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Sustainable asset management for utility streetworks

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ABSTRACT Utility infrastructures are one of the critical elements of urban environments. However, utility installation and maintenance operations are costly, both in terms of direct construction costs (estimated to be around £1.5 billion in the UK in 2006) and in terms of indirect and social costs, which adversely impact the UK economy. These costs are significantly increased when the considerable environmental costs are considered. These adverse impacts are mainly due to traffic congestion, both in terms of energy wasted and vehicle emissions. It is now established that the true total cost of any activity can only be measured by considering all aspects encapsulated by the three 'pillars of sustainability', i.e. taking account of social and environmental impacts along with economic (both direct and indirect) costs. After a critical review of the existing sustainability assessment tools, it is proposed that an existing tool should be adapted to provide a holistic, robust sustainability costing framework specifically for utility streetworks. This paper discusses key sustainability assessment indicators and provides recommendations for developing a value-based asset management framework for utility streetworks.

1 INTRODUCTION

Conventional development in industrialised and developing countries has caused human beings to face global warming and adverse climate changes. Additionally, increases in global population, the rate of consumption of natural resources without known replacements, and production of waste and emissions are increasing the pressure on the planet and its ability to supply resources. Consequently, societies now encounter serious problems such as flooding, forest fires, droughts, loss of biodiversity, and the negative impacts of urbanization on individuals (Butchart et al. 2010).

In recent years, however, the sustainability agenda has been introduced into world development plans, and consequently adopted for the built environment. The most common general assessment of sustainability, the Triple Bottom Line (TBL), emphasizes an enhancement in the three pillars of sustainability: economic, social and environmental. Several studies have investigated the impacts of economic developments on the environment and society within the context of decision-making (Ariaratnam et al. 2013). It is generally easier to quantify the economic and environmental elements of the 'TBL' sustainability than the social aspects, yet it is essential to consider all three pillars holistically (Hayes et al. 2012). This supports the argument underpinning 'Pareto Optimality (efficiency)' which states that in decision-making, performance of different options must be examined to establish the 'decision-frontier', where it is almost impossible to enhance one objective without having a negative effect on the performance of at least one other (Elghali et al. 2008) – i.e., it is normally difficult to improve one of the three pillars of sustainability without having any impact (often a negative effect) on the other two pillars (Hunt et al. 2008).

Holt at al. (2010) state that Sustainable Development is no longer a fringe activity, and over the past few decades has been recognized by governments and industry as a core activity. Academics and industry professionals, and even the aware public, use the term 'Sustainable Development', yet no fixed definition can truly explain the concept (Elghali et al. 2008). Nevertheless, as infrastructure systems act as an interface between citizens and the natural environment, all infrastructure projects can be considered as sustainable development projects.

This paper discusses sustainability assessments within the context of utility infrastructure operations (placement, maintenance, renewal), focussing on the challenges and opportunities of sustainability costing of utility streetworks, and concludes with recommendations for an asset-management framework.

2 SUSTAINABILITY COSTS OF UTILITY STREETWORKS

As the UK's utility infrastructure has been greatly expanded during the last 200 years, a vast amount of ground has been dug and different utility services have been placed underground. From the gas pipes installed to power streetlights, shops and homes in 1807 and sewer networks in 1866, to 20th century communication cables, maintenance, renewal and upgrading has been a constant feature (Rogers and Hunt, 2006), and one usually achieved by digging up the ground at significant economic cost. In response, road occupation charging schemes have been trialled (e.g. £1000 per day charged to utility companies for upgrading works by the Camden and Middlesbrough Borough Councils, Balance et al. 2002). The direct costs of utility streetworks excavations is ~£1.5 billion a year in the UK (McMahon et al. 2006), while the 'collateral damage' includes interrupting traffic flow, damaging tree roots, waste production, leakage and soil and air pollution (Kolator 1998).

Utility services are an essential part of well-functioning urban environments; indeed, quality of life in the 21st century is highly dependent on an invisible utility system (Rogers and Hunt, 2006), and as ever more people live in cities (estimated to reach ~70% of the world's population by 2050), these services will gain in importance (Sterling et al. 2012). However, McMahon et al. (2006) estimated that the social costs of traffic congestion in the UK in 2005 were as high as £5.5 billion per annum, with ~5% (~£275 million) attributed to utility streetworks. To this must be added the very considerable environmental costs due to traffic congestion, both in terms of energy wasted and vehicle emissions. Inaccurate location of pipes and cables lengthens streetworks operations and exacerbates congestion, e.g. via major delays due to repairs caused by third party utility damage, the annual direct cost to utility companies being estimated at ~ £150 million (McMahon et al. 2006).

3 ALTERNATIVE WORKING PRACTICES FOR UTILTY STREETWORKS

The combined pressures of population growth – an additional 10 million UK citizens by 2065 – new housing and urbanisation will see urban areas grow and densify, and demand for new buried utility infrastructure, while maintaining the existing, will grow concomitantly. Traditional methods of utility placement, i.e. open-cut trenching, are becoming unsustainable in terms of their disruption to city systems, and their (social, economic and environmental) costs will progressively become prohibitive. Thus, while trenching is now often considered to be the cheapest and most convenient option (for asset owners), and least risky construction method (all assets are exposed), growing awareness of the physical damage they cause (to roads, adjacent pipes) necessitates the use of alternatives such as Trenchless Technologies (TT) and Multi-Utility Tunnels (MUTs; Figure 1).

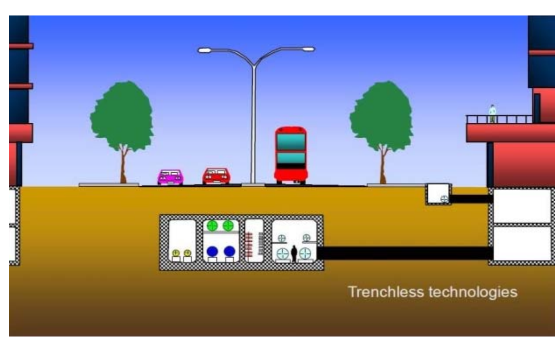

Figure 1. Combined use of MUTs and TT (Rogers and Hunt 2006)

3.1 Comparison of utility placement techniques from a sustainability viewpoint

Multi-Utility Tunnels (or Common Service Tunnels) have been advocated as the least expensive method of utility placement when a range of long-term costs were considered across all three pillars of sustainability (Hunt et al. 2014). However, traditional, open-cut methods of utility placement and maintenance are widely considered to be the cheapest short-term option from an economic point of view. For example, Laistner (1997) makes the point that trenching is less expensive than MUTs and trenchless technologies in terms of machinery and labour. It is therefore the length of view taken, as well as the misalignment between who pays and who benefits, that is important, even though it is the same citizens who benefit from both the utility services and the city systems that are disrupted (Hayes et al. 2012).

Rogers and Hunt (2006) derived a costing model for sustainability of MUTs compared with open-cut and TT. The model assesses both short-term and long-term costs via a simple credit system, suggesting that MUTs (by gaining +30 credits) have significant long-term advantages over TTs (with +8 to +18 credits) and trenching (with +6 credits). Although short-term economic costs of implementation of MUTs – e.g. 'cost of machinery' (e.g. excavators, barriers and traffic signals) for initial utility installation, 'cost of labour' for the construction works, 'cost of materials' needed for construction – will be high, the long-term economic advantages are significantly improved. Examples of these long-term economic advantages include, but are not limited to, 'quality of installation' causing long-term economic savings, 'leakage detection' (including gas leakage) and repairs (this is facilitated by sensors within MUTs), and 'preventing the costs of repairing and resurfacing of roads' due to excavations for the purpose of maintenance and renewal (road lives are not reduced).

Social costs of utility placement in the short-term by trenching were shown to be lower than for MUTs due to the existence of good and well-practiced management systems for trenching methods and the more extensive works required to introduce an MUT, whereas in the long-term MUTs offer an ideal socially-efficient system (Rogers and Hunt 2006) compared to open-cut and TTs. This is because the utility maintenance, upgrading, renewal or expansion will be carried out within the MUT (except for shallow, surface-opening MUTs), therefore, risks and disruptions to both public and workers can be minimised.

Environmental costs of utility placement vary between different methods of installation. Although short-term costs such as 'energy use' and 'materials' are less for TTs than MUTs, these would be improved in the long-term with MUTs. Examples of environmental damage – e.g. leakage from sewer pipes and air pollution resulting from 'delayed vehicles' (Kolator, 1998) – could be controlled through the use of MUTs. Similarly, ecological issues were considered; e.g. the damage to tree roots and also vice versa (i.e. damage from tree roots to utilities) is common with trenching methods, whereas these costs can be prevented or at least minimised by the implementation of MUTs and trenchless technologies.

4 SUSTAINABILITY ASSESSMENT TOOLS

In general, there are many tools and evaluation methods available for sustainability assessment. This is equally true for the field of civil engineering and for different types of construction projects. It is not easy to choose the most appropriate tool/assessment framework for use in a particular project. Many tools are commonly rejected because it is thought that using them might take too long or they might not be the right tool for a particular purpose. As stated in PETUS (2005), a tool could provide guidance or consist of a procedure, method, assessment or evaluation of a set of indicators based on a defined benchmark in order to accomplish an objective or to achieve a result.

In order to consider sustainability impacts and ultimately measure those impacts/costs, many tools have been developed by companies and organisations around the world such as BREEAM, LEED, DGNB and SBAT for buildings, and CEEQUAL, SPeAR® HalSTAR and EnvISIon for infrastructures, to name but a few. Rating systems such as BE^{2}ST-In-Highways, GreenLITES, Greenroads and I-Last have been designed particularly for the transportation infrastructure industry. Examples of other new sustainability assessment and rating tools developed for the construction industry in general are ATHENA (Canada), Estidama (UAE), and QSAS/GSAS (Qatar), which are likely to reflect the context and vision of their respective countries. Pearce et al. (2012) indicate that in the UK there are a range of assessment tools from voluntary rating schemes such as BREEAM and CEEQUAL through to a number of public and private sector 'Sustainability toolkits', and also statutory processes such as Sustainability Appraisal (SA). Most of the tools are either developed with a context in mind, which is normally very prescriptive and hence they do not bring much value, or they are so general that they do not include all of the aspects that are important in any particular context.

Surveys of sustainability assessments and costing of utility streetworks (Jung 2012; Hayes et al. 2012; Hunt et al. 2014) have indicated that in some cases monetary assessments of impacts could be suitable, but where this is not appropriate other measures should be employed. Where such monetary assignment is not possible, or would be unreliable, then a means of assessment should aim to determine value and its associated benefit. Only then can a direct cost associated with delivery of the benefit be estimated with any degree of certainty, allowing an assessment of the sustainability value-to-cost ratio to be made.

Methods to establish direct and indirect economic costs of streetworks are available (Hunt et al. 2014). However, building on recent research at the University of Birmingham a new method that captures the total costs and impacts is being developed. After an extensive review of the options, the suggested way forward is to adapt an existing assessment tool to provide a holistic, robust sustainability costing framework specifically for utility streetworks.

4.1 Assessment indicators

Although there are many sustainability and sustainable development indicator sets, or sets of criteria for sustainability assessment, there is not any standard or complete set of indicators available for utility streetworks sustainability assessment. It has been stated indicators associated with the United Nations Millennium Development Goals (UN 2008), either Global or National, and many other indicator sets developed for building rating systems are not directly related and appropriate for civil infrastructure (MacAskill and Guthrie 2013), and this is more acute still for the specificity of streetworks operations.

As described by Fenner and Ainger (2014), there are different types of general indicators. Some of them measure impacts or project outcomes, while others measure inputs, and there are also indicators that focus on the process, i.e. how the project is carried out rather than relating to specific inputs or objectives. MacAskill and Guthrie (2013) created a summary of sustainability indicators and themes under headline indicator categories collected from different infrastructure assessments and research including CIRIA's guidelines (Berry et al. 2011), AGIC (2010), BREEAM (2011) and CEEQUAL (2011). It is not, however, a comprehensive collection of all existing tools and indicators and none of the tools in that summary covered all the indicator themes.

Building on the growing literature in this field and avoiding unnecessary tool development, an existing well-established tool is being adapted to specifically deal with utility placement and maintenance works. However, this raises the question of how and to what extent these tools or methods should be modified to satisfy the requirements of utility streetworks projects while complying with their original design thinking. As a result, a new indicator system including headline costs, indicators and sub-indicators, has been developed to match the requirements and nature of the streetworks projects in particular (Figure 2).

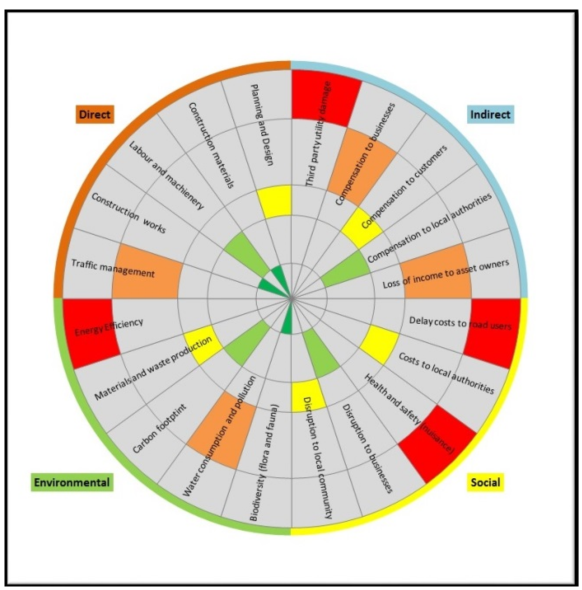

Figure 2. Rose diagram containing the set of bespoke indicators for utility streetworks

The indicator sets are divided into four main categories of impacts – Direct Economic, Indirect Economic, Social and Environmental – to create a complete picture of the total costs of utility streetworks. A summary of the headline costs with associated main indicators is shown in Table 1.

The indicator sets were initially developed from the literature and they have been reviewed based on initial discussions between the authors and a group of experts from the fields of sustainability and infrastructure. These initial indicator sets were then revised following three expert panel discussions to refine the final set.

As an example, 'Third Party Property Interference and Damage' as an initial indicator within the 'Construction Indirect Economic Impact' category was changed to 'Third Party Utility Damage' to crystallise the idea in terms of the utility streetworks context and highlight the potential seriousness of 'utility strikes' as an indirect cost of utility streetworks. Deeper research into its causes and costs (e.g. see Metje et al. 2015) will aid in further refinement.

Table 1- Sustainability indicators for utility streetworks costs and impacts

Headline Indicator	Indicator Category
Construction Direct Economic Impact	Planning and Design
	Labour and machinery
	Construction materials
	Construction works
	Traffic management
Maintenance Direct Economic Impact	Planned maintenance
	Monitoring
	Access
	Emergency repairs
	Decommissioning
Construction Indirect Economic Impact	Third Party utility damage
	Compensation to businesses for loss of profit
	Compensation to customers for interruptions to services
	Loss of income to asset owners or utilities
	Compensation to local authorities for damage to their assets
Maintenance Indirect Economic Impact	Goodwill
	Required Training (upskill)
	Insurance
	Loss of business to competitors
	Lost Opportunity Cost
Construction Social Impact	Delay costs to road users
	Disruption to businesses
	Disruption to local community
	Health and Safety (nuisance)
	Costs to local authorities
Maintenance Social Impact	Delay costs to road users
	Disruption to businesses
	Disruption to local community
	Health and Safety (nuisance)
	Costs to local authorities
Construction Environmental Impact	Energy efficiency
	Materials and waste production
	Carbon footprint
	Water consumption and pollution
	Biodiversity (flora and fauna)
Maintenance Environmental Impact	Energy efficiency
	Materials and waste production
	Carbon footprint
	Water consumption and pollution
	Biodiversity (flora and fauna)

4.2 *Advantages and limitations of the tool*

Unlike other sustainability assessment tools such as BREEAM and CEEQUAL, which apply weighting factors for the different categories or impacts, the indicators and sub-indicators in the tool under development are not weighted. This is an advantage because it prevents subjective bias in assigning weighting factors and maintains the tool's flexibility when applied to different projects. Furthermore, it is not a reward driven tool, which tends to introduce an in-built bias to the system (Holt et al. 2010). Moreover modification of an existing assessment tool addresses the concern over tool fatigue, which is routinely raised as an issue when the development of an entirely new assessment method is proposed.

5 THE WAY FORWARD: A VALUE-BASED ASSET MANAGEMENT FRAMEWORK

Due to the diverse nature of utility infrastructure projects, and the very large number of streetworks carried out annually – more than 480,000km of underground utilities, including water, wastewater, gas, electricity and telecommunication, are laid around the world each year (Najafi 2005) – a robust and comprehensive, yet simple and easy to use, assessment tool is required. This must be able to evaluate both the benefits and adverse impacts of the economic, social and environmental aspects associated with streetworks, and accommodate the variety of contexts in which the works are carried out. Given the complexity and bias that are often associated with cost based (monetary) assessment, the most appropriate approach is now considered to use 'value'. This enables the assessor to move away from simple, narrow, often misleading assessments deriving from a single monetary measure. Thus, further research should form the core of an assessment framework that informs decision-making in an environment where competing private and public financial interests interact with peoples' daily lives, as well as providing a basis on which to support investment decisions for streetworks projects, by enabling a more holistic view to be taken of the overall value of the works.

Oversimplification of the scoring system of some well-established assessment tools (e.g. SPeAR® and CEEQUAL) increases the potential of the tool to be misused. To avoid this, a detailed and rigorous analysis of the costs (impacts) as well as benefits of the chosen utility placement/rehabilitation/maintenance method is planned to identify the value of the proposed works. This will be in the form of a Whole Life Costing (WLC) exercise (considering short- and long-term impacts) within a broader asset management framework to realise the value of a particular streetworks option to both asset owners (utility companies) and society and the environment as a whole.

6 CONCLUSIONS

A tool for sustainability assessment of utility streetworks is much needed to help the process of decision-making for the selection of the best engineering solution in any given case for this important context. Consideration of 'value' as well as 'costs/impacts' is now considered the best approach. A tool and set of indicators were developed. The indicators are not weighted to avoid bias. Ultimately, time will be included in the assessment framework to determine whole life costs and provide better assessments of short-term and long-term benefits.

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