Achieving sustainable underground construction in Birmingham Eastside?

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Abstract: The £6bn redevelopment of a 130 hectare area to the east of the Birmingham city centre, referred to as Eastside, aims to turn an area characterised by its industrial heritage into the region's first 'sustainability quarter'. A major part of this programme involves demolition of existing buildings, modification and extension of existing infrastructure and the provision of a new city landscape (i.e. residential areas, offices, hotels, retail outlets, visionary underground parking and a new city park).

Sustainability as part of a three-pillar approach (i.e. economic, social and environmental) is complex and many would advocate that construction, by its very nature, can never be truly sustainable. Whilst the sustainable credentials (most obviously environmental performance) of the built environment are clearly visible and measurable following construction, those for the underground environment are not. The increased demand for high-rise buildings, and notably their requirements for water and electricity will place greater demands on underground space for Eastside. The sustainable development of underground space is an essential part of sustainable construction which must be addressed sooner rather than later to ensure a better quality of life for present and future occupants of Eastside.

This paper investigates the complexities of providing sustainable underground construction within the Eastside redevelopment project and investigates the barriers that stand in the way of their implementation. The paper introduces sustainable practices that are being integrated within the development, including re-use of demolition materials, treatment of contaminated land, sustainable water supplies and sustainable urban drainage systems. The paper also highlights the sustainable options for underground development that should be considered when constructing on a city centre Brownfield site, including controlling rising groundwater levels and the sustainable provision of utility service.

Résumé: La reconstruction de £6bn d'un secteur de 130 hectares au à l'est du centre de la ville de Birmingham, désignée sous le nom d'Eastside, vise à tourner un secteur caractérisé par son héritage industriel dans le 'quart de la durabilité 'de la région première. Une majeure partie de ce programme implique la démolition des bâtiments existants, de la modification et de la prolongation de l'infrastructure existante et de la fourniture d'un nouveau paysage de ville (c.-à-d. secteurs résidentiels, bureaux, hôtels, débouchés pour les ventes au détail, stationnement souterrain de visionnaire et un nouveau parc de ville).

La durabilité en tant qu'élément d'une approche de trois-pilier (c.-à-d. économique, social et ambiant) est complexe et beaucoup préconiserait que la construction, de par sa nature, peut jamais être vraiment soutenable. Tandis que les qualifications soutenables (exécution le plus évidemment environnementale) de l'environnement établi sont clairement évidentes et mesurables après construction, ceux pour l'environnement souterrain ne sont pas. La demande accrue des gratte-ciel, et notamment leurs conditions pour l'eau et l'électricité placeront de plus grandes demandes sur l'espace souterrain pour Eastside. Le développement soutenable de l'espace souterrain est une partie essentielle de construction soutenable qui doit être adressée plus tôt plutôt que plus tard assurer une meilleure qualité de la vie pour les occupants présents et futurs d'Eastside.

Cet article étudie les complexités de fournir la construction souterraine soutenable dans le projet de reconstruction d'Eastside et étudie les barrières qui incommodent leur exécution. Le papier présente les pratiques soutenables qui sont intégrées dans le développement, y compris la réutilisation des matériels de destruction, le traitement de la terre souillée, les approvisionnements en eau soutenables et les canalisations urbaines soutenables. Le papier accentue également les options soutenables pour le développement souterrain qui devrait être considéré en construisant sur un emplacement de Brownfield de centre de la ville, y compris les niveaux de montée de contrôle d'eaux souterraines et la fourniture soutenable de service de service

Keywords: Case studies, contaminated land, groundwater provinces, regional planning, underground installations

INTRODUCTION

This paper gives an up-to-date report on underground construction being implemented, and opportunities being missed, within an ongoing £6bn re-development project, known locally as Birmingham Eastside. It is reported that the redevelopment programme, one of the largest regeneration projects being undertaken within the UK currently, has the potential to turn a 130 hectare (420 acre) area of Birmingham into the region's first 'sustainability quarter', when finally completed around 2010 (Birmingham City Council 2003a).

Underground construction is the necessary first step for any construction programme and it provides the building blocks upon which a city or town is built. Its placement therefore has certain critical implications in terms of achieving a truly 'sustainable quarter'. Typically underground construction includes tunnelling (transport, water supplies), deep and shallow basements, foundations and utilities provision (i.e. energy, water and communications). The sustainable credentials of space above ground, in-particular with respect to the built environment, are clearly visible following construction, and its environmental performance can be measured with relative ease during and after construction (e.g. BREEAM and Eco-points in the UK, see Dickie and Howard 2000). However construction with regard to sustainability is not compulsory and therefore remains the exception rather than the rule (e.g. in the period prior to August 2003 only 3,400 units in 100 developments had been certified under the Eco-homes scheme – see Ends Report, 2003). The situation for underground space is far worse, although this is partly because the space is not visible following underground construction and hence for far too long the sustainable performance, specifically within the UK, has been ignored. As the population density within the UK increases, particularly in major cities, so too does the competition for space above ground. Therefore many countries worldwide, including Hong Kong, Japan, Singapore, Scandinavia and Denmark have already realised the true value of underground space. In Demark the motives for underground construction include: quality of environment, efficient use of space and spatial functional structure (see Monnikhof *et al* 1999). In effect by constructing a percentage of all buildings underground (i.e. the most suited parts of a facility: goods delivery, utility systems, car parks, shops and entertainment) higher development densities within these cities can be achieved (Horvat *et al* 1997). This policy for underground construction within these countries should avoid leaving a legacy of elevated environmental social and economic costs for future generations, something to which Eastside would aspire.

This paper deals with the sustainable provision of underground development *per se* within Eastside and gives an overview of the individual sustainability aspects relating specifically to:

- Transport Infrastructure (Both Public and Private) including Parking
- Utility Infrastructure (including Energy Supply, Water Supply and Utility Placement)

In assessing the sustainability of underground construction within Eastside an insight into the complexities of the decision making processes are given. Whilst the development as a whole has not reached a *fait accompli,* opportunities will undoubtedly be missed during the decision making processes because the knowledge base on sustainable solutions is in a state of development. This paper describes the legacy that could be left for future generations who will live and work in Eastside.

BIRMINGHAM EASTSIDE: A BRIEF DEVELOPMENT HISTORY

Birmingham, Britain's second largest city, is recognised for its world class facilities (commercial, business, industry, entertainment and sport), its heritage (home to James Watt and Mathew Boulton, inventors of the steam engine) and its truly multi-cultural society (over 50% ethnic minorities). Birmingham Eastside is an area of some 130 hectares (420 acres), including Digbeth and the Aston triangle, and is located to the south eastern side of the city centre within the Nechells Ward (shown by a thick dashed line in Figure 1). In 1996 a small team of city planners and designers was assigned the ambitious task of expanding the city centre into the Eastside area. The initial master plan, drawn up by HOK, depicted areas for development (i.e. commercial, retail and residential) within a new Quarter based around the themes of Learning, Technology and Heritage (HOK 1996). The first step of the programme involved the removal of Masshouse Circus, an elevated section of ring road constructed in the early 1960s during Birmingham's motor city era. The so-called 'concrete collar' (shown by a thin dotted line in Figure 1) spanned the boundary of Eastside creating both a visible and logistical barrier to development which prevented outward expansion of the city into the surrounding area. This major barrier had caused planners to continue developing western quarters of Birmingham (e.g. Brindley Place) in preference to the east, thereby causing a decrease in social wellbeing, environmental quality and economic prosperity for the area. As an 'Objective 2' Birmingham City Council (BCC) sought and gained European funds for removal of the roadway in 2002, and major infrastructure changes followed to facilitate future development.

Subsequently various development plots, created through the removal of the roadway, were sold off by BCC to facilitate new build projects. In total eight plots were created (referred to as Sites 1-8) although two plots were abandoned (1 and 2) and subsequently plans for Sites 3-7 were drawn up in accordance with the governments' guidance on urban design. For Eastside these sought to *'ensure the creation of an attractive and sustainable quarter which provides places and spaces which will enhance the quality of life for people who work, live and play in the city and in this part of the city centre in particular'* (GVA Grimley 2002a). Masshouse is situated on Sites 3 and 7 and has sustainable regeneration as a key theme (David Mcleans 2002) in accordance with the 'Sustainable Eastside: A Vision for the Future' document written by the Eastside Sustainability Advisory Group (ESAG), an independent advisory group for Eastside (Groundwork Birmingham and Friends of the Earth 2002). The development is a joint venture between David Mcleans, Nikal Developments and the Royal Bank of Scotland and construction is underway currently. City Park Gate, situated on Sites 4, 5 and 6, is being developed by Countryside Properties (renowned developer of the Greenwich Millennium Village). Having been selected on a basis of 50% design and sustainability, 30% financial and 20% deliverability, the development is expected to exceed relevant standards and minimise environmental effects (e.g. low energy systems, heat recovery, grey water recycling, heat and power and photovoltaics). It will include residential development, offices and a food store, and construction is due to start early in 2006. The last site, Site 8, referred to as the 'New Library Site' was proposed as the site for an innovative Richard Rogers designed city library (GVA Grimley 2004) replacing an existing outdated 1970s library situated at Paradise Circus (although under review currently).

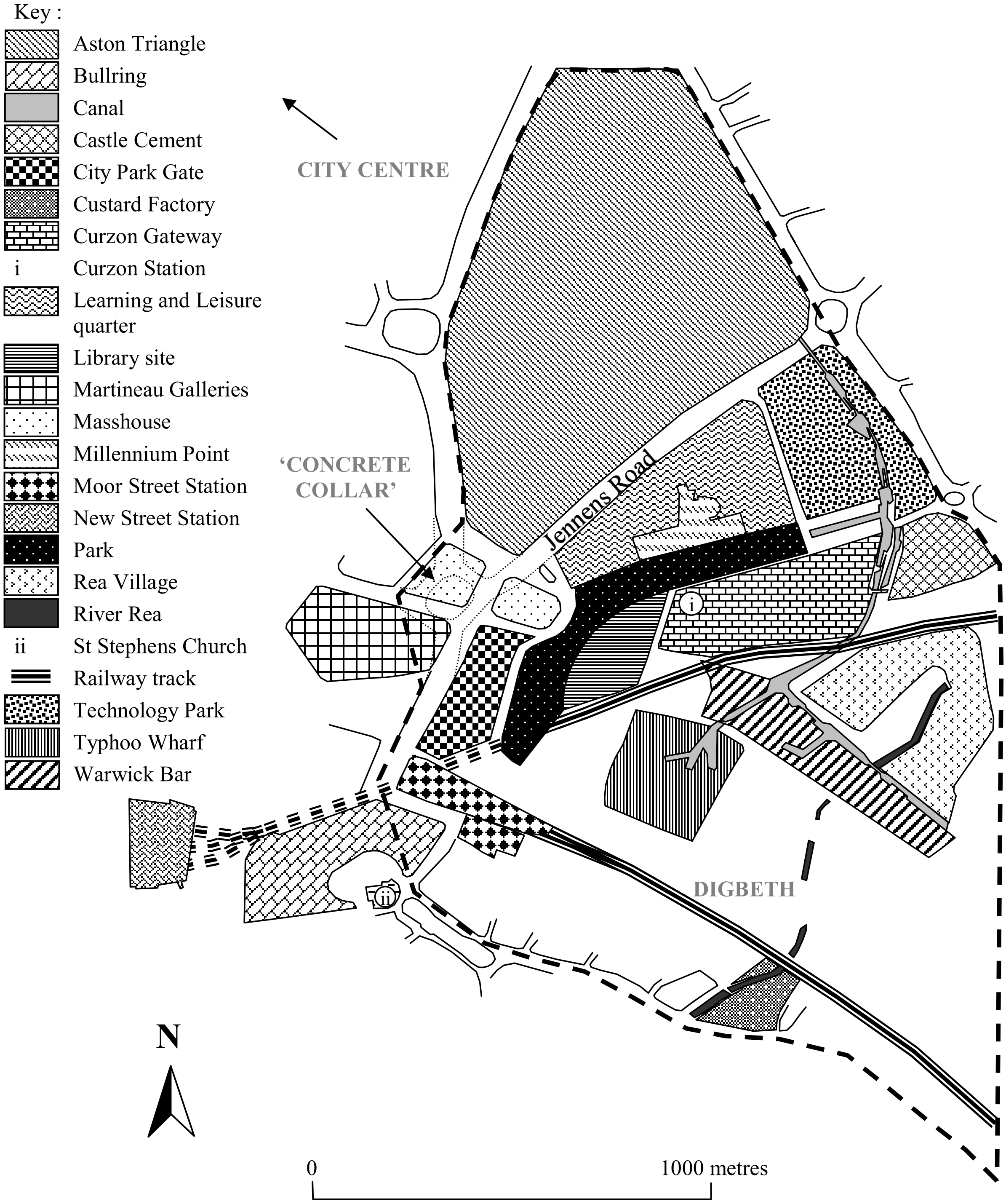

Figure 1. Sites for re-development in Birmingham Eastside

During this time Advantage West Midlands (AWM), the local redevelopment agency, sought compulsory purchase of land surrounding Millennium Point (a Millennium project which opened in 2000 and is home to the IMAX cinema and Young Peoples' Parliament) for creating the New Technology Park and Learning and Leisure Quarter. These are also in the early stages and visioning meetings were held from February to May 2005 by LDA design (who have previously delivered a strategy for development of sustainable communities along the Thames) and Arup. Sustainability is at the heart of AWM philosophy and hence the development is expected be an exemplar of sustainable design, one of the outputs being the creation of 5000 jobs, which will have major impact on the economic pillar of sustainable development. Other new build sites have also been established, although again these are at the early planning stages. They include the former Castle Cement works (former producer of cement) and Curzon Gateway (currently the Royal Mail depot, which is due to relocate in 2006), which are both being developed as residential sites (mainly student accommodation) through the Eastside Partnership (a private collection of investors). To the south of the railway tracks is the heritage area. Here the new Rea Village (named due to its location alongside the River Rea) will build on the built and natural aspects of the environment and has a clear opportunity to provide a demonstration project of sustainable design (Birmingham City Council 2003a). Typhoo Wharf (former home of Typhoo Tea) and Warwick Bar (being developed by ISIS) are also situated in the heritage area and border onto the canal systems. These will be completely refurbished to a high standard. Previously completed refurbishments include the Custard Factory, former home to Birds Custard and now home to enterprising small industries and artists. On the western tip of Eastside is the newly completed Bullring, which opened in 2003. It was reportedly the third most visited shopping centre behind Glasgow and London in 2004 with over 36 million visitors. This £500m project includes Selfridges (a Future Designs project), Martineau Galleries, the refurbished St Stephen's church and an area for open market stalls. The Bullring has brought much needed economic regeneration to the area (a headline indicator of sustainability and a significant driver in this regeneration programme) through the creation of over 8000 new jobs. The location of the various developments mentioned above can be seen in Figure 1.

In 2005 development within Eastside is progressing at a steady rate. By 2010 it is reported that it will have a new sustainable transport infrastructure which includes new roads, a bus route and integrated cycle network, improved pedestrian facilities and better access to public transport networks and the canals. It is envisaged that this will result in the creation of a high quality urban environment that is both sustainable and economically viable (Birmingham City Council 2003a).

SUSTAINABLE UNDERGROUND CONSTRUCTION IN BIRMINGHAM EASTSIDE?

In order to evaluate whether Birmingham Eastside has made progress towards achieving sustainable underground construction, a clear definition needs to be given. Sustainable development, as defined by Bruntland (1987), is one which '*meets the needs of the present without compromising the ability of future generations to meet their own needs'*. The sustainability criteria within a development are traditionally assessed through a three pillar approach, whereby the economy, environment and society are assessed in parallel rather than isolation (Figure 2). These three pillars were used to define and measure sustainable development at a national level within the UK until March 2005 and included 15 headline indicators (DEFRA 2003). Through further inspection of these it is clearly evident that construction is a necessary tool for achieving both economic growth and social progress. However, this is sometimes to the detriment of protecting the environment (e.g. air quality, river quality, climate change). This shows that a careful balance is required between each pillar and this simply emphasises the complex nature of achieving sustainable construction when conflicts exist. In reality the economy cannot exist without a society and society cannot exist without an environment (Giddings *et al* 2002), and therefore the primary assessment for sustainable construction should logically be its environmental performance, as shown in the embedded model (Figure 3).

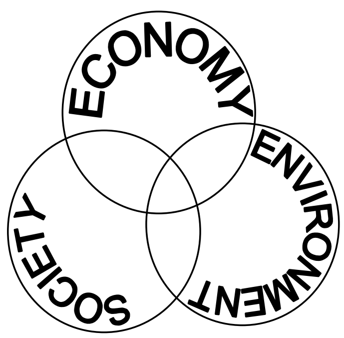

Figure 2. Conventional sustainability model

Figure 3. Embedded sustainability model

Even so, this is a conceptual model only and many would advocate that construction, by its very nature (e.g. relatively short life expectancy in real terms, embodied energy of materials, harmful emissions and finite resources), is un-sustainable, particularly when demands for space, caused by increases in population density, continue to place increased demands for all types of construction above and below ground. Interestingly the pressing issue of security of supply (for water and energy) is not a headline indicator, and yet it is vital requirement for sustaining any modern development. Therefore it is not surprising that indicators developed within the construction industry, such as SPeAR™, include a fourth pillar termed 'natural resource conservation'. The SPeAR™ indicators are being used on the Technology Park and the Learning and Leisure Quarter within the Eastside development as a tool for assessing existing sustainability criteria and for shaping future criteria through the decision making processes (i.e. visioning stages to final construction stage). Resource use is, however, now included within the UK Sustainable Development Strategy Framework indicators, which were proposed in March 2005 (DEFRA 2005). Even with this addition indicators are, however, merely a tool and not a solution for achieving success within the field of sustainability (McGregor and Cole 2003) and in reality the realisation of 'sustainable construction' may be an ideal that cannot be reached. Therefore, in defining 'sustainable underground construction' a process-led approach should be advocated, in which impact on the environment is minimised and the potential for securing supplies (i.e. transport, water and energy) is maximised. However, in reality this may require replacement of conventional methods for supply and inevitably this will require a significant step change in policy making to be made. In striving towards sustainable underground construction the determination and collaboration of all the stakeholders, who are themselves decision makers, is required and since within Eastside there are many, this realisation is not as straight forward as it would first appear.

TRANSPORT AND PARKING

During the removal of the Masshouse flyover 95% of the concrete was crushed and re-used as hardcore in the new roads, likewise the metal reinforcing bars were removed and recycled – two essential principles for sustainable construction. However, in creating a new landscape 19,000m^2 of granite paving was imported from China and Portugal and the trees (8.5m tall, Platenus Acerifolia Tremonia) were imported from Holland, a contravention of the principles of local sourcing (Figure 4).

The Masshouse area region has very little land contamination, mainly due to the removal of such material during the construction of the flyover in the early 1960s. Whilst the Eastside area is not classified as contaminated land, under the UK definition, small isolated pockets of contamination do exist throughout, primarily due to previous industrial use (GVA Grimley 2002b). Birmingham City Council's contaminated land team expressed a preference for removal or capping at these locations rather than treatment *in situ* (e.g. through solidification methods), this being due mainly to a lack of confidence in the method based upon previous experience, although costs were also found to be high. This emphasises the importance of reliable case history data for informing the decision-makers, who are reluctant to go against accepted wisdom when faced with alternative innovative sustainable solutions. Although Eastside has been testament to innovative underground construction of the past, this in some cases has prohibited the achievement of truly sustainable underground development. The example of pedestrian underpasses, which categorised Birmingham's past where the car dominated, can be used to emphasise this fact. Whilst they allowed for safe pedestrian movement away from traffic they became notorious for crime (a headline sustainability indicator). This innovation of the early 1970s has been removed subsequently during Eastside's redevelopment programme (Figure 5).

Figure 4. Granite paving and new trees in Eastside

Figure 5. Landscape, following removal of underpasses

Figure 6. New routes for buses, cars and a metro

Figure 7. Existing car parking and open space

Birmingham is well known for its past changes in terms of transport, particularly within the Eastside area. Birmingham's first railway station, Curzon Street, is situated in the centre of Eastside and New Street Station, its subsequent replacement, is located just outside the Eastside boundary (Figure 1). Moor Street Station is situated within Eastside and having been closed in 1987 (see Turner, 1991), its £11 million refurbishment was completed as part of the regeneration programme and it reopened in October 2003. Transport and pedestrian movement have been a fundamental part of the Eastside regeneration scheme, the main design guide being aptly named 'The Design and Movement' framework (Birmingham City Council 2003a). The new ground level transport system, a boulevard scheme, which replaced the concrete collar and runs along Jennens Road (Figure 1) consists of bus lanes, car lanes and, although not yet constructed, a new metro system which will be situated along the central reserve (Figure 6). Ironically, historical records show that a tram system was removed from the Eastside area during the 1960s (GVA Grimley 2002b) in favour of constructing the Masshouse circus. Currently, the Metro system ends at Snow Hill (situated just outside Eastside) although plans were drawn up by Centro (the midlands rail network) to extend this into Eastside and through to the city centre (Centro 2003). The current infrastructure has been planned around this type of scenario.

One might expect, with such emphasis on transport and movement, that development on the scale of Eastside would be exemplary. Unfortunately this is not the case and emphasises the complex nature of redevelopment. Many users of the new transport system report that it does not work effectively and that unobstructed pedestrian access to the Eastside area, the reason for removing the concrete collar, is not straightforward; subsequently the two way bus routes have been made one way (Figure 6). It should be noted that political will plays a strong role within successful regeneration projects also and the transport system within Eastside is a prime example of where changes in political party (from Labour to Liberal/Conservative) are strongly influencing the decision-making processes for underground construction. The proposed metro scheme, brought about through the political will of the last party, is currently on hold whilst the £100,000 feasibility study for an underground rail system is carried out for the new party (Dale 2004). It may then be asked by those who reside in Birmingham why the second largest city in the UK does not have an underground system already, the most evident barriers including deregulation and privatisation which ended the large transport subsides that Eastside would require. The question within this current climate is where these funds will be sought, especially when tunnelling costs of £50 million per kilometre are reported (Paul *et al* 2002) and these are likely to be elevated considerably due to the presence of existing underground construction (the Anchor Exchange - a telephone exchange built in the 1950s; the Queensway Express Tunnels - a dual carriage way; and the New Street and Snow Hill railway tunnels) and ground conditions (i.e. very high water table). Clearly, this shows the importance of integrating the potential for underground construction at the visioning stages of the decision-making processes for regeneration schemes such as Eastside (see Horvat *et al* 1997 and Goddard 2004). However, removal of transport routes constructed at high levels above ground and downgrading of transport capacity in favour of public transport systems does show a clear step towards sustainable development. This occurs at a time when international projects such as the 'Boston Artery' (see Chandra *et al* 2002) are advocating more routes at high levels. However, the Eastside routes could have gone underground in order to create more open space and pedestrian access to the area, an essential criterion for the scheme, and this, it could be argued, may not have been met under the Eastside scheme currently.

Nevertheless, the development programme will see the construction of underground multi-storey car parks beneath many of the key developments located within Eastside (see Table 1). The number of spaces available is less than that advocated by Planning Policy Guidance 13 (PPG13) in light of sustainable transportation objectives for the area (Birmingham City Council 2003a). Nevertheless the fact that the car parks are underground is a bold and visionary move by decision-makers which pushes the boundaries of existing planning laws and this was made possible only as an integral part at the earliest stages of decision-making within the redevelopment scheme. Removing the surface car parking and placing it underground will enable many direct and indirect sustainable benefits to be gained, not only for those who live and work within the region but for those who travel to and shop within it. One of the key benefits is more open space, which offers psychological relief (ITA Working Group no.13. 1995) contributed to in part by the creation of a 3.2 hectare (8 acre) park situated in front of Millennium Point (Figure 1). The construction of underground parking is not straightforward and for Eastside is very expensive because of high ground water levels, a well reported scenario for Birmingham city centre (see Knipe *et al* 1992). The developers of the Selfridge's underground car park scheme employed expensive dewatering schemes and provided tanking to slabs for prevention of water ingress. However, in many respects this can be seen as a temporary unsustainable solution to the problem of rising groundwater in cities. Interestingly sustainable solutions for dealing with rising ground water levels were considered during the decision-making processes for the Masshouse scheme and these are discussed hereafter in the water supply and disposal section.

Table 1. Summary of Underground Car Parking in Eastside (Birmingham City Council 2003a)

Development	**Capacity**
City Park Gate	650
Masshouse (site 3 and 7)	650
Library Site	650
Beneath New Park	650

UTILITY INFRASTRUCTURE

Utility placement

The provision of utility infrastructure is the necessary first step for any redevelopment scheme. Its capacity for continual and upgradeable supply will dictate whether a modern development such as Eastside can be sustained. Whilst conventional utility placement through trenching is regulated (The New Roads and Streetworks Act 1991 and updated by the Traffic Management Act 2004) and voluntary best practice standards exist (see NJUG 2003) they are not mandatory. The utility infrastructure was completed in 2004 and includes high voltage (HV) and low voltage (LV) electricity, communications, street lighting, gas and water. The standard of new utility placement within one of Eastside's 2m wide pedestrian walkways is shown in Figure 8. Clearly, where best practice is not applied, an unsustainable legacy (e.g. for utility repair and maintenance, asset location, capacity expansion) is being left for future generations who will live and work within these areas.

Figure 8. Utility placement within a Eastside

Figure 9. Pavement with high quality finish in Eastside

Why then, within the UK and especially within a so-called 'sustainable quarter', are utilities placed in this manner? The main reasons include inherited utility systems and a lack of knowledge of alternative methods by key decision makers within Eastside, and in a wider context the UK, and where this knowledge does exist there is reluctance to change the current practice (i.e. entrenched behaviour). However, the most important issue for Eastside is the fact that underlying disorder is not visible once high quality pavements are in place (Figure 9).

Utilities remain an unseen part of the built environment and therefore are of little apparent consequence to the end users of Eastside. This will remain the case until systems begin to break down or when design capacities for supply and disposal to the area are exceeded, and this vitally important scenario will undoubtedly have to be addressed by future generations within the region. Interestingly, whilst there are sustainability indicators which deal with the various processes of utility placement through trenching, as shown in Table 2 (see Rao *et al* 2001), the method has been classified by many authors to be inherently unsustainable, due to its direct and indirect costs to the environment (see Giacomello and Trombetti 2001), society (see Iseley and Tanwani 1990) and economy.

Table 2. Sustainability Indicators for utilities (after Rao *et al* 2001).

Economic	Social	Environmental
Capital cost	Community disruption	Material transport
Whole life cost	Training	Aggregates
Efficiency	Health and safety	Waste
Accessibility	Site security/safety	Leakage
Research		Materials
Risk		Energy use
Quality		Resource sharing
		Pollution control
		Packaging

Utility placement through alternative methods such as multi-utility tunnels (MUTs) would make a positive step towards achieving sustainable underground construction. A multi-utility tunnel is *'any system of underground structure containing one or more utility service which permits the placement, renewal, maintenance, repair or revision of the service without the necessity of making excavation ; this implies that the structure is traversable by people and, in some cases, traversable by some sort of vehicle as well'* (APWA, 1997). MUTs have received little attention within the UK and yet they provide a logical means for utility placement. Many examples exist worldwide, and the lack of global standards means that a variety of alternatives exist and are in operation currently. They vary in terms of size (e.g. 1m to 15m wide), shape (e.g. round, oval, square or rectangular see Legrand *et al* 2004), material (i.e. concrete, steel, PVC), placement (cast *in situ*, pre-cast sections - see Figure 10 - or ring tunnel segments placed using a tunnelling machine) and location. Location includes depth which affects accessibility, i.e. surface mounted within or next to the pavement (see Figure 10), just below roads or a metro, which is of particular relevance to Eastside (see Figure 11), or deeper as in the case of Japan and Helsinki. Whilst the method has many advantages (see for example Cano-Hurtado and Canto-Perello 1999), including less disruption to the urban realm and facilitation of future utility maintenance through easier placement, many barriers to its adoption exist. These are not restricted to Eastside and operate within the UK (see Hunt and Rogers 2005). Whilst costs are cited as a significant barrier for widespread adoption of such schemes, these are short term only (i.e. initial construction). Laistner (1997) showed that the long term costs for such schemes were considerably lower than trenching methods when considering such schemes in Germany. A state-of-the art report for Multi Utility Tunnels within the UK, including costs, is being compiled currently at the University of Birmingham and it is hoped that this will facilitate decision-makers within the UK to adopt such schemes.

Figure 10. CHP pipes at the University of Birmingham

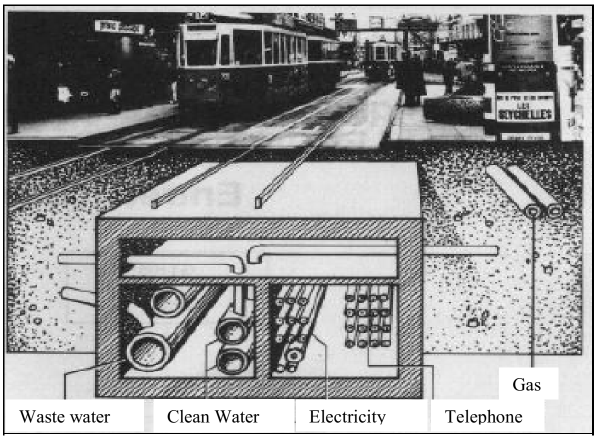

Figure 11. MUT under a tramway in Geneva (Pierre, 1977)

Energy supply

The new offices, hotels and retail outlets within the Eastside scheme will place new demands on the area in terms of energy requirements (i.e. supply) and therefore utility infrastructure underground. The Eastside development, in line with UK policy (DTI 2003), is seeking to reduce CO_2 emissions (climate change, is a headline indicator for sustainable development) through a variety of methods being advocated by the government. One of these is a reduction in demand brought about through good design (e.g. natural ventilation and maximised solar gain), while another is the implementation of a large-scale Combined Heat and Power (CHP) system (current policy seeks to implement 10 GW_e of CHP capacity in the UK by 2010). Unfortunately, the decision-making processes for Eastside have given little attention to the logistics of implementing CHP infrastructure and the consequent requirements this will have for underground space. The feasibility study for this scheme was not undertaken until late 2003 when funding through the Carbon Trust was gained. Therefore such a system will need to be retrofitted within the development. This could increase costs significantly and emphasises the need to consider alternative sustainable solutions for energy supply at the earliest stages in the decision making processes. However, these difficulties could be overcome if the new CHP infrastructure were mapped and placed away from existing utilities, likewise if trenchless technologies were used for utility placement the disruption associated with utility placement both above and below ground could be minimised. However, this would not address future asset location or maintenance issues which significantly could have been addressed through the implementation of MUTs designed to accommodate CHP in addition to other utilities (see Figure 10). Fortunately, however, the scheme secured £1.3million of funding in 2005, leading to a requirement for £2.8million of further funding.

The proposed scheme will deliver heat and power through CHP to six public sector buildings. Two are located within Eastside (Aston University, Millennium Point) and four are situated in close proximity (Victoria Law Courts, Crown Courts, Children's Hospital and 1 Lancaster Circus). The CHP system would be located within an energy centre located in close proximity to Millennium Point and would consist of two gas driven 1.5MW_e reciprocating engines (as opposed to steam turbines) with an overall efficiency of 73%; 35% electrical and 38% thermal. Over a typical year this equates roughly to 45 GWh_{th} of heat and 41 GWh_e of electricity. The centre will have sufficient space capacity to introduce a further 3MW_e for delivery of CHP to other new buildings within the Eastside scheme (L'Industrielle de Chauffage Enterprise, UK, 2004).

Interestingly the CHP scheme, being gas driven, will increase demands for gas in Eastside considerably, firstly because mains gas will be used to generate electricity (substituting mains electricity) and secondly because gas sourced from within Eastside will be used to provide heat and power to developments outside the Eastside area. It is plausible therefore that current newly installed gas infrastructure may not cope with this extra (unallocated) gas demand and may require further modifications to underground utility infrastructure. This emphasises the necessity for presentation of well-informed unambiguous information to decision makers at the earliest stages within a redevelopment programme (i.e. the masterplanning phase).

The underground strata can provide overlying buildings with a significant source for geothermal energy (i.e. heat) which can be captured using a standard ground source heat pump buried within the soil and used within houses (Doherty et al, 2004) and larger buildings. As a more innovative solution they can be attached to the surface of piled foundations also (Ryozo *et al* 2005). It was envisaged that the library would install a geothermal scheme (GVA Grimley 2004). However, funds for building the library were based on Birmingham winning the 'capital of culture' bid, which subsequently went to Liverpool. This illustrates that funding streams have a critical influence within the decision-making process, especially when faced with a decision for implementing sustainable technologies (above or below ground) versus conventional methods.

Water supply/disposal

The new offices, hotels and retail outlets within the Eastside scheme will also place new demands on the area in terms of clean water supply and waste water disposal, both of which require utility infrastructure underground. Eastside's water supply originally came through localized borehole abstraction until completion of the Elan Valley reservoir in the early 1900s, when abstraction ceased (excepting two licensed abstracters in close proximity to Eastside). This lack of abstraction has ultimately allowed ground water levels to rise to current high levels and there is much debate locally on whether rebound levels have been reached or not. Conventional solutions for facilitating underground construction are to employ expensive dewatering schemes in the ground and waterproofing of the underground construction. However once dewatering stops these water levels will rise again.

In addition, the Eastside area receives 819 Mega litres of water per year as rainfall (assuming 630mm falling over an area of 1,300,000 m^2). Any water that falls on porous ground surfaces and green landscaping is removed through evaporation and natural attenuation into the underlying ground, and in part this allows for recharge of the underlying aquifers (Birmingham sits on a major Sherwood Sandstone aquifer). In order to reduce the burden on underground systems the current scheme is encouraging sustainable urban drainage systems (SUDS), which will let more water attenuate naturally into the ground (see CIRIA C522 2000 and CIRIA C523 2001) rather than being directed into the combined sewer system. Ironically, encouraging such a process may not be the most appropriate solution, especially when developers are already facing problems with underground construction. This merely emphasises the need for the problems of high water tables to be addressed on a city scale. These examples show that Birmingham is on the learning curve with regard to sustainability and this re-emphasises the findings made by the PRESUD report (see Birmingham City Council, 2003b). This illustrates the need for clear channels of communication and information sharing within Birmingham City Council and between decision makers in different councils. For example Islington Borough Council, London, encourages developers through its sustainable planning guidance, SPG, to consider borehole abstraction for lowering ground water levels when considering new development schemes (see Islington Council, 1999). Such guidance was not available for developers in Eastside and information concerning sustainable solutions was not available. Notwithstanding this comment, installation of permanent boreholes for lowering water levels during the construction phase and then for abstracting water for cooling during the operation phase were considered for the Masshouse development (Gregory 2004). However, the idea appeared at too late a stage within the decision-making process. In this case the pace of development, the requirement for 'hydrogeological modelling' (i.e. to prove that the scheme will work) and the financial liability of capital works (i.e. the recurring issue of who should pay?) meant conventional schemes were adopted instead (Hunt and Rogers 2005).

The remaining water lands on roofs and roads. Conventionally some 50-80% of this is removed through surface drains connected to a combined sewer system and these can be overburdened easily in storm surges, leading to flooding. Ironically, flooding appears to be the responsibility of those working in areas downstream of the Eastside development. Whilst flooding within Eastside is unlikely, due to the River Rea being culverted, the problems of flooding do originate upstream. This demonstrates the requirement for reliable information and fact finding, from within and outside a locality, as an essential part of the decision-making process and especially when planning for a sustainable urban redevelopment scheme on the scale of Eastside. Equally it emphasises the importance of concise information being made available within the decision-making process itself. High-level decision makers should not be presented with ideas for sustainable solutions in isolation, without taking an overall objective view of the implications that will result from such implementation. This type of *ad hoc* decision-making can mean that sustainable solutions are being used in the wrong situation, inadvertently making them unsustainable, whilst opportunities for other sustainable solutions are being missed.

The Eastside scheme will undoubtedly increase demands for water (a natural resource), and in light of this water saving schemes have been encouraged. One of these, rainfall harvesting, will subsequently be implemented at the City Park Gate development (Birmingham City Council 2003c) and, if it goes ahead, within the Library development (GVA Grimley 2004). These schemes will require underground space for storing harvested rainfall, which conventionally are in the form of isolated pre-fabricated storage units. The largest commercial size is 80 Mega litres and these would be easily hold three days' worth of water within each development. The rate at which the tank fills will depend on the rainfall (which in the UK varies seasonally) and the rate at which the tank empties will depend on the demand for non-potable water which is dictated by end use (toilet flushing, watering, vehicle washing) and user type (i.e. these can vary considerably depending on whether it is an office, domestic property, college, hotel or retail outlet). Whilst there is potential for large-scale collection of rainfall on a development level it is not being realized, therefore being overlooked in favour of small-scale systems. With respect to water supply and disposal in Eastside, what appears to be missing is a holistic plan for dealing with problems of rising ground water, rainfall removal, flood abatement and water supply.

THE REQUIRMENT FOR LARGE-SCALE INTEGRATED SYTEMS

It is often assumed that the biggest barriers facing the achievement of sustainable utility infrastructure in the UK is the fact that systems are inherited. Ironically, whilst this may be true today, especially in relation to conventional utility placement through trenching, the problems have been known worldwide, yet ignored, for many generations. The first realisations appear to have come in 1901, at the time of the construction of the rapid transit subway in New York, when it was recognised that there was an opportunity to make proper provision for the mass of electricity cables and gas and water pipes within special galleries placed along one or both sides of the new subway (Figure 12a).

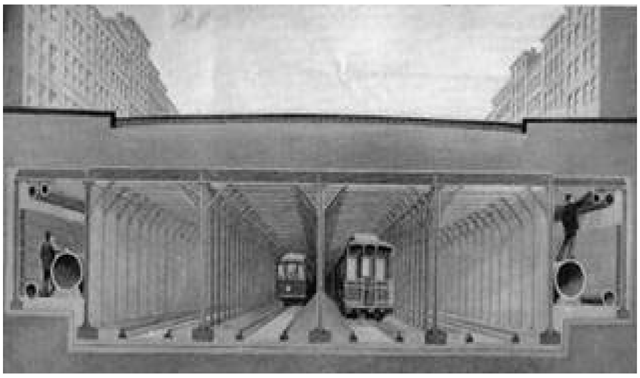 

Figure 12 (a) New subway for MRT (Scientific America, 1901a) **(b)** MRT in 1901 (Scientific America, 1901b)

Whilst this type of underground construction appealed to the engineers of this time (being non-complex in terms of its engineering requirements) the pipe galleries were abandoned in favour of conventional trenching schemes (Figure 12b). Primarily, so it is claimed, this was the result of semi-political pressures brought to bear upon the Railroad Commission (Scientific America 1901b). The following concluding passage was written at the time: *"The present interruptions to traffic, the interminable and absolutely stupid way in which our choicest streets are dug up, re-laid and dug up again, is a perpetual and obtrusive nuisance, which would not be tolerated in any provincial town, and cannot be too soon removed from the streets of the second greatest city in the world."*

Yet, ironically, at the start of the 21st Century utility provision through trenching is still tolerated within most major cities within the UK, and Eastside is no exception. Methods for utility placement are on the whole unchanged, excepting where trenchless technologies are used, and hence location, maintenance and capacity expansion of existing assets within city centres (transport included) is logistically complex and remains far from sustainable. What is more, those with rights to access carriageways (estimated to be 130 different organisations in the UK) at any point in time, has increased significantly since 1901. Following these early warnings from our forefathers disruptions in the UK have worsened (1 million street works were reported in 2003 – see DfT 2003) whilst direct and indirect costs have escalated (4 million holes dug each year in the UK's highways and footpaths by the utility companies which have a direct cost of £1 billion – UKWIR 2005). As the populations grow, already dwindling supplies of water and energy will be depleted at a faster rate, whilst the infrastructure that carries them deteriorates, leading to increased losses within the system. This exacerbates an already serious situation (e.g. in England and Wales for the period 2002/2003 water abstraction was approximately 40 billion litres per day with losses estimated at 4 billion litres per day - OFWAT 2004).

Currently within the Eastside development the opportunity for delivering total, rather than isolated examples of, sustainable underground construction appear to have been missed, partly it seems because transport infrastructure and the various branches of utility infrastructure are dealt with in isolation. In resolving this significant barrier to sustainable underground construction the solution may be in the provision of newly designed, fully integrated systems for the 21st Century which include all, rather than some, of the following infrastructure requirements:

- Transport
- Energy supply/storage
- Water supply/storage/disposal
- Waste disposal
- All other utility infrastructure

The Multi-Utility Sustainable Tunnel (MUST) could be such a solution (an artistic impression is shown in Figure 13). It would be 'visit-able' for facilitating asset location and future maintenance requirements and upgradeable (i.e. open ended) allowing for further utility placement as city centre populations grew. By placing transport systems underground there would be a clear reduction in traffic noise, an improvement in air quality (through air filters and CO_2 scrubbers) and more available land on the surface for further development or for provision of green open space. The system would be symbiotic in nature, for example heat pumps could be embedded into the outer casing for sourcing energy from the ground (it could help in addition keep electricity cables cool).

Abstracted water and rainfall water would be collected, stored and utilised within the development through the use of a MUST system, whilst waste could be collected via a Pneumatic Refuse Collection (PRC) system as in a novel scheme devised for Singapore's new downtown shopping centre. The PRC would have an emphasis on sorting within the system itself, removing the requirements for specialised recycling collections and normal bin collections, therefore reducing emissions and traffic congestion further. In essence the MUST system would deliver a holistic planning solution for logically networking the veins and arteries of the city, avoiding the complexities of micro-surgery which are faced currently.

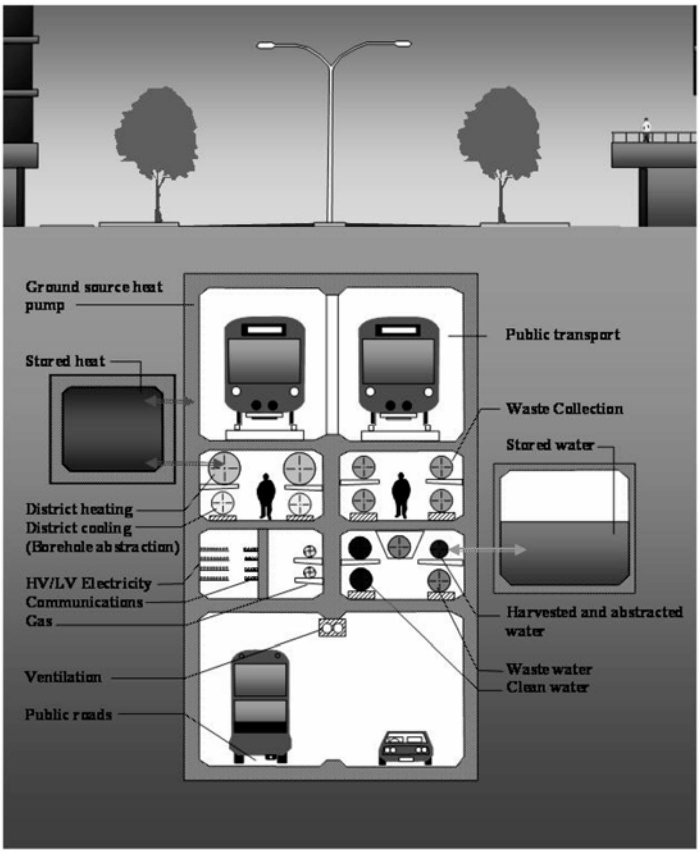

Figure 13. A ‘MUST’ system for sustainable underground construction

CONCLUSIONS

The achievement of sustainable underground construction is a necessary additional requirement for sustainable development. The decision-making processes are complex and they remain the conduit into which ideas for sustainable development are fed, and therefore they can be both an enabler and barrier to sustainable underground development. Whilst it can be argued that large-scale developments with large budgets are a fundamental requirement for implementing sustainable underground development, such schemes require holistic planning, integrated logical decision making (i.e. using indicators within the master plan phase) and a true political will (which gives clear leadership) for their implementation. The logistical effort of integrating decision making (getting people to sit at the same table) within an area on the scale of Eastside (more than 20 development sites) is fraught with difficulties, and this remains a significant barrier. Unfortunately, therefore, what exists in Eastside an assemblage of isolated examples of sustainable technologies where the sum is not greater than the individual parts. Birmingham’s transition from motor city to eco-city (Porter and Hunt 2005) is far from over and hence long-term economically viable solutions, as demonstrated in this paper, need to be sought if sustainable underground construction is to be realised.

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REFERENCES

APWA. 1997. The ‘how-to’ book on utility coordination committees, *Report by the American Public Works Association (APWA)*, Kansas City, MO,USA, pp21.

BIRMINGHAM CITY COUNCIL. 2003a. Design and Movement Framework (Draft), Birmingham City Council, Birmingham, UK, pp22.

BIRMINGHAM CITY COUNCIL. 2003b. PRESUD: Peer review for European sustainable urban development. Review, final report, Birmingham City Council, Birmingham, UK, March, pp40.

BIRMINGHAM CITY COUNCIL. 2003c. Report of the Director of Eastside: City Park Gate – Disposal of Sites 4, 5, 6 and 8 at Masshouse, 15 January. Birmingham City Council, Birmingham, UK.

BRUNDTLAND, G.H. 1987. Our Common Future. Oxford University Press, Oxford, UK.

CANO-HURTADO, J.J. & CANTO-PERELLO, J. 1999. Sustainable development of urban underground space for utilities. *Tunnelling and Underground Space Technology*, 1999, **14** (3), July, 335–340.
CENTRO. 2003. Midland Metro: Birmingham City Centre Extension. An application to the Secretary of State under the Transport and Works Act (TWA) 1992, Birmingham, UK.
CHANDRA, V., RICCI, A.L., RIAD, H. & HREN, J. 2002. Boston's Central Artery/Tunnel project and its interchanges. *Structural Concrete*, **3** (4) December, 183-194.
CIRIA 2000. Sustainable urban drainage: design manual for England and Wales. *Construction Industry Research and Information Association (CIRIA*), Report C522, Westminster, London, UK, pp111.
CIRIA. 2001. Sustainable urban drainage: best practice manual for England, Scotland, Wales and Northern Ireland. *Construction Industry Research and Information Association (CIRIA),* Report C523, Westminster, London, UK, pp131.
DALE, P. 2004. Brum to go underground. The Birmingham Post, May 14, 2004.
DAVID MCLEANS 2002. Detailed masterplan and design statement. August, David McLeans Limited, UK.
DEFRA 2003. Headline indicators of sustainable development for the UK. *Department for Environment Food and Rural Affairs*, London, UK.
DEFRA 2005. UK government sustainable development strategy indicators. *Department for Environment Food and Rural Affairs*, London, UK.
DfT 2003. Assessing the extent of streetworks and monitoring the effectiveness of Section 74 in reducing disruption. Second annual report, Department for Transport, London, UK, October.
DICKIE, I. & HOWARD, N. 2000. Assessing environmental impacts of construction, industry consensus, BREEAM and UK Ecopoints. *Building Research Establishment*, Garston, Watford, UK.
DOHERTY, P.S., AL-HUTHAILI, S., RIFFAT, S.B. & ABODAHAB, N. 2004. Ground source heat pump-description: preliminary results of the Eco House system. *Applied Thermal Engineering,* **24**, 2627-2641.
DTI. 2003. Energy White Paper - Our Energy Future: Creating a low carbon economy. *Department of Trade and Industry (DTI*), London, UK.
ENDS REPORT. 2003. Demand grows for sustainable homes. ENDS, UK.
GIACOMELLO, L. & TROMBETTI, P. 2001. Environmental and social costs evaluation for innovative dig techniques. *Exp-In Search of Innovation*, **1**(1), December, 71-76.
GIDDINGS, B., HOPWOOD, B. & O'BRIEN, G. 2002. Environment, Economy and Society: Fitting them together into sustainable development. *Sustainable Development* **10**, 187-196.
GODARD J-P. 2004. Urban underground space and benefits of going underground. *World Tunnel Congress 2004 and 30th ITA General Assembly - ITA Open Session.* Singapore. 1-9.
GREGORY, R.W. 2004. Masshouse development: Initial review into the potential for ground water extraction for use as a water supply on the development, confidential report, 18th June, pp7.
GROUNDWORK BIRMINGHAM & FRIENDS OF THE EARTH. 2002. Have we got Eastside sussed? Sustainable Eastside: a vision for the future. Birmingham City Council, Birmingham, UK.
GVA GRIMLEY. 2002a. Design Statement – Masshouse Redevelopment: Planning statement (outline planning). REF: C/00412/02OUT, January, Birmingham City Council, Birmingham, UK.
GVA GRIMLEY. 2002b. Masshouse Redevelopment, Birmingham – Environmental impact assessment. January. 229pp.
GVA GRIMLEY. 2004. Design Statement – New Library of Birmingham & City Park (outline planning). Birmingham City Council, Birmingham, UK, December.
HOK, 1996. Birmingham Eastside Masterplan. HOK International Ltd, London, UK.
HORVAT, E., VAN DER CROGT, R.A.A., HAASNOOT, J.K., EDELENBOS, J., MONNIKHOF, R.A.H. & VAN DER HOEVEN, F. 1997. Strategic study on the utilization of underground space. *COB study N710.* Delft University of Technology, Delft, The Netherlands.
HUNT, D.V.L & ROGERS, C.D.F. 2005. Barriers to sustainable infrastructure in urban regeneration, *Proceedings of the Institution of Civil Engineers*, *Engineering Sustainability* **158** (2), 67–81.
ISELEY, D.T. & TANWANI, R. 1990. Social costs of traditional methods of utility installation. *Proc. of microtunnelling and horizontal directional drilling symposium,* AA1-7.
ISLINGTON COUNCIL. 1999. Supplementary Planning Guidance: Groundwater. Part of Islington's Unitary Development Plan. Approved June 1999, updated 2002. Islington Borough Council, Islington, UK.
ITA WORKING GROUP NO.13. 1995. Underground Car Parks: International case studies. *Tunnelling and Underground Space Technology* **10** (3) July, 321-342.
KNIPE, C.V., LLOYD, J.W., LERNER, D.N. & GRESWELL, R. 1992. Rising groundwater levels in Birmingham and engineering implications. *CIRIA Special Publication 92: Construction Industry Research and Information Association*, London, UK.
LAISTNER, A. 1997. Utility Tunnels - Long-term investment or short-term expense? The new economic feasibility of an old idea. *No Dig International* **15**, 10-11.
LEGRAND, L., BLANPAIN, O. & BUYLE-BODIN F. 2004. Promoting the urban utilities tunnel technique using a decision making approach. *Tunnelling and Underground Space Technology* **19** (1) Jan, 79-83.
L'INDUSTRIELLE DE CHAUFFAGE ENTERPRISE 2004. *Report on the feasibility of developing a large-scale CHP/Community Energy Scheme in Eastside*. Crawley, UK, 50 pp.
McGREGOR, I.M. & COLE, R. 2003. Using the SPeAR™ assessment tool in sustainable masterplanning. *Presented at the US Green Building Conference – Greenbuild 2003,* Pittsburgh, USA, 10 pp.
MONNIKHOF, R.A.H., EDELENBOS, J., VAN DER HOEVEN, F. & VAN DER KROGT, R.A.A. 1999. The New underground planning map of The Netherlands: A feasibility study of the possibilities of the use of underground space. WG4 Subsurface Planning. *Tunnelling and Underground Space Technology* **14** (3), 341-347.
NEW ROADS AND STREETWORKS ACT. 1991. Elizabeth II. Chapter 22. The Stationery Office, London, UK.
NJUG 2003. Utilities guidelines on positioning and colour coding of apparatus, *National Joint Utilities Group*, London, UK.
OFWAT 2004. Security of supply leakage and the efficient use of water 2003-2004 report. Office of Water Services, London, UK, 90 pp.
PAUL, T., CHOW, F. & KJEKSTAD, O. 2002. Hidden aspects of urban planning: Surface and underground development. *American Society of Civil Engineers,* 88 pp.
PIERRE, G. 1977. La revolution douce de la telegestion, article in Le Moniteur'. 11th September 1978, 4 pages. (in French).
PORTER, E.J. & HUNT, D.V.L. 2005. Eastside: Making steps towards sustainability? *Local Environment* **10** (5) October, 525-542.

RAO, S., SARGANT, H. & MILLS, K. 2001. *Sustainability indicators for utilities*. BRE Information Paper IP21/01. Building Research Establishment, Watford, UK.
RYUZO, O., KENTARO, O., MUTSUMI, S., YOSHIRO, S. & SUCKHO, H. 2005. Development of a ground source heat pump system with ground heat exchanger, utilising the cast in place concrete pile foundation of a building. *8th IEA Pump Conference,* 10 pp.
SCIENTIFIC AMERICA 1901a. Some features of the New York Rapid Transit Tunnel. *Scientific America* May 25, 327.
SCIENTIFIC AMERICA 1901b.Pipe Galleries for the Rapid Transit Subway, *Scientific America*, 322.
TRAFFIC MANAGEMENT ACT. 2004. Elizabeth II. Chapter 18. The Stationery Office, 2004.
TURNER, K. 1991. *The Lost Railways Of Birmingham*, Uralia Press. 56 pp.
UKWIR, 2005. Leakage. *UKWIR News* **36,** UK Water Industry Research, London, UK, September.