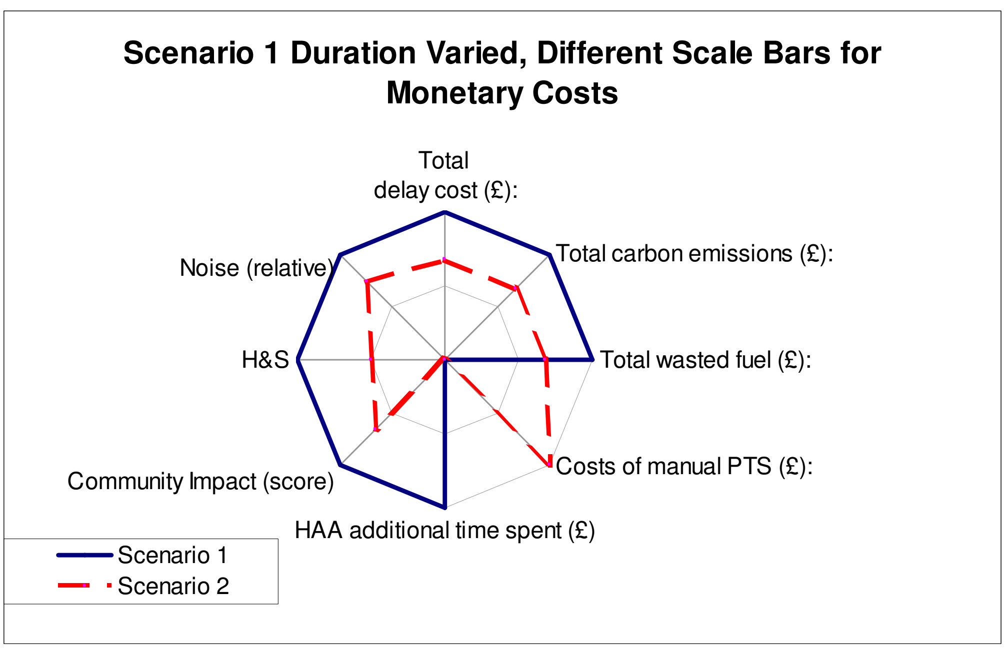

Figure D-4: Results when the duration is varied, using different scale bars for monetary costs; Scenario 2 figures included for comparison.

APPENDIX E: COMPARISON WITH CEEQUAL

Version: D&C-v4.1b(PA)

DESIGN & CONSTRUCT AWARD PRE-ASSESSMENT SPREADSHEET VERSION 4.0

PROJECT NAME: Russell Hayes

this should be entered on the Project Information Sheet along with all other background information

Section 1 - Project Management

Section and Ques No.	Section Titles & Question topics	Scope Out 'Y' or 'N'	Design Score	Const.Score	Max Total Score	Initial Assess. Score as at 02/11/2012	Evidence for scores awarded or reason for scoping out	Potential Score Still to Come	Evidence Required to achieve Potential Score	Potential Final Score
1.1.1	Was there a documented commitment to consider and assess the environmental aspects for each stage of the project?	NSO	2	2	4	4	Assumption that quality assurance procedures and project management are undertaken - project briefing and overall Scope of Works are created			4
1.1.2	Is there clear evidence that a member of the project team was identified as responsible for managing the environmental aspects of the project and was aware of the duties and responsibilities involved?	NSO	4	4	8	8	Assumes that other parties use the same Project Environmental Coordination (PEC) review as MM			8
1.1.3	Have the environmental impacts, opportunities for environmental enhancements and associated social issues been: (a) identified and clearly recorded for each stage, and (b) prioritised according to significance?	NSO	10	10	20	20	Screening exercise by a qualified environmental specialist			20
1.2.1	Have appropriate mechanisms been put in place to manage the project's environmental issues, impacts and opportunities?	NSO	4	4	8	8	Assumes that Environmental Management Plan (EMP) for small works is created, and identification of issues (local business, residence, pollution rosks and waste management, material use) is carried out			8
1.2.2	Have regular checks been made to ensure that these mechanisms have been implemented?	NSO	4	4	8	8	Designers and Supervising Engineer to carry out these checks			8
1.2.3	Is there a record of actions to be taken as a result of these checks, with individuals identified and timeframes stipulated?	NSO	2	2	4	4	Minutes and Actions from site inpsections required			4
1.2.4	Have the results (success or otherwise) of the implementation of these mechanisms been assessed?	NSO	4	4	8	8	KPI measures should form part of the contract			8

1.2.5	Has there been a programme of training on environmental and social issues relevant to the project delivered at an appropriate level for those engaged in the project?	NSO	6	6	12	12	Design briefings and site inductions to be carried out			12
1.2.6	Is there evidence that the project team actively considered the principles of sustainable development in the planning, design and construction of the project?	NSO	6	2	8	8	Feasibility / screening exercise required			8
1.3.1	Have all those directly engaged in the project been informed of the significant environmental impacts and associated social issues of their part and/or stage of the project?	NSO	4	4	8	8	Assumes Yes			8
1.3.2	Did the selection procedure for: (a) the principal designer (b) the main contractor (c) the key sub-contractor's), consider their past environmental performance?	N	12	6	18	18	Assumes that normal systems of procuring contractors was in place			18
1.4.1	Is there clear evidence that the client and the design team have adopted a whole-life approach to environmental aspects of the project?	NSO	10		10	0	If used, the assessment tool will allow this criterion to be scored 10/10			0
1.4.2	Did the whole-life approach include consideration of the potential effects of predicted climate change scenarios, leading to appropriate adaptation strategies?	NSO	10		10	0	If used, the assessment tool will allow this criterion to be scored 10/11			0
1.4.3	Is there evidence that the design team has addressed the environmental and social implications of different construction methods and materials (including their whole life cycle) for the project (for example, through workshops, briefing papers or an environmental statement)?	NSO	8		8	8	This criterion is partly the objective of the assessment tool created by the research.			8
1.4.4	Have specific targets been set during the design process for the environmental and social performance of the project during construction and is progress towards them monitored?	NSO	6		6	6	This has been considered in the case study - constraints such as the location of the works and the timing of manually controlled traffic signals create targets that will help to score this criterion.			6
1.4.5	Have specific targets been set during the design process for the environmental and social performance of the project during operation or once in use, and is there a monitoring programme in place for the operational phase?	N	8		8	8	YES- the targets here would be the start and end timing for the project, the inspection of the highway by HAA, and the monitring of the repairs by SGN.			8

1.4.6	At design stage, was an assessment of risk undertaken and/or a pollution control plan prepared to minimise emissions of the completed works to air, land and water?	NSO	8		8	8	No residual impacts due to nature of works (this will change based on the type of work being undertaken)			8
1.5.1	Is there evidence that the construction team proposed changes to the specifications to improve the whole-life environmental performance of the project, that is, during the rest of the construction stage, during operation and/or in easing its re-use or ultimate disassembly?	NSO		8	8	0	Assumed No			0
1.5.2	Has a pollution control plan or a pollution section of the SEMP been prepared to specify actions to prevent and mitigate pollution to air, land and water during construction, and has it been implemented?	NSO		8	8	8	Method Statement and contract to specify			8
			Section Total		172	144		0		144
				Section %		83.72%		0.00%		83.72%

Section 2 - Land Use

2.1.2	Has a desk study been undertaken that assists the client in deciding that thier chosen site is suitable, including collation of information on past and current land uses, site sensitivities and land condition, and including review of previous investigations into ground stability, soil quality, groundwater, ground gases, residual man-made structures and surrounding land uses?	NSO	10		10	10	No other option available - repairs have to be carried out where they occur			10
2.1.3	Has the land-take of different scheme designs, process designs and layouts of the planned works been calculated and have these calculations influenced the design process and the land-use efficiency of the final design?	Y	0		0	0	N/A			0
2.1.5	Is there evidence that the construction team has made effective use of land resources made available to them, and minimised the long-term adverse impacts of the temporary greenfield land-take during construction?	NSO		5	5	5	No relevance to in-road works, but effect of welfare and storage of materials may require considerations.			5
2.1.6	Is there evidence that the project has improved the capability and/or productivity of the land resource?	y	0		0	0	not relevant to streetworks			0

2.1.7	Apart from the actual land-take, did the design or construction of the project also take into consideration the conservation of topsoils, subsoil and conservation or use of on-site mineral resources?	y	0		0	0	not relevant to streetworks			0
2.2.1 a)	Was the desk study covered by Question 2.1.2 a formal Phase 1 Desk Study assessing risk and implications that may be associated with the land including issues related to soil, groundwater, gas, residual man-made structures and surrounding land uses, or has it been extended into such a formal Phase 1 Desk Study?	NSO	5		5	0	not relevant to streetworks			0
2.2.1 b)	Did the study go beyond the above scoring to provide additional input to project decision-making?	y	0		0	0	not relevant to streetworks			0
2.2.2	If the studies mentioned in 2.2.1 have suggested that contamination may be present on site, has a suitably experienced chartered environmental specialist or even a SiLC been consulted?	y	0		0	0	not relevant			0
2.2.3	If contamination was present on site, was the site assessed in line with CLR11?	y	0		0	0	not relevant			0
2.2.4	If the site had been contaminated and remediation was part of the CEEQUAL-assessed work, what was the remedial solution?	y	0		0	0	not relevant			0
2.2.5	If ground-generated gases were present, was there evidence of risk reduction and management in place and fully implemented?	Y	0		0	0	not relevant			0
2.2.6	Is there evidence that the impacts of the implementation of the remedial solution have been assessed and appropriate control measures been put in place?	y		0	0	0	not relevant			0

2.2.7	Is there evidence that the effectiveness and durability of the remedial solution and maintenance and monitoring, have been considered over the lifetime of the project and beyond and operational information conveyed to the operator?	y	0		0	0	not relevant			0
2.2.8	Is there evidence that pollution control measures are in place to prevent any future contamination of the site?	y	0		0	0	not relevant			0
2.3.1	Have the run-off, flood risk, and potential increased flood risk elsewhere as a result of the completed works all been assessed over their expected working life, in line with the requirements of PPS25 in England, TAN15 in Wales, PPS15 in Northern Ireland or equivalent, and appropriate flood resilience measures included in the design?	NSO	15		15	15	Assumed to be designed into scheme - reinstatement materials etc specified			15
2.3.2	Is there evidence that the design team has actively considered the merits of designing for a larger event or for greater flood resilience than required by PPS25 or appropriate equivalent?	y	0		0	0	not relevant to streetworks			0
2.3.3	If the consideration assessed in question 2.3.2 led to proposals for designing for a larger event or greater flood resilience than required by PPS25 or its equivalents, is ther evidence that those features have actually been included in the design and incorporated in the project?	y	0		0	0	not relevant to streetworks			0
2.3.4	Is there evidence that the project team has made provision for capturing run-off for beneficial use on the project or nearby and if appropriate, have those provisions actually been incorporated in the completed project?	y	0	0	0	0	not relevant to streetworks			0
			Section Total		35	30		0		30
				Section %		85.71%		0.00%		85.71%

Section 3 - Landscape Issues (includes rural landscape and townscape)

3.1.1	Is there evidence that landscape and visual factors have been considered at each stage of the project, including the evaluation of scheme options?	NSO	2	2	4	4	not relevant to streetworks			4

3.1.2	Is there evidence that there has been a suitable level of consultation on, or consideration given to the permeability of the development to pedestrians and cyclists, links with existing and proposed routes to local services, links between communities, the quality of new open space and its position within the hierarchy of local amenity space provision?	NSO	5		5	5	not relevant to streetworks			5
3.1.3	Have opportunities been taken during design to introduce new public amenity features including any identified in 3.1.2 or to enhance existing ones over and above the minimum required by planning guidance, legislation or the functioning of the facility?	y	0		0	0	not relevant to streetworks			0
3.1.4	Is there evidence that the project design fits the local character in terms of: landforrm or levels, materials, planting, style/detailing, scale, landscape/townscape pattern?	NSO	18		18	18	not relevant to streetworks			18
3.2.2	Are the landscape proposals in accordance with the aims of applicable landscape development or enhancement policies published by the relevant local, regional or national authority?	Y	0		0	0	not relevant to streetworks			0
3.2.3	Is there evidence that a) the project team have actively considered retention of trees and other vegetation as part of design; and/or b) that the layout design has been influenced by the results of a tree survey carried out by a suitably qualified arboriculturist in accordance with the current version of BS5837: Trees in Relation to Construction or equivalent?		11		11	11	May be requried if work incudes footway works to alter utilities, but in this case 'no'			11
3.2.4	Is there evidence that trees and other vegetation that were to be retained as part of design have been adequately protected and effects mitigated during construction?	N		10	10	10	Assumed yes			10
3.2.5	What percentage of substantial trees, trees protected by a Tree Preservation Order, other trees of value and/or substantial hedgerows present on the site have been retained as part of the design?	Y	0		0	0	not relevant to this particular case study			0
3.2.6	Has any other loss of valuable, distinctive or historic landscape features been: a) not balanced b) balanced by proposals within the project c) exceeded or bettered by proposals in the project d) avoided altogether?	y	0		0	0	not relevant to streetworks			0

3.3.1	Has a system or plan been formulated during the design process and implemented during the construction period to ensure that current best practice was applied for planting or habitat areas: to avoid any damage to landscape features; to safeguard soil conditions; to safeguard water conditions?	NSO	3	5	8	8	Assumed yes			8
3.3.2	Does the plan referred to in Question 3.3.1 also reflect the commitments and proposals made during the planning consents process?	N	8		8	8	Unlikely to be requried but NRSWA Notices etc are required so it may apply. Assumed yes			8
3.3.3	Have opportunities been taken for advance works, such as planting prior to construction, thus enabling plants to become established during the construction phase?	Y	0		0	0	not relevant to streetworks			0
3.4.1	Does the management plan for the scheme include objectives for the creation and management of different habitat and vegetation types, specify monitoring requirements and set a date for ongoing review of the plan?	Y	0		0	0	not relevant to streetworks			0
3.4.2	Is there evidence that appropriate funding is in place and appropriately skilled personnel commissioned to undertake the implementation of the management plan, monitoring of establishment and review of objectives and management prescriptions?	Y	0		0	0	not relevant to streetworks			0
			Section Total		64	64		0		64
				Section %		100.00%		0.00%		100.00%

Section 4 - Ecology and Biodiversity

4.1.1	Is the project, including land used for temporary works, being placed on or using land that has been identified as of high ecological value or as having species of high value? (Note that points cannot be scored here unless surveys or desk studies are carried out to identify the ecological value of the site)	y	0		0	0	N/A			0
4.1.2	Has consultation with a relevant nature conservation organisation on the ecological impact of the proposals been undertaken and communicated to project team members at each stage of the project (planning, design and construction)?	y	0	0	0	0	N/A			0

4.1.3	Has an Ecological Works Plan or an ecological section in the Integrated Project Management Plan or SEMP been drawn up and then implemented during construction?	NSO	4	7	11	11	N/A			11
4.2.1	Have appropriate surveys for protected species been undertaken?	y	0	0	0	0	Assumed 'no'			0
4.2.2	If protected species were found on site, have plans for protecting these been: drawn up and approved / monitored / achieved?	y	0	0	0	0	N/A			0
4.2.3	If there were Schedule 9 species (W&C Act 1981 or Wildlife (Northern Ireland) Order 1985), injurious weeds, or other invasive plants or animals present on has: a Method Statement (or equivalent) been drawn up and approved for their control and management / has it been monitored / achieved?	y	0	0	0	0	N/A			0
4.3.1 a), b) & c)	Have recommendations been included in the design for: a) conserving existing ecological features (including BAP species and habitats) identified in an ecological assessment as being of value b) mitigating or compensating for any loss of such ecological features c) enhancing the ecological value of the site?	y	0		0	0	N/A			0
4.3.2	Is there evidence that the implementation of these recommendations has been monitored throughout the course of the contract?	y	0		0	0	N/A			0
4.3.3	Does monitoring data show that implementation of these measures has been successful?	y	0		0	0	N/A			0
4.4.1	Have recommendations or opportunities for enhancing existing wildlife habitats or creating new ones (including BAP species and habitat) been identified and incorporated in the project?	y	0	0	0	0	N/A			0

4.4.2	Have recommendations or opportunities for installing special structures or facilities for encouraging or accommodating appropriate wildlife (especially BAP species) been identified and incorporated in the project?	y	0	0	0	0	N/A			0
4.4.3	Is there evidence that the implementation of these recommendations is being monitored?	y		0	0	0	N/A			0
4.4.4	On completion of the construction stage, is there any evidence of a net increase in area of wildlife habitat compared to site baseline data?	y		0	0	0	N/A			0
4.5.1	Has a programme been drawn up for the ongoing ecological management of habitats and species conservation measures, including instructions for emergencies or abnormal events, to be handed over to the owner or managing agent of the completed project?	y	0		0	0	N/A			0
4.5.2	Is there a programme in place (for the years after project completion) for monitoring the success or otherwise of any management, habitat creation or translocation and species conservation measures undertaken on site?	y	0		0	0	N/A			0
			Section Total		11	11		0		11
				Section %		100.00%		0.00%		100.00%

Section 5 - The Historic Environment

5.1.1	Has a baseline historic environment study/survey been carried out at the project planning stage? And has it considered the full range of registered and non-registered historic environment assets?	NSO	10		10	10	May be issues in Conservation Areas but not for this case study			10
5.1.2	Has the baseline study/survey been: (a) prepared or authorised by a suitably qualified historic environment professional? (b) prepared to a recognised standard appropriate to the scope and location of the project?	NSO	8		8	8	May be issues in Conservation Areas but not for this case study			8
5.2.1	Have the relevant statutory consents been sought, approved and complied with at all project stages?	N	7		7	7	Assumed Yes			7

5.2.2	Have the relevant consultations been carried out with: (a) local government (b) national government agency (c) statutory amenity societies (d) other voluntary consultations with local and amateur public organisations	N	9		9	9	Assumed Yes			9
5.3.1	If statutory listed or registered heritage assets have been identified in 5.1.1, has: (a) the project design enabled their retention, restoration and successful re-use or integration into the development? (b) a future management strategy been agreed?	Y	0		0	0	not relevant to streetworks			0
5.3.2	Has the design successfully addressed any setting issues and provided a neutral or enhanced setting for listed buildings, scheduled monuments or historic landscape areas?	y	0		0	0	not relevant to streetworks			0
5.3.3	If the potential for significant below ground archaeological remains has been identified in 5.1.1 have the appropriate staged surveys been undertaken to establish the extent and condition prior to design being finalised? (These may include both non-intrusive and intrusive methods as identified in CIRIA Report C672)	y	0		0	0	not relevant to streetworks			0
5.3.4	If the surveys identified in 5.3.3 above have revealed the presence of significant archaeological remains has a mitigation strategy document been prepared for archaeological investigation and agreed with the relevant development control archaeologist?	y	0		0	0	not relevant to streetworks			0
5.3.5	If historic environment assets (whether listed, scheduled, registered or not) have been demolished or removed, has an appropriate mitigation design been developed and agreed with the relevant conservation regulator? (This may include relocation or restoration/replacement, or in-situ building recording)	y	0		0	0	not relevant to streetworks			0
5.3.6	Is there evidence that the mitigation designs referred to in 5.3.5 have been implemented, managed and monitored in accordance with a SEMP or other management framework?	y		0	0	0	not relevant to streetworks			0
5.3.7	Have sensitive receptors been cordoned off or other protection measures put in place to avoid accidental damage and have site staff received appropriate instruction (e.g. via Toolbox Talks)?	N		7	7	7	not relevant to streetworks			7

5.3.8	Has an appropriate historical environment professional (archaeologist, conservation architect or historic buildings specialist) been appointed to manage and inspect the mitigation works?	N		7	7	7	Assumed Yes			7
5.3.9	If restoration or enhancement works have been completed is there evidence that current best practice has been applied and historically appropriate materials used?	y	0	0	0	0	not relevant to streetworks			0
5.3.10	Has the project been able to contribute to maintaining key conservation skills and creating sustainable heritage employment?	y	0		0	0	not relevant to streetworks			0
5.4.1	Has the final output from the archaeological excavation or building recording works been prepared and agreed with the relevant regulator?	y	0		0	0	not relevant to streetworks			0
5.4.2	Has there been any public opportunity provided to learn about, observe or take part in any activity to understand or promote the historic environment local to the project?	y		0	0	0	not relevant to streetworks			0
			Section Total		48	48		0		48
				Section %		100.00%		0.00%		100.00%

Section 6 - Water Resources and the Water Environment

6.1.1 a)	Has a plan to control the impacts of the completed project on the water environment been produced and implemented?	NSO	15		15	15	deisgn should consider run off			15
6.1.1 b)	Has a plan to control the impacts of the project on the water environment during construction been produced and implemented?	NSO		15	15	15	Assumed yes working within 10m of water course etc			15
6.2.1	Has consultation been undertaken with Regulatory Authorities about water issues related to the project, including the need for any consents, and has the outcome been communicated to project team members at each stage of the project (planning, design and construction)?	NSO	3	3	6	6	Assumed yes working within 10m of water course etc			6

6.2.2	Have there been Regulatory actions during construction?	NSO		3	3	3	Inspection reports			3
6.3.1	Have measures to conserve water and reduce water consumption during operation of the completed project been incorporated in the design?	Y	0		0	0	not relevant to streetworks			0
6.3.2	Has a practical system been put in place to minimise consumption of mains or abstracted water during the construction process?	NSO		8	8	8	Unlikely to be relevant			8
6.3.3	At construction stage, has the amount of water used been measured and monitored, for example, by metering the input to the site?	NSO		5	5	5	Unlikely to be relevant			5
6.4.1	Have specific measures been taken to prevent pollution of groundwater or existing water features?	NSO	8	10	18	18	Construction methods to consider this			18
6.4.2	Have measures (or equipment) been incorporated in the project that will allow long-term monitoring of the project's impact on the water environment?	Y	0		0	0	Not relevant to streetworks unless water/drainage based repairs			0
6.4.3	Is there evidence that the incorporation of Sustainable Drainage Systems (SuDS) has been considered?	NSO	4		4	4	Assumed yes subject to specific works			4
6.4.4	Have Sustainable Drainage Systems been incorporated in the scheme where appropriate?	N	16		16	16	Assumed yes subject to specific works			16
6.4.5 a)	If the works could affect a body of ground or surface waters, has the water quality of that water body been monitored before construction and then regularly during construction in accordance with the regime identified as appropriate in the risk assessment?	N		6	6	6	Assumed yes subject to specific works			6

6.4.5 b)	If the monitoring shows no adverse effect / If the monitoring shows adverse effect, but effective mitigation measures can be demonstrated.	N		6	6	6	Assumed yes subject to specific works			6
6.4.6	Have the impacts on the water environment been considered for the operation and maintenance of the project?	N	6		6	6	Assumed yes subject to specific works			6
6.4.7	At construction stage, have existing water features been protected from degradation or physical damage by construction plant and processes?	N		5	5	5	Assumed yes subject to specific works			5
6.5.1	Have opportunities to improve the local water environment been included in the design and implemented?	N	16		16	16	Assumed yes subject to specific works			16
6.5.2	Have existing water features been incorporated (for example as an amenity and/or for site drainage) in the design of the project?	N	8		8	8	Assumed yes subject to specific works			8
			Section Total		137	137		0		137
				Section %		100.00%		0.00%		100.00%

Section 7 - Energy and Carbon

7.1.1	Has a life-cycle energy assessment been undertaken for the key materials and components to be used in the project?	NSO	10		10	10	Assumed yes using appropriate tool kit			10
7.1.2	What percentage of the energy consumption reduction identified in the life-cycle assessment has subsequently been incorporated in the design and the completed works?	NSO	20		20	8	Assumed yes using appropriate tool kit			8
7.1.3	Has a life-cycle carbon assessment been undertaken for the key materials and components to be used in the project?	NSO	10		10	10	Assumed yes using appropriate tool kit			10

7.1.4	What percentage of the carbon emission reduction identified in the life-cycle assessment has subsequently been incorporated in the design and the completed works?	NSO	20		20	20	Assumed yes using appropriate tool kit			20
7.2.1	Is there evidence that the design has considered options for reducing the energy consumption and carbon emissions of the project during operation, including the option of designing-out the need for energy-consuming equipment and the energy requirements in maintenance?	NSO	9		9	9	Assumed yes using appropriate design guidance			9
7.2.2	Is there evidence of appropriate measures having been incorporated to reduce energy consumption in use?	N	22		22	22	Assumed yes using approraite design guidance			22
7.2.3	Is there evidence that the design has explored opportunities for the incorporation of energy from renewable and/or low- or zero-carbon sources and thus a reduction in carbon emissions?	N	7		7	7	Assumed yes using approraite design guidance			7
7.2.4	Has energy from renewable and/or low-or zero-carbon sources been incorporated in the scheme where appropriate?	N	22		22	22	Assumed yes using approraite design guidance			22
7.3.1	Is there evidence that the project has considered the energy consumption of the project during construction?	NSO	4	6	10	10	Assumed yes using approraite design guidance			10
7.3.2	Is there evidence that the contractor has considered the carbon emissions of the project during construction?	NSO		6	6	6	Assumed requirement of contract completion			6
7.3.3	Is there evidence that the design has incorporated appropriate measures to reduce energy consumption during construction where feasible?	N	12		12	12	Assumed requirement of contract completion			12

7.3.4	Is there evidence that the contractor has considered appropriate measures to reduce energy consumption and/or carbon emissions during construction and have these been incorporated through an energy management plan, or energy management section of a SEMP or Integrated Project Plan?	NSO		12	12	12	Assumed yes			12
7.3.5	Has the procurement, maintenance and use of construction plant been influenced by consideration of their energy efficiency, energy type or carbon emissions?	NSO		7	7	7	Assumed yes			7
7.3.6	Has energy from renewable and/or low- or zero-carbon resources been used during construction?	NSO		7	7	7	Assumed yes			7
7.3.7	Is there evidence that construction plant and ancillary equipment has been maintained to maximise fuel efficiency and minimise carbon emissions?	NSO		6	6	6	Assumed yes			6
7.3.8	Is there evidence that energy use has been monitored and controlled on site as and where possible?	NSO		10	10	10	Assumed yes			10
			Section Total		190	178		0		178
				Section %		93.68%		0.00%		93.68%

Section 8 Material Use

8.1.1	Was a plan that makes recommendations for material use to minimise environmental impact drawn up?	NSO	6	6	6	Standard requirement of specifications and contracts			6
8.1.2	Has this plan been implemented?	NSO	12	12	12	Standard requirement of specifications and contracts			12
8.2.1	Is there evidence that the selection and use of prefabricated units has been considered on the merit of their environmental benefits?	NSO	6	6	6	Standard requirement of specifications and contracts			6

8.2.2	Have the outcomes of this consideration been implemented?	N	6		6	6	Standard requirement of specifications and contracts			6
8.2.3	Has an assessment been made at design stage to ensure optimisation of cut and fill to reduce the quantity of excavated material to be taken off site?	N	4		4	4	Standard requirement of specifications and contracts			4
8.2.4	What percentage by volume of excavated material that is suitable for use, has been beneficially re-used on-site?	N	10		10	2	Standard requirement of specifications and contracts			2
8.2.5	Have subsoil and topsoil been separated and stored correctly for re-use after construction?	N		4	4	4	Standard requirement of specifications and contracts			4
8.2.6	Has all topsoil been re-used beneficially as topsoil on the site or on a site within a reasonable distance?	N		4	4	4	Standard requirement of specifications and contracts			4
8.2.7	Is there evidence that materials have been stored appropriately so as to avoid wastage?	NSO		8	8	8	Standard requirement of specifications and contracts			8
8.3.1	Is there evidence that the responsible sourcing of materials has been considered prior to placing the order?	NSO	4		4	4	Standard requirement of specifications and contracts			4
8.3.2	Has responsible sourcing been specified?	NSO	8		8	8	Standard requirement of specifications and contracts			8
8.3.3	a) Have the designer and contractor researched all locally available material sources, including recycled materials? b) Have the designer and contractor adapted the designs and specifications to allow for their use, where appropriate?	NSO	12		12	0	Standard requirement of specifications and contracts			0

8.4.1	Is there evidence that the highest possible proportion of timber and timber products used in permanent works has been specified to be (or, in a Construction-only Award, has been) either from legal and sustainably managed sources with recognised timber labelling, or from re-use?	y	0		0	0	Standard requirement of specifications and contracts			0
8.4.2	Is there evidence that the highest possible proportion of timber and timber products used in temporary works has been from re-use or certified sources?	y		0	0	0	Standard requirement of specifications and contracts			0
8.5.1	What percentage by volume of any existing structures, such as roads, tanks, pipework etc, have been retained and used within the project?	N	6		6	6	Standard requirement of specifications and contracts			6
8.5.2	What percentage by volume of materials (excluding bulk fill and sub-base) for use in the permanent works has been specified to be made from reclaimed or recycled material, whether reclaimed from the site or elsewhere?	NSO	12		12	12	Standard requirement of specifications and contracts			12
8.5.3	What percentage by volume of bulk fill and sub-base material specified and used in the project was made from previously used material, whether reclaimed from the site or elsewhere?	N	10		10	4	Standard requirement of specifications and contracts			4
8.6.1	Have all coatings and treatments for permanent work materials been factory applied (except for cut ends)?	Y	0		0	0	Standard requirement of specifications and contracts			0
8.6.2	What percentage of all coatings and other treatments used (for temporary and permanent works) have been specified as low-VOC and/or biodegradable?	N	6		6	2	Standard requirement of specifications and contracts			2
8.6.3	Can use of the specified coatings and other treatments identified in 8.6.2 (whether specified or actually used even if not explicitly specified) be demonstrated?	Y		0	0	0	Standard requirement of specifications and contracts _ not requried for road repairs			0

8.6.4	a) Has the COSHH assessment process for hazardous materials been extended to cover the wider environmental impacts of those materials? b) Have the results of this been used in drawing up the SEMP or equivalent?	NSO		6	6	6	Standard requirement of specifications and contracts			6
8.7.1	Is there evidence that durability and low maintenance of structures and components have been actively considered in design and specification?	N	6		6	6	Standard requirement of specifications and contracts			6
8.7.2	Is there evidence that long-term planned maintenance has been considered properly in the design process?	NSO	4		4	4	Standard requirement of specifications and contracts			4
8.8.2	What percentage by volume of components or pre-fabricated units used can be easily separated on disassembly/de-construction into material types suitable for recycling?	N	12		12	2	Standard requirement of specifications and contracts			2
8.8.3	Has a materials register provided to the client or future managing agent at hand-over that identifies main material types to facilitate recycling during disassembly or de-construction?	NSO		4	4	4	Standard requirement of specifications and contracts			4
			Section Total		150	110		0		110
				Section %		73.33%		0.00%		73.33%

Section 9 - Waste Management

9.1.2	Is there evidence that the designer has incorporated the principles of waste minimisation in the design of the completed works, and/or for the construction process?	NSO	10		10	10	Standard requirement of specifications and contracts			10
9.2.1	Have all regulations relating to the planning for site waste management been implemented on the project, including provision of information from the client and designer as well as the principal contractor and the key subcontractors?	N	4	4	8	8	Standard requirement of specifications and contracts			8
9.2.2	Has all waste taken from the construction site been carried by licensed carriers?	NSO		6	6	6	Standard requirement of specifications and contracts			6

9.2.3	Is there evidence that all waste has been taken to licensed facilities or an exempt site?	NSO		6	6	6	Standard requirement of specifications and contracts			6
9.2.4	Has the disposal or transfer site been checked to ensure it is licensed to take this material?	NSO		6	6	6	Standard requirement of specifications and contracts			6
9.2.5	Has the disposal or transfer site been checked to ensure the waste was taken there?	NSO		6	6	6	Standard requirement of specifications and contracts			6
9.2.6	If transfer stations and/or recycling facilities were used, is there evidence that the recycling rate of the transfer station was considered prior to placing the order?	Y		0	0	0	N/A			0
9.2.7	Is there evidence that hazardous (special) waste has been appropriately segregated (from other controlled waste) and taken to a suitable facility and, that the site has been registered as a hazardous waste producer where appropriate?	N		6	6	6	Assumed yes			6
9.3.1	Have the most environmentally beneficial ways of dealing with clearance and disposal of existing vegetation been explored and recommendations been made?	y		0	0	0	Assumed yes			0
9.3.2	Have these recommendations been implemented for the majority of vegetation cleared?	y		0	0	0	Assumed yes			0
9.3.3	What proportion by volume of material present on site (excluding topsoil and subsoil) has been incorporated into the project, as opposed to being disposed of?	N		8	8	0	Material removed is unlikely to be reused within the road repairs SCORE 0			0
9.3.4	What percentage by volume of waste from demolition or de-construction has been taken to landfill?	N		14	14	0	70% >Most would be transported to landfill.			0

9.3.5	Does the principal contractor have specific documented mechanisms for adopting an approach to waste minimisation and for identifying and dealing with all wastes arising from the civil engineering work?	NSO		12	12	12	Construction Strategy would cover this			12
9.4.1	Has an identification of waste streams arising on site been undertaken?	NSO		4	4	4	Assumed Yes			4
9.4.2	Have appropriate options for disposal been considered and implemented?	N		6	6	6	Assumed Yes			6
9.4.3 a)	Has a formal project waste minimisation plan or equivalent section of a SWMP been developed and implemented?	N	6		6	6	Assumed Yes			6
9.4.3 b)	Does the waste minimisation plan set targets to reduce, re-use and/or recycle waste, and have they been actively monitored for the duration of the project?	N	6		6	6	Assumed Yes			6
9.4.3 c)	Have the targets in the waste minimisation plan been met?	N	10		10	10	Assumed Yes			10
9.4.4	What percentage by volume of inert waste material has been segregated (on or off site) and diverted from landfill?	N		6	6	4	55% to 70% Inert material			4
9.4.5	What percentage by volume of non-hazardous waste material has been segregated (on or off site) and diverted from landfill?	N		6	6	6	Assumed maximum			6
9.4.6	What percentage of unused materials have been beneficially re-used (or stored for re-use)?	NSO		12	12	12	Assumed maximum			12
			Section Total		138	114		0		114
				Section %		82.61%		0.00%		82.61%

Section 10 - Transport

10.1.1	Has the scheme been designed to take account of PPG 13 in England, PPS3 in Northern Ireland, Planning Policy Wales: Technical Advice Note 18 or equivalent?	y	0		0	0	N/A			0
10.1.2	Has the location of the project been chosen to utilise or improve existing transport infrastructure?	y	0		0	0	N/A			0
10.1.3	If the project is not located near existing public transport links, has provision been made to create new links to existing public transport, rather than relying on private motor vehicles?	y	0		0	0	N/A			0
10.1.4	Has the design team considered measures to minimise traffic impacts of the completed project on the local community and have these been incorporated in the design?	Y	0		0	0	N/A			0
10.2.1	Have local traffic movements been reviewed or considered by the project team prior to the construction stage commencing?	NSO	6		6	6	Yes, because the assessment tool has been used			6
10.2.2	Is there evidence that transport impacts during the construction stage have been considered at the design stage? And that steps have been taken to minimise these?	NSO	10		10	10	Yes, because the assessment tool has been used			10
10.2.3	Has a Construction Traffic Management Plan or a transport section in the SEMP or Integrated Project Management Plan been drawn up to outline measures for minimising disruption caused by construction traffic; and has this plan been implemented during construction?	NSO		14	14	14	The output from the assessment tool indicates the most sustainable traffic management option			14
10.2.4	Have the measures outlined in 10.2.3 been monitored during construction and successful in reducing disruption caused by construction traffic?	N		8	8	8	The output from the assessment tool indicates the most sustainable traffic management option. This option was monitored during the work to prove the decision was based on minimising community impacts and traffic delays. This should also have been monitored by SGN.			8

10.2.5	Has the project team assessed possible use of other, more sustainable transport routes (other than road), such as rail, water etc, for the movement of construction materials and/or waste?	NSO	6		6	6	Assumed to be identified as a requirement of the specification and contract, but unlikely to be a feasible option for small works.			6
10.2.6	Has the outcome of this assessment been fully implemented?	N		16	16	16	Assumed yes			16
10.2.7	Is there evidence of measures (and their effectiveness) to keep access roads that are open to the public clean and any site roads properly managed?	NSO		10	10	10	Assumed that photos were taken			10
10.3.1	Is there a contract requirement for contractors to have Green Travel Plans in place?	NSO	4		4	4	Small works, so minimal labour force. Design team might limit vehicles and space for undertaking such a small repair job by using rolling block or staged works			4
10.3.2	Did the site set-up include measures to minimise travel impacts of the workforce and/or did the Contractor prepare a Green Travel Plan, whether a contract requirement or not?	N		8	8	8	Small works, so minimal labour force. Design team might limit vehicles and space for undertaking such a small repair job by using rolling block or staged works			8
10.3.3	Have these measures been successful in reducing workforce travel impacts during construction?	N		6	6	6	Assumed yes			6
			Section Total		88	88		0		88
				Section %		100.00%		0.00%		100.00%

Section 11 - Effects on Neighbours

11.1.1 a)	Does the contractor have a policy or code of practice regarding considerate behaviour (e.g. Considerate Constructors Scheme or its own Code of Practice)?	NSO	3		3	3	Assumed yes			3
11.1.1 b)	Has the policy been communicated to all appropriate people working on the project?	NSO		4	4	4	Site Inductions			4

11.1.1 c)	Is there evidence that the policy is embedded in your management system?	NSO		4	4	4	Assumed yes (Preference for CCS by Client)			4
11.1.1 d)	Were the policy and its implementation independently assessed and judged to be at least satisfactory?	N		4	4	4	The use of the assessment tool would satisfy this criterion.			4
11.1.2	Are there any measures included in the design of the scheme that go beyond those agreed at the planning permission stage that are intended to mitigate any nuisance caused by the operation of the scheme once constructed?	N	14		14	14	Contract specification to identify measures that need reducing - materials used for surfacing for example.			14
11.1.3	Has a SEMP or equivalent section in a Project Environmental Management Plan considered the effects of the construction process on neighbours and has this been implemented and monitored?	NSO		14	14	14	The assessment tool examines impacts on neighbours (nuisance) in order to establish the best option for TM			14
11.2.1 a)	Has the local authority been consulted regarding the noise implications of construction?	NSO		2	2	2	Assumed yes			2
11.2.1 b)	If there are noisy aspects of construction, have they been monitored at appropriate intervals throughout the construction stage?	N		3	3	3	Assumed Yes			3
11.2.2	On completion of the contract, have any Abatement Notices been served and not revoked?	NSO		11	11	11	Assumed No score 11			11
11.3.1 a)	Have baseline studies and predictions for noise been carried out for the project at the design stage and have proposals been put forward for mitigating noise during operation?	Y	0		0	0	Assumed no			0
11.3.1 b)	Have the proposals for mitigation for the operational stage been implemented in full as far as can be expected at the end of construction?	N		4	4	4	N/A			4

11.3.2 a)	Have proposals been put forward at the design stage for mitigating noise during the construction stage?	N	2		2	2				2
11.3.2 b)	Is there evidence that that these measures have been implemented during construction to minimise the disruption caused by noise?	N		4	4	4	Assumed Yes			4
11.3.3	Did the monitoring of noise levels assessed at Question 11.2.1 (b) demonstrate that acceptable noise levels were achieved throughout the construction stage?	N		7	7	7	Assumed Yes			7
11.3.4 a)	Have baseline studies and predications on vibration been carried out for the project at the design stage and have proposals been put forward for mitigating vibration during operation?	N	4		4	4	Assumed Yes			4
11.3.4 b)	Have the proposals for mitigation for the operational stage been implemented in full as far as can be expected at the end of construction?	N		4	4	4	Assumed Yes			4
11.3.5 a)	Have proposals been put forward at the design stage for mitigating vibration during the construction stage?	N	2		2	2	Assumed Yes			2
11.3.5 b)	Is there evidence that these measures have been implemented during construction to minimise the disruption caused by vibration.	N		4	4	4	Assumed Yes			4
11.3.6	Have vibration levels been monitored at appropriate intervals and locations throughout the construction stage and has corrective action been taken where necessary?	N		3	3	3	Assumed Yes			3
11.3.7	On completion of the contract, has any physical damage been caused to buildings and structures by vibration caused by construction processes?	N		4	4	4	Assumed Yes			4

11.4.1 a)	Is there evidence that appropriate measures have been taken in design to minimise adverse impacts on local air quality during operation of the completed works?	N	6		6	6	Assumed Yes			6
11.4.1 b)	Is there evidence that these measures have been implemented?	N		6	6	6	Assumed Yes			6
11.4.1 c)	Is there evidence that appropriate measures have been taken in design to minimise adverse impacts on local air quality during the construction stage?	N	4		4	4	Assumed Yes			4
11.4.2	Is there evidence that appropriate measures have been taken to minimise dust emissions during construction?	**NSO**		3	3	3	Assumed Yes			3
11.4.3	Is there evidence that appropriate measures have been taken at construction stage to minimise adverse impacts on local air quality?	**NSO**		3	3	3	Assumed Yes			3
11.5.1 a)	Is there evidence that appropriate measures have been taken in the design of the project to prevent light spillage to neighbouring areas during operation?	y	0		0	0	Assumed Yes			0
11.5.1 b)	Is there evidence that these measures have been implemented?	N		3	3	3	Assumed Yes			3
11.5.2	Is there evidence that appropriate measures have been taken at each stage of the project to prevent nuisance light spillage to sensitive receptors into neighbouring areas during construction?	N	2	2	4	4	Assumed Yes			4
11.6.1	Is there evidence that measures have been taken to minimise the adverse visual impact of the site during the construction stage?	**NSO**		7	7	7	Assumed Yes			7
			Section Total		133	133		0		133
				Section %		100.00%		0.00%		100.00%

Section 12 - Relations with the Local Community and Other Stakeholders

12.1.1	Has a community consultation exercise been carried out at each stage of the project and the results been passed to appropriate members of the project team and, as and where appropriate, the results fed back to consultees?	N	10	3	13	10	The assessment tool should look at criteria for local communications issues to guage impacts on social sustainability aspects			10
12.1.2	Has a member of the project team been made responsible for ongoing community consultation?	NSO	2	2	4	4	Assumed yes and local help line in place			4
12.2.1	Has there been a continuing community relations programme covering all relevant project stages?	N	9		9	9	Assumed yes and local help line in place			9
12.2.2	Did the community relations programme include a mechanism for local interest groups to communicate with the project and/or construction team?	N	3	3	6	6	Assumed yes and local help line in place			6
12.2.3	Have any partnership links been established with local groups (for example, donation of skills or surplus materials)?	NSO	2	9	11	2	Unlikely to be a full requirement			2
12.3.1	Has there been a mechanism to ensure that comments from the local community were recorded?	N	1	1	2	2	Assumed yes			2
12.3.2	Has the client and design team assessed the responses from the community relations programme; and taken appropriate action within the project decision making and design?	N	23		23	23	Assumed yes			23
12.3.3	Has the construction team assessed the responses from the community relations programme; and taken appropriate action within the construction process?	N		19	19	19	Assumed yes			19

12.4.1	Is there evidence that due consideration has been given, during the project's feasibility stage and during design, to wider social impacts of the project during construction and operation, and to the effects of the completed project on the human environment?	N
12.4.2	Is there evidence that potential impacts of the project on the health and welfare of any occupants, users, neighbours and/or any operational staff have been considered, and the design modified as a result?	N
12.4.3	Is there evidence that the client and principal contractor has taken steps to actively encourage local firms to compete for work?	NSO
12.4.4	Is there evidence that consideration has been given to a high quality of design, (this includes 'user enjoyment' and additional facilities for the benefit of users) and that this has been fully achieved in the construction stage?	N
12.4.5	Is there evidence that the needs of all different user groups have been considered and respected in the design solution (for example, car drivers, cyclists, pedestrians, disabled people etc) and the specification achieved in the completed project?	N
12.4.6	Is there evidence that the project has been designed to be sympathetic to its human users and in scale with its surrounding environment?	NSO

3		3	3	The assessment tool should look at criteria for local communications issues to guage impacts on social sustainability aspects
3		3	3	Unlikely to be a full requirement
	4	4	4	Assumed Yes
5	2	7	7	Assumed Yes
4		4	0	Assessment tool takes this crierion into consideration and focuses on reducing inconvienience to local raod travellers/pedestrians.
6		6	6	Assessment tool takes this crierion into consideration and focuses on reducing inconvienience to local raod travellers/pedestrians.
Section Total		114	98	
	Section %		85.96%	

		3
		3
		4
		7
		0
		6
0		98
0.00%		85.96%

APPENDIX F: EXTRACTS GATHERED FOR CASE STUDY 2

Primary and Contributory Impacts Selected for Case Study 2

The following contributory impacts were selected as being relevant to the given scope, aim and boundaries of assessment, as well as the Scenarios created.

Primary Impact: Direct Costs of Design and Construction (£)

- Labour and plant
- Reinstatement / resurfacing of the trench
- Traffic management
- Supervision during construction
- Repair costs due to damage caused to underground utilities
- Compensation payments
- Cost of restoring brand / image

Primary Impact: Road User Delays

- Queuing prior to reaching the works
- Reduced traffic flow through the works

Primary Impact: Carbon and Other Air Emissions (Measured in £)

- Emissions from delayed traffic

Primary Impact: Noise Pollution

- Excavation work
- Reinstatement works
- Queuing traffic

Primary Impact: Impact of Reinstatement (£)

Any type of reinstatement work

Primary Impact: Impact on Business and the Community

- Location specific criteria used within the score sheet

Primary Impact: H&S

- Location specific criteria used within the score sheet

Example timeline. The schedule is based on the dates shown in the quotes supplied. The aim was to quantify the number of days when traffic management was in operation, and hence the number of days when traffic was affected. This timeline was sent to CA for their comment.

		From CA Evidence	Assumed by RH	Total TM Costs from invoice	Please Add 'X' for days where you think traffic flow was affected on R/B
Mon	07/03/2011	CB mobilise on site		£0.00	
Tue	08/03/2011	Commence drilling, strike uncharted water main		£0.00	
Wed	09/03/2011	Standing, job aborted		£0.00	
Thu	10/03/2011	CB demobilise and return to Bolton		£0.00	
Fri	11/03/2011		**No work on site?**	£250.00	
Sat	12/03/2011		**No work on site?**	£0.00	
Sun	13/03/2011		**No work on site?**	£0.00	
Mon	14/03/2011		**No work on site?**	£0.00	
Tue	15/03/2011	Cost of repair = £3,165	**The TM erected on this day was required so water main could be repaired?**	£300.00	**X?**
Wed	16/03/2011		**TM erected and water main repaired?**	£727.00	**X?**
Thu	17/03/2011		**TM erected and water main repaired?**	£647.00	**X?**
Fri	18/03/2011		**TM erected and water main repaired?**	£647.00	**X?**
Sat	19/03/2011		**No work on site?**	£72.00	
Sun	20/03/2011		**No work on site?**	£72.00	
Mon	21/03/2011	HDD launch pit D to receiving pit C: CB re mobilise to site and commence drilling, but slow progress to the roundabout as they hit rock		£647.00	**X?**
Tue	22/03/2011	Pilot drilling		£72.00	

APPENDIX G: EXTRACTS GATHERED FOR CASE STUDY 3

Primary and Contributory Impacts Selected for Case Study 3

The following contributory impacts were selected as being relevant to the given scope, aim and boundaries of assessment, as well as the Scenarios created.

Primary Impact: Direct Costs of Design and Construction (£)

- Labour and plant
- Traffic management
- Supervision during construction
- Cost of restoring brand / image
- Lost opportunity cost

Primary Impact: Road User Delays

- Queuing prior to reaching the works
- Reduced traffic flow through the works
- The need to accelerate/decelerate adjacent to the work area

Primary Impact: Carbon and Other Air Emissions (Measured in £)

- Emissions from delayed traffic

Primary Impact: Noise Pollution

- Excavation work
- Reinstatement works
- Queuing traffic

Primary Impact: Impact on Business and the Community

- Location specific criteria used within the score sheet

Primary Impact: H&S

- Location specific criteria used within the score sheet

An example of a vehicle count report.

From	To	PCL	MCL	CAR	BUS	LGV	MGV	HGVs
700	730	0	1	163	0	20	0	10
730	800	0	0	258	3	20	0	15
800	830	0	0	260	1	16	0	20
830	900	0	1	240	1	10	0	17
900	930	0	0	161	4	13	0	10
930	1000	0	0	111	0	18	0	16
1000	1030	0	0	108	1	21	0	15
1030	1100	0	1	92	1	10	0	12
1100	1130	0	0	88	1	14	0	16
1130	1200	0	0	87	2	11	0	14
1200	1230	0	1	113	0	24	0	18
1230	1300	0	0	92	0	9	0	18
1300	1330	0	0	79	0	19	0	13
1330	1400	0	0	117	0	26	0	18
1400	1430	0	0	98	0	22	0	10
1430	1500	1	1	100	0	21	0	3
1500	1530	0	0	110	0	20	0	20
1530	1600	0	0	133	2	17	0	17
1600	1630	0	1	127	2	24	0	15
1630	1700	0	1	120	0	32	0	15
1700	1730	0	2	172	0	36	0	16
1730	1800	0	1	164	0	20	0	7
1800	1830	0	0	143	0	14	0	6
1830	1900	0	0	117	0	8	0	3

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APPENDIX H: EXTRACTS GATHERED FOR CASE STUDY 4

Primary and Contributory Impacts Selected for Case Study 4

The following contributory impacts were selected as being relevant to the given scope, aim and boundaries of assessment, as well as the Scenarios created.

Primary Impact: Direct Costs of Design and Construction (£)

- Site survey to locate existing apparatus, infrastructure, trees etc and to determine the ground conditions
- Repair costs due to damage caused to underground utilities
- Compensation payments
- Cost of restoring brand / image

Primary Impact: Road User Delays

- Queuing prior to reaching the works
- Reduced traffic flow through the works
- The need to accelerate/decelerate adjacent to the work area

Primary Impact: Carbon and Other Air Emissions (Measured in £)

- Emissions from delayed traffic

Primary Impact: Noise Pollution

- Excavation work
- Reinstatement works
- Queuing traffic

Primary Impact: Impact of Reinstatement (£)

Any type of reinstatement work (considered but removed).

Primary Impact: Impact on Business and the Community

- Location specific criteria used within the score sheet

Primary Impact: H&S

- Location specific criteria used within the score sheet

Comments received from Jim Anspach regarding what would be required for the SUE process if it was used at the roundabout:

- Establish reasonable project limits for a QLB mapping attempt. Since it is not known if other utilities need to be diverted at this stage, the limits of the survey are set so they cover the area where there is a new electrical supply, as well as approximately 30m along each carriageway from the roundabout itself. This will allow sufficient coverage in case utilities need to be diverted
- All available network records will be reviewed, and the limits of the QLB study area will be adjusted outwards if utility congestion makes this necessary.
- A meeting will be held with the client at this point to review utility data against the preliminary design
- SUE practitioner will offer their opinion on the utilities affected by the project, including costs and the time to relocate so that designers can avoid diversions if possible
- Once the design is around 30% complete, a coordination meeting will be held between designers and all affected utility owners. Review potential relocation options, easement requirements, time scales and costs of relocation. Identify points where diversions may be avoided if slight changes in design are possible. Select locations for test holes, paying close attention to any unknown utilities and QLC / QLD utilities which may need more test holes than the QLB areas.
- Obtain test hole results and return to designers to find out if further design changes are required
- When the scheme is approximately 60% complete, call in utility owners and recommend mutual diversions. If they agree to this joint working, relocation design will begin.
- Check whether any new utilities are installed within the area of interest during this process, and if they are, ensure they are accurately added to the design plans and possible conflicts are identified

- The SUE mapping firm will supply information to the contractor to ensure they understand where all utilities are located and marked in the field for the benefit of the constructor.
- Prepare accurate as-built information following construction to include any new or relocated utilities
- At the end of the project, provide a completed and updated utility map with all appropriate QLs shown to all parties.