INTERNATIONAL SOCIETY FOR TRENCHLESS TECHNOLOGY	**TRENCHLESS TECHNOLOGIES RESOURCE CENTRE**	
	TRENCHLESS TECHNOLOGY OVERVIEWS	SECOND EDITION
	COSTS AND ENVIRONMENTAL IMPACT	LAST UPDATED OCTOBER 2006

1. INTRODUCTION

This section provides information on the costs of trenchless technology and the impact of the technology on society and its environment. "What is the Cost relative to conventional methods?" is the most frequently raised question by potential trenchless users, but unfortunately it is also the most difficult to answer.

The total cost of a pipeline rehabilitation/renewal project can be divided into components as shown in the following table.

Cost category	Cost PAID by	Examples	
DIRECT	OWNER	CONTRACTOR COSTS	D1
		ENGINEERING	D2
		BIDDING COSTS	D3
		CONTRACT MANAGEMENT	D4
INDIRECT		COMPENSATION CLAIMS CUSTOMERS	I1
		COMPENSATION FOR CONTINGENT DAMAGE TO PROPERTY	I2
SOCIAL QUANTIFIABLE	SOCIETY	TRAFFIC DELAY	S1
		BUSINESS DISRUPTION	S2
		ACCIDENT COSTS	S3
		POLLUTION	S4
SOCIAL NON QUANTIFIABLE		ENVIRONMENTAL IMPACT	S5
		QUALITY (OF LIFE)	S6

The main problem in discussing and comparing costs is to define which of these components has been included. The second problem is the time scale over which the costs are to be considered. The simplest and most commonly used approach is to consider only current expenditure. However modern asset management practice strongly recommends Life Cycle Costing (LCC), in which costs are assessed over the expected lifetime of the asset. This approach should be used to select rehabilitation/renewal options by comparing the life cycle cost implications of each option, then selecting the one that gives the best net present value after applying an appropriate discount rate. However, if the aim is to make a fair comparison between open cut and trenchless options, the analysis must make proper allowance for social costs. In practice, this level of sophistication is rarely achieved, and in most cases selection of rehab/renewal method is based on comparison of short term direct costs. Fortunately in markets with reasonable volumes of work even this comparison favours trenchless technologies in most circumstances.

Cost estimates can be obtained from a wide range of sources including:

Rehabilitation Contractors	Will always be concerned that any estimate will be used by the client as a benchmark for future bids. May reflect the contractor's particular technology preferences.
Consulting Engineers	Reflects quality of their information source – ask the obvious questions.
Experience of other owners	Can be very valuable providing projects are truly comparable.
Published papers	Need to verify basis of costs provided.
Cost surveys based on bid analysis	Examples are annual Louisiana Tech report and occasional surveys by Canadian research bodies.
Cost models from independent consultants/research bodies	Example is cost model provided to UK utilities by Water Research Centre (WRc)
Data from utility regulators etc	Example is benchmark data and cost report issue by UK water regulator OFWAT.

Further information on direct and indirect costs can be accessed using the Guidelines below, published papers and literature.

For more detailed Guidelines covering Direct and Indirect Costs click more>

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2. SOCIAL COSTS

These are costs which arise as a direct consequence of the rehabilitation/renewal works but which are borne by society as a whole rather than the individual utility. Social costs arise from the impact of utility works on society and the environment, as illustrated in the table in the introduction section above. Various estimates of the overall cost of these impacts have been made with the most recent assessment of social costs being in the order of **twice the sum of the actual direct and indirect costs borne by the utility.**

Whilst most utilities agree that use of trenchless technologies can substantially reduce these social costs and environmental impacts, they argue that it is impractical to include such social costs in the selection and bid evaluation process.

Social costs are just one aspect of the Environmental impact of pipeline installation and rehabilitation. The status of trenchless technologies in terms of Environmental Sustainability and related concepts is considered in the separate Guidelines below.

For more detailed Guidelines covering Social Costs click more>

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1. DIRECT COSTS

Direct Costs are borne by the utility owner and usually include:

A. Planning, Design and Supervision.
B. Payments to contractors and suppliers.
C. Diversion of flows and/or provision of temporary service.
D. Permanent reinstatement of excavations.

Direct costs are the most easily measured and compared component of overall costs, but there is still plenty of room for confusion over what is and is not included in a published cost. Table 1 (below) provides an example check list of activities which should be included in direct cost assessments for both sewer and water mains.

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2. INDIRECT COSTS

These generally include any additional costs associated with a contract which are borne by the utility. Typical examples are:

A. Compensation for damages paid to other utilities and the owners of property and land.
B. Compensation to businesses for loss of profits.
C. Compensation to customers for any excessive service interruptions.

These costs are difficult to assess in advance of the contract, but it is clear that all of these items should be significantly less in the case of trenchless technologies due to the reduction in collateral damage and disruption.

It should be noted that in many published papers, indirect costs are used to describe all additional costs which are not included in direct costs but which can be quantified. This comprises many of the social costs described below.

TABLE1 – CHECK LIST OF DIRECT COST ITEMS IN REHABILITATION PROJECT

Activity	Tasks	Open cut Replacement	Trenchless off line	Trenchless on line	Renovation sewer	Renovation water mains –non structural	Renovation Water Mains-Structural
Project Planning and Design		√	√	√	√	√	√
Pipe condition assessment					√	√	√
Site and Route Investigation		√	√	√	√	√	√
Bid Preparation and Management		√	√	√	√	√	√
Contract Management		√	√	√	√	√	√
Preparation	Access Pit excavation		√	√		√	√
	Establish bypass			√	√		
	Establish temporary services			√		√	√
	Removal of fittings			√		√	√
	Cleaning and CCTV			√	√	√	√
Rehabilitation Process	Pipe/Liner supply and installation	√	√	√	√	√	√
Completion	End seals and fittings			√			√
	Reconnection	√	√	√		√	√
	Inspection and Test	√	√	√	√	√	√
	Backfill and Reinstatement	√	√	√		√	√
	Re-commission					√	√

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3. SOURCES OF COST INFORMATION

The main sources of information on costs are summarised in the table seen in the introduction section. The most common method used by utilities, is to ask an 'expert'. Unfortunately, the information provided by such experts, often reflects their preferences for a particular technology. In addition, rehabilitation/renewal contractors are always concerned that the price provided on the basis of limited information will be used by the client as a benchmark for future bids. The best source of all is the experience of other utilities that have performed similar work.

There are also a number of published documents available, via the web. A bibliography (available through ISTT, Email: info@istt.com), conference papers, and other published documents, which provide cost information.

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4. EXAMPLES OF PUBLISHED COST DATA

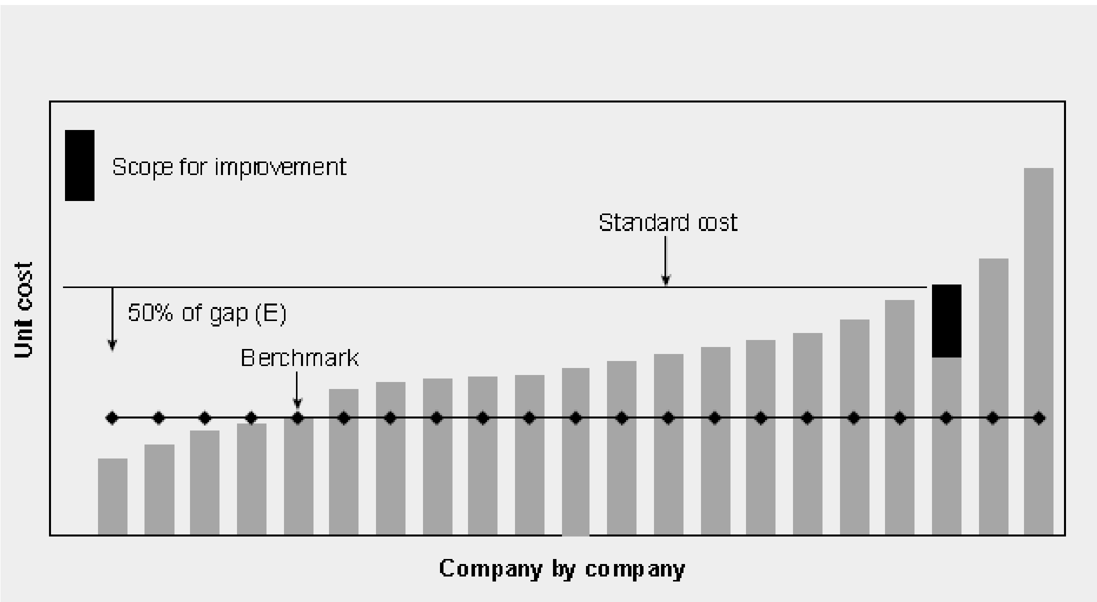
The main problems in comparing costs between different regimes are related to activities such as engineering, planning and condition evaluation which may be carried out by the owner, but are not included in the contractor's perception of costs.

This has lead to the concept of Standard Costs which are prepared using an agreed protocol and a common set of assumptions, and are frequently used to benchmark utility companies in terms of relative performance. One of the most extensive and widely publicised examples of this approach can be found in the publications of OFWAT, the organisation responsible for the regulation of the UK privatised water industry.

4.1 OFWAT STANDARD COSTS

OFWAT has developed a standard cost and benchmarking process to monitor the maintenance and rehabilitation performance of the water companies in England and Wales. Standard Costing procedures for a wide range of activities have been agreed with the Companies, which then report the costs to OFWAT on an annual basis.

The histogram below shows a typical set of costs after adjustment by OFWAT and typically exhibiting a 2:1 ratio between the highest and lowest. The benchmark cost is determined by OFWAT, and is a cost which should be achievable by all the companies if they work efficiently.



The Table below lists benchmark costs for a range of diameters and rehabilitation/renewal methods, including open cut replacement in grass verge, suburban highway and urban highway locations. The table also shows the cost differences between HDD and open cut in all three locations, and between the other rehab/renewal technologies and urban open cut. It can be seen that the trenchless methods are cost competitive in most situations.

	OFWAT BENCHMARK COSTS UKP/METRE					
DIAMETER mm	100	150	200	300	450	600
open cut grass(ocg)	28	36	41	62	132	179
hdd grass	35	47	66			
cost inc/dec %	20%	23%	38%			
open cut suburb	77	89	102	140	197	262
hdd subrb	40	52	71			
	-93%	-71%	-44%			
open cut urban	91	101	114	153	232	314
hdd urban	41	53	73			
	-122%	-91%	-56%			
epoxy spray lining	38	45	36	44		
	-58%	-55%	-68%	-71%		
close fit sliplining	52	63	53			
	-43%	-38%	-54%			
pipe bursting	41	49	51			
	-55%	-51%	-55%			
sliplining (insertion)	33	40	52	66	120	
	-64%	-60%	-54%	-57%	-48%	

Detailed study of the OFWAT Benchmark costs provides an interesting insight into the variability of costs within and between utilities, contractors and locations. The absolute values are, of course, specific to the purposes of OFWAT, but the relationship between the costs of Open Cut Replacement, and the various trenchless technologies are probably of wider validity.

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4.2 COSTS BASED ON ANALYSIS OF BIDS

In both the UK and USA, cost models based on analysis of project bid data are available. In the UK these are produced by the Water Research Centre (WRc) and are issued privately to the utilities. Many utilities then modify the basic model to suit their own circumstances. A typical set of costs is listed in the table below, and, as might be expected, these are comparable with, but not identical, to the OFWAT costs.

DATA FROM UK BID TAB ANALYSIS UKP/M						
diameter mm	**cement mortar lining**	**epoxy spray lining**	**pipe bursting**	**sliplining insertion**	**close fit sliplining**	**open cut urban**
80	51	38	35	44		
100	52	39	39	47	66	91
150	53	43	47	55	71	101
200	55	46	54	65	77	114
250	56	50	60	76	84	134
300	58	54	65	90	90	153
350	59	58	70	105	98	179
400	61	63	75	124	106	206
450	63			146	114	232
500	65			171	124	299
600	68			236	145	434

In the USA, bids submitted by contractors for public tenders are published, and are easily accessible. The Trenchless Technology Centre at Louisiana Tech (LATECH) publishes a regular analysis of all the bids related to municipal pipelines. The data is presented in graphical form, by plotting each bid against the diameter of the pipe, for each technology. A curve fit is then performed on the data, and the best fit equation is then derived. In each case, the analysis is performed for all bids, and also for those bids which won the contracts. Some typical costs for open cut, and some trenchless technologies are tabulated together below with the parameters of the curve fit in each case. The data used is from the 2003 survey, and more recent data is directly available from LATECH.

The curve fit equations are of the form:

UNIT COST = $KD^{M.} + C$
Where D = Diameter in inches and K,M and C are curve fit constants

	K	M	C	D MIN	D MAX	6	12	24	36	48
OPEN CUT	0.6	1.5	76	4	96	85	101	147	207	278
CIPP	0.77	1.5	25.9	6	108	37	58	116	193	282
SLIPLINE	0.71	1.5	40.1	6	120	51	70	124	194	278
HDD	0.31	2	32.9	2	42	44	78	211	435	
FOLD AND FORM	0.48	1.5	39.6	6	16	47	60			
DEFORM REFORM	0.38	1.5	20.4	8	12	36				
SPIRAL WIND	0.34	1.5	57	14	18					
BURST HYDRAULIC						26	82	171		
BURST PNEUMATIC	2.63	1.25	30.3	6	24	55	89	170		
BURST STATIC	0.67	1.25	79.52	6	20	85	93	114		
SPRAYED	5.16	0.75	13.6	8	20000	48	57	80	99	117

The data is presented as a ratio between the unit cost of the various technologies, and the cost of Open Cut, at the same diameter. Once again, it is apparent that trenchless techniques are directly competitive with Open Cut in most circumstances.

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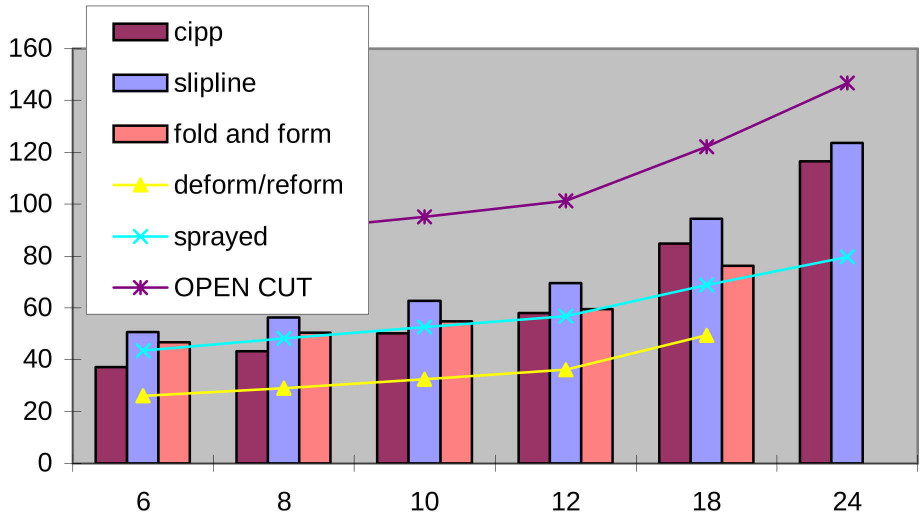
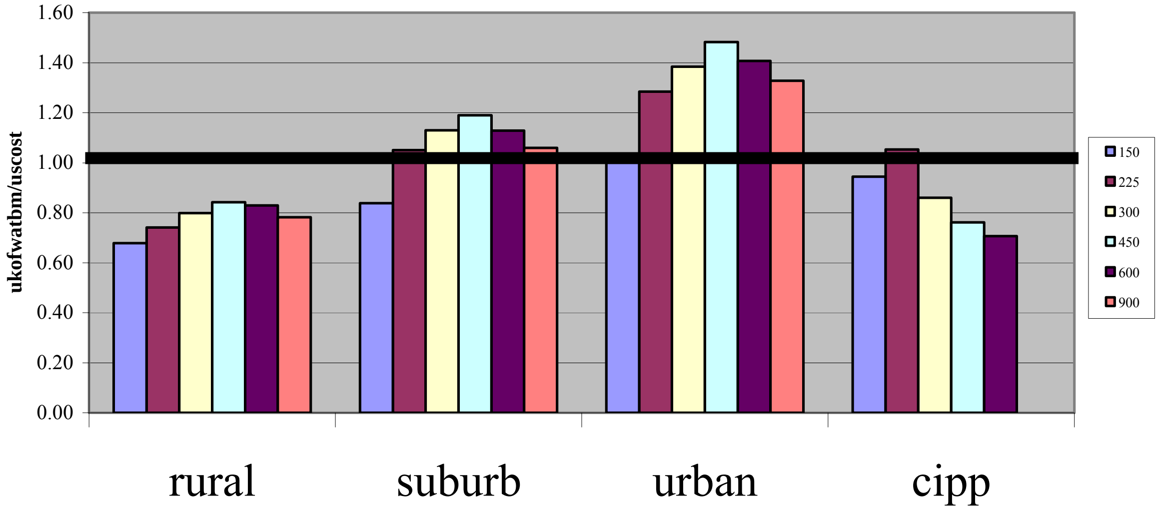
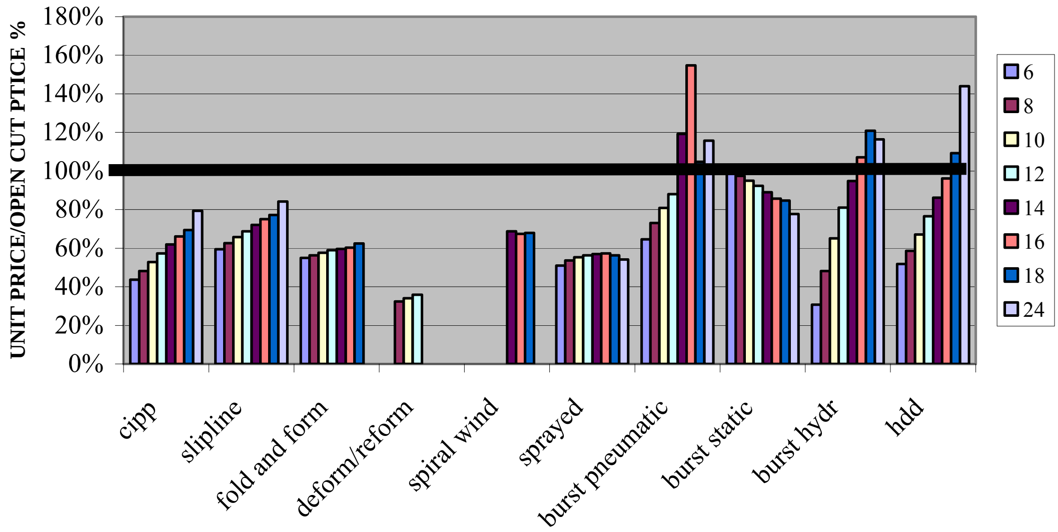
5. COMPARISON OF COSTS

It is interesting to compare the costs, from OFWAT and LATECH. Care is needed, because the majority of the OFWAT costs are related to water mains, whereas, the LATECH costs are mainly for sewers. The only area of direct overlap is between the OFWAT open cut, and CIPP sewer costs, and the equivalent costs from LATECH. The US costs, have been converted from $/ft, to GBP(£)/metre, using an exchange rate of 1.82. The results are shown in below, which compares the ratio between the costs for different technologies and diameters. Surprisingly, the costs are very similar, although, in view of the many variables involved, this is almost certainly, a coincidence. More normally, comparison of costs between different countries, is of little significance.





LATECH BID DATA 6 TO 24 IN



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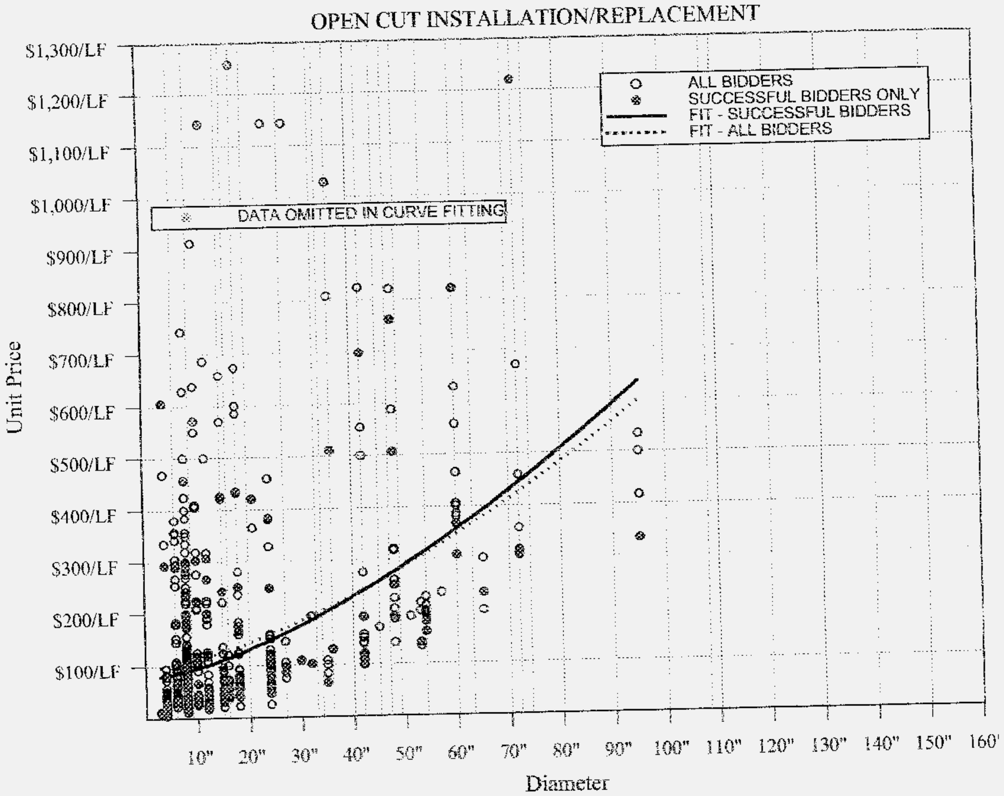
The documentation below may also be of interest.

4. OPEN CUT

1. Pipeline New Installation/Replacement

Cost of open cut pipe installation depends very much on depth of installation and location (surface condition). The graph below includes some high-cost installations from Honolulu, HI, 1997 (green dots). These values have been omitted in curve fitting. The fitted curve represents low-cost to medium-cost installations.

Graph: Price in 2002 Constant Dollars vs. Pipe Diameter. Price Unit: $/LF



	N	St Error of the Estimate	FIT
SUCCESSFUL BIDS:	154	143.75	$up = 0.60 \cdot D^{3/2} + 76.24$
ALL BIDS:	547	138.93	$up = 0.54 \cdot D^{3/2} + 94.23$

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1. INTRODUCTION

It has long been accepted that the open trench approach to the installation of utility infrastructure is capable of causing major disruption to commerce and the general public. Indeed, this was one of the motivating factors for Ted Flaxman when he chaired those historic meetings in London in 1985, that heralded the birth of the ISTT. No doubt he believed that the new society would rapidly find a means of assessing the financial impact of such disruption, so that it could be incorporated in the bid process. However, 21 years later, as these guidelines were being drafted, the following comment was made in a paper by Pucker, Allouche, and Sterling:

> Delivered at the 2006 North American, No Dig Conference in Nashville,
>
> ***"For the most part, social costs are not considered during a construction project's planning, design and bid evaluation stages, because they cannot be calculated using standard estimating methods. In recent years efforts have been made to introduce approaches for predicting social costs associated with utility construction projects. Nevertheless, unit cost data needed for the verification of such prediction methods is lacking.***

The efforts referred to in this extract, are chronicled in numerous papers presented over the years at No-Dig Conferences, and listed in papers and the Bibliography available from ISTT (Email: info@istt.com). As will be seen later, social costs are now seen as just one component of the overall environmental impact of utility works. Fig 6.1 summarises some of the main impacts, and it can be seen, that in addition to the immediate impacts associated with the works, there are some broader issues. These are generally considered in an overall assessment of the ENVIRONMENTAL SUSTAINABILITY of a product, or process, which is considered in a subsequent section of this document.

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HISTORY

The first serious attempt to assess the magnitude of the disruption associated with open cut utility installation, was made by Thomson et al, in conjunction with the UK Transport and Road Research Laboratory [TRRL]. Based on observations of a number of contracts, it was concluded that social costs could be more than double the direct costs of an installation, and that the cost to society in the UK, was at least UKP 2.1 billion per annum. This figure has been frequently quoted, although, some argue it is a gross exaggeration. This project was intended to be the catalyst for a mass of new legislation aimed at encouraging the use of trenchless methods. This included such innovations as charging contractors for road occupancy, and for the extent of open trench used. Unfortunately it coincided with the privatisation of the UK Water Industry, and the legislation became a victim of politics.

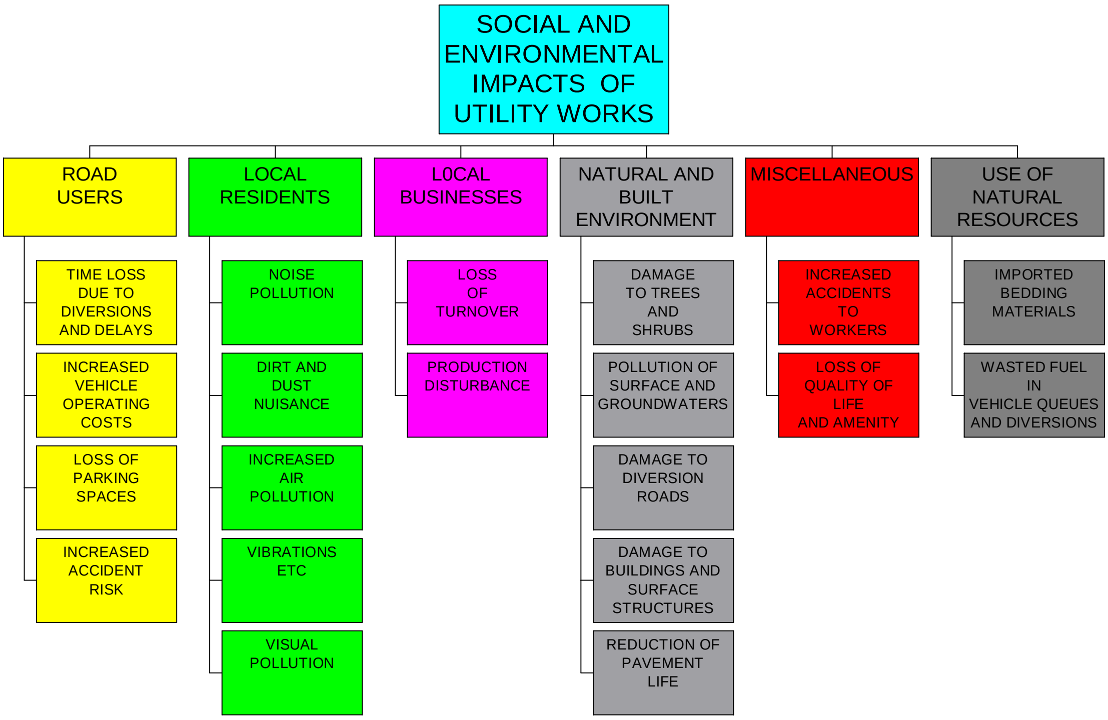
In spite of all the detailed research carried out in the ensuing twenty years, there is still considerable controversy in the UK and many other countries. The benefits of trenchless methods in reducing disruption are widely accepted. However, there is still no agreement over the magnitude of social costs, and their precise role in the bid process.
The paper quoted earlier, provides an excellent summary of the status of this endeavour, and is partially summarised below.

SOCIAL COST CATEGORIES

Social cost categories related to construction work are numerous. The case histories reported in the paper considered the following eight social cost categories:

1. *Travel delay*: Utility construction work can cause significant traffic delay due to lane closures or complete road closures. Pedestrians also can be forced to detour because of lane closure and other construction activities.
2. *Vehicle operating costs*: Longer travel distances and stop-and-go traffic induce higher vehicle operating costs. For example 1,000 speed changes from 50 mph to 15 mph and back to 50 mph cause an additional fuel consumption of 12.2 gallons for light duty vehicles. (Budhu and Isely, 1994).
3. *Decreased road surface value*: Open excavations can result in pavement deformations and asphalt cracking at the edges of the trench, which leads to an accelerated degradation of the pavement. Reduction in useful pavement life to due an open-cut excavation is estimated to be as high as 30% (Tithe, et al, 2002).
4. *Loss of trade*: Construction zones can decrease the accessibility to businesses due to congested traffic conditions, blocked parking spaces and barriers from the construction site itself. On one hand businesses lose customers, who prefer to go to more convenient places, while on the other hand businesses depending on deliveries may have problems with their supplies.
5. *Loss of parking spaces*: Loss of parking spaces leads to a decreased parking meter revenue for the city and lower revenues from parking fines.
6. *Cost of dust control*: Open excavations result in a significant amount of dust in their surrounding. Cleaning needs, and thus costs, increase. Also the quality of life for people living near the construction zone decreases.
7. *Noise pollution costs*: The use of heavy construction equipment results in a higher noise level in the vicinity of the work area. In addition construction work may lead to a higher noise pollution due to changing traffic conditions compared to the ‘normal’ situation.
8. *Worker safety*: Open trenches pose a higher risk to workers and pedestrians than trenchless technologies. Accidents related to trenching are about 112% higher than the average value for construction work in general. Each year more than 60 workers are killed in trenching accidents (Jung and Sinha, 2004).

FIG 6.1



Other factors that could be considered as being a Social Cost by nature include:

a) The use of material and energy resources to extract the base material used.
b) The use of energy to convert the materials to their final form.
c) Pollution and safety hazards arising from these activities.
d) Quantity and disposal of waste.
e) Impact of the use of the product or process on all aspects of the human, natural and built environment (The issues normally included in social costs).
f) Impacts arising from the operation of the product or process over its working life.
g) Impacts arising from disposal – recyclability.

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In 2000, the ISTT began collaboration with UNEP (United Nations Environmental Program). The background to this is summarised below using information extracted from various UNEP documents

1. **ABOUT UNEP/IETC…**
   a. IETC is part of the UNEP Division of Technology Industry and Economics (DTIE)
   b. IETC's mandate is the promotion and transfer of Environmentally Sound Technologies (ESTs) to developing countries and those with economies in transition

2. **UNEP/IETC ASSISTS DECISION MAKERS BY:**
   a. Identifying and helping to solve water and urban related environmental problems
   b. Developing tools and techniques to assist in the identification, selection and use of appropriate ESTs
   c. Promoting implementation of environmentally sound technologies (ESTs) and better practices

d. Activities focus on water and urban environmental issues

3. **THE NEED FOR NEW APPROACHES**
   a. Past environmental problems have arisen primarily because of inappropriate management and a lack of understanding of the impact of management practices upon the environment.
   b. New management methods and tools must be developed and applied.

4. **SUSTAINABLE DEVELOPMENT**
   a. Part of an integrated management and governance framework which addresses:
   b. The needs of the present without compromising the ability of future generations to meet their own needs (WCED 1987);
   c. Improving the quality of human life within the limits of supporting ecosystems (IUCN/UNEP/WWF 1991).

5. **THIS MEANS INTEGRATING:**
   a. Ecological imperative - living within the limits of global biophysical carrying capacity and biodiversity;
   b. Social imperative - ensuring that basic needs are met through democratic systems of governance and equity;
   c. Economic imperative - ensuring a vibrant economy based on eco-efficiency and sustainability.

6. **ENVIRONMENTALLY SOUND TECHNOLOGYESTS**
   a. Definition of Environmentally Sound Technologies (ESTs) is based on Agenda 21.
   b. … Arising from the 1992 United Nations Conference on Environment and Development (UNCED), also known as the Earth Summit.

7. **AGENDA 21 DEFINES ESTS AS TECHNOLOGIES WHICH:**
   a. Protect the environment;
   b. Are less polluting;
   c. Use all resources in a more sustainable manner;
   d. Recycle more of their wastes and products;
   e. Handle residual wastes in a more acceptable manner than the technologies for which they are substitutes.

8. **INHERENT TO THIS IS:**
   a. The improvement of technology currently used
   b. Its replacement with more appropriate environmentally sound technology, and
   c. Its consideration within the ecological and socio-economic context.

9. **ESTS AND SUSTAINABLE DEVELOPMENT N THE CONTEXT OF POLLUTION ESTS IS PROCESSES AND TECHNOLOGIES THAT:**
   a. Generate little or no waste
   b. Prevent or avoid pollution
   c. Control or treat pollution after it has been generated.

10. NOT JUST INDIVIDUAL TECHNOLOGIES ESTS ARE ALSO TOTAL SYSTEMS THAT INCLUDE:

a. Know-how,
b. Operating procedures,
c. Goods and services, and
d. Equipment, as well as
e. Organizational and managerial procedures.

11. HENCE, THE TERM EST:

a. Applies to all technology and its transition in becoming more environmentally sound
b. Covers the full spectrum from basic technologies adjunct to the production system, to fully integrated technologies where the EST is the production technology itself

12. Captures the full life cycle flow of the material, energy and water in the production and consumption system.

UNEP CHECKLIST OF CRITERIA FOR ENVIRONMENTAL SUSTAINABILITY

EST Criteria

Criteria are principles or standards against which something is judged. Appropriate criteria are needed to help guide the identification and selection of ESTs in a manner consistent with sustainable development objectives. Figures 4 and 5 each provide a checklist of selected generic criteria and indicators that can be used in assessing and evaluating ESTs. These checklists were developed by the UNEP/IETC Expert Group on Environmentally Sound Technologies as an initial working template in an effort to define the essential criteria and indicators for identifying and selecting ESTs. The checklist in Figure 4 provides environmental criteria and related indicators. Figure 5 provides a limited perspective on some of the relevant socio-economic indicators. IETC's immediate interest is to examine the relevance of the environmental criteria and indicators.

Figure 4: Proposed Checklist of Environmental Indicators for ESTs

(Prepared by UNEP/IETC Expert Group on Environmentally Sound Technologies)

Criteria	Indicators	Yes	No	Quantitative Indicators (i.e., amount saved/spent and/or reduced/ increased)	Qualitative Indicators (i.e., based on potential local, regional and global impacts)
Technical Suitability	• Addresses fundamental scientific and engineering principles (i.e., laws of thermodynamics and reactivity) • Production or process yield • Contaminant removal rates or treatment efficiency • Potential for generation of secondary pollutants/by-products • Noise • Thermal losses and radiation emissions • Performance at different settings and different locations • Sensitivity to specific operating conditions • Reliability • Replicability • Potential for system failure • Profiling of risks and uncertainties				
Compliance with Regulations and Standards	• Quantity of waste generated (water, air and solids) • Quantity of waste controlled by environmental permits • Compliance with local and regional standards • Compliance with MEAs (i.e., POPs, Biosafety, etc.) and other internationally recognised standards (i.e., ISO, etc.) • Availability of reliable data • Part of a 3rd party assessment programme (i.e., Ecolabelling, ETV, etc.)				

Eco-Efficiency and Conservation of Biodiversity	• Useful life (in accordance with optimal performance specifications) • Efficiency of energy, water and materials use relative to the service provided • Lifecycle performance (i.e., overall GHG emissions throughout lifecycle) • Use of renewable resources • Incorporation of closed loop processes • Design for the environment • Cumulative air, water and waste emissions • Impact on ecosystems health & integrity (including biodiversity and ecological footprint)				
Protection of Water Resources	• Water use • Conservation of water • % use of recycled water • Wastewater treatment requirements • Level of treatment (primary, secondary, tertiary) • Overall water efficiency				
Optimisation of Materials and Energy Use	• Use of fuels and energy resources • Quantity of renewable resources • Quantity of non-renewable resources • % of recyclable and reused materials in the production process • Use of environmentally friendly materials • Use of locally sustainable resources • Duration of product use or useful life • Energy efficiency and savings • Overall efficiency of resource use				
Minimisation of Toxic Materials and Waste	• Quantity of waste (air, water and solids) • Quantity of toxic and hazardous waste used and generated • % of waste materials used as raw materials for other industries (i.e., based on industrial ecology and CASE principles) • Quantity of by-product recovered • Cost of pollution control abatement technology • Need for waste treatment and disposal • Ultimate disposal costs of unmarketable by-products and waste • Overall operations and maintenance cost				
Protection of Terrestrial Resources	• Space required for construction • Compatibility with immediate or adjoining facilities and systems • Transportation and materials flow requirements • Potential for soil contamination • Potential for geomorphology, landscape and ecohydrological impacts				
Protection of the Atmosphere	• Air emissions • Potential for long range transport of atmospheric pollutants • Potential for climate change impacts				

Figure 5: Proposed Checklist of Socio-Economic Indicators for ESTs

(Prepared by UNEP/IETC Expert Group on Environmentally Sound Technologies)

Criteria	Indicators	Yes	No	Quantitative Indicators (i.e., amount saved/spent and/or reduced/ increased)	Qualitative Indicators (i.e., based on potential local, regional and global impacts)
Financial Viability	• Capital investment • Return on investment • Payback period				
Operations & Maintenance Viability	• Management and labour costs • Expertise and skills requirements for operation and maintenance • Utilities cost (water and energy) • Cost of other consumables • Cost of pollution prevention and control • Cost of residuals management and solid waste disposal • Cost of environmental remediation and restoration • Cost of natural capital • Cost of environmental health and safety liabilities • Frequency of maintenance • Parts and service cost • Overall cost effectiveness				
Responsive to Local Needs and Benefits	• Public acceptance • Public health & safety risk • Social benefits • Cultural value • Employment • Use of local resources • Capacity building requirements				
Quality of Information	• Reliability of data • Existence of a QA/QC programme • Available comparisons to existing systems • Transparency of data collection and reporting • 3rd party substantiation				

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Bibliography: The Bibliography may be accessed via the TRC Home page. If none is currently available on-line, please contact ISTT – info@istt.com for further information.

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