Sustainability as an integral component of underground infrastructure tunnelling in an urban environment

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City dwellers, as they go about their daily life within their chosen urban environment, seldom give any thought to the fact that beneath their roads and footpaths lay a vast infrastructure network that interconnects the operating and maintenance systems of their entire city. In many large modern capital cities this underground network can include utility tunnels for power and water, sewerage tunnels and even rail tunnels. Although underground space is establishing itself as an integral component of current and future above-ground sustainable urban planning, further attention is needed by stakeholders in incorporating sustainable design criteria as an integral component of underground tunnelling from the conception stage.

Basic underground tunnelling construction methods can trace their origin back to ancient times (Frumkin and Shimron 2006, 234). Many ancient cultures have engaged in tunnelling in one form or another—from the primitive mining of raw materials, including stone and iron ore, to the specialised mining of gems and precious metals such as silver and gold. The construction of the Siloam Tunnel beneath Jerusalem in the eighth century BCE (Sneh, Weinberger and Shalev 2010, 57) highlights the historical social awareness that infrastructure, in this case an underground water utility tunnel, has a practical and ongoing sustainable role within an urban society.

Despite human society’s initial sustainable approach towards rudimentary tunnel construction and excavation, many modern city planners are faced with a complex series of non-sustainable existing underground tunnels created by their predecessors. These disorganised tunnel systems have, in many cases, been greatly contributed to by the industrialisation and evolution of modern cities. This growth and expansion of modern cities has seen the ever increasing sporadic relocation of utilities from above ground to underground with little regard to future sustainability issues (Canto-Perello and Curiel-Esparza 2013, 82). Today’s multi-purpose utility underground tunnel structures, such as those used beneath London streets, can trace their engineering history back to the days of the Roman Empire (Canto-Perello and Curiel-Esparza 2013, 83). Their open-cut engineered tunnel construction process often necessitates the closure of large sections of roadways and can be very disruptive to the community. Engineering advances achieved over the past 100 years have had very little effect on the basic open-cut process for utility tunnel construction (Hunt, Nash and Rogers 2014). Although underground utility tunnels form an integral and important part of modern urban infrastructure the traditional approach of open-cut and cut-and-cover construction is no longer practicable and neither can it be sustainable in the long term. However, by their inherent design criteria multi-purpose utility tunnels can be sustainable as they are primarily designed to achieve sustainability through the commissioning of underground space for a variety of utility purposes.

Around the world many large cities owe their current layout and infrastructure design to inconsistent planning decisions made centuries ago, and in some cases, such as Rome, thousands of years ago. From the onset of the Second Industrial Revolution the unrelenting sprawl of the urban city landscape has created an organic underground utilities tunnel network that has spread with little regard for long-term sustainability issues (Canto-Perello, Curiel-Esparza and Calvo 2013, 4707). In learning from historical urban infrastructure mistakes modern city planners are now adopting built environment sustainability principles.
In addition, today's society in general is increasingly becoming aware of the need for sustainability within the built environment, especially within larger cities. This awareness, coupled with ever increasing government public policy that is shifting towards sustainability for the long term, is driving city planners and researchers to take a more all-encompassing societal approach to infrastructure planning rather than project-by-project thinking (Boyle et al. 2010, 4873).

Unfortunately some infrastructure decisions can still be made with little regard for the sustainability of the city overall as opposed to the sustainability of the political careers of the politicians making them. In commenting on modern sustainability in an ever-changing political climate, Mark Jarzombek wrote "as sustainability becomes ever more involved in the politics-of-change, it becomes saturated with the problem of hypocrisy" (Vandevyvere and Heyne 2014, 352 quoting Jarzombek 1999, 33). The adoption of a sustainable approach to underground tunnel construction in general involves more than just the actual construction process, political promises, or the delivering of the project as has historically been the case.

While modern cities rapidly increase in population and size, statutory city planners are having to resort to relocating an ever increasing volume of essential infrastructure services underground (Marshall and Haji 2015, 43). In balancing sustainability issues within the construction process, Shen et al. (2010, 256) recommends the inclusion of "economical, social and environmental issues" at the project conceptualisation stage. If a balanced approach is applied to the commissioning of underground utility tunnels within major cities then it would be feasible to conclude that any tunnels commissioned would also be constructed within the parameters of any current regulatory requirements relating to sustainability.

For a company involved in the development of urban infrastructure, including underground utility tunnels, sustainability can include the idea of creating a genuine corporate environment that promotes sustainability as a marketing business advantage (Shen et al. 2010, 254). The design of a privately-owned sustainable building is often generally carried out to meet the specific needs of the owner. With regards to public infrastructure, public buildings, and public benefit underground utility services, the design should also satisfy the requirements and needs of the service user. To achieve this requires the consideration of stakeholders towards implementing a sustainable approach. Rekola, Makelainen and Häkkinen (2012, 78) draw attention to the design phase of buildings and infrastructure as an appropriate time for stakeholders to introduce sustainable construction methods and materials into the project.

The consideration of innovation by stakeholders can also be viewed as an appropriate launch to address sustainability within the built environment (Häkkinen and Belloni 2011, 246). As is often the case in relation to underground tunnel construction sustainable design principles are seldom adopted when carrying out site exploration. Sustainability in tunnelling construction can benefit from consideration of ground settling in tunnel construction so that better protection can be afforded to adjacent infrastructure thereby creating an overall sustainable project (Gong et al. 2014, 70).

Today, as sustainable design principles are rapidly becoming an integral part of the built environment, many government departments now require specific sustainability principles and criteria be addressed when developing new infrastructure projects. A sustainability criterion also needs to be included as an integral component of project specifications for it to be effectively implemented into construction projects (Lam et al. 2011, 789). In the construction of the Brenner Base Tunnel, which forms a major section of the trans-European transport route, the chosen sustainable construction process required the implementing "of an interdisciplinary planning and design process, in which not only the classic construction professionals in infrastructure design but also specialists for railway equipment and operational management are involved" (Eckbauer, Insam and Zierl 2014, 601).
It is only in recent years that sustainability issues have been considered in relation to the design and construction of multi-purpose underground utility tunnels within major cities. Gharouni-Nik et al. (2014, 1-2) found, in their case studies on the analysis of tunnel support systems, that fundamentally sound tunnel engineering benefits from the introduction of sustainable design at the outset. Engelhardt, Schwarz, and Thewes (2014, 594) go further and argue that the sustainability of tunnel construction should not be based solely on construction costings. It may just be that to create sustainable underground infrastructure we may have to look back to our basic roots, namely tunnelling within the urban environment for the benefit of future generations, such as was the benefit in the construction of the Siloam Tunnel beneath Jerusalem 2700 years ago. To achieve such a balance infrastructure planners may need to approach the design of utility tunnels from a long-term sustainable perspective rather than a quick-fix solution to a pressing problem—limited above ground space in urban cities.

Historically construction related disciplines have indirectly complimented each other for the improvement of urban infrastructure without actually working together for mutual improvement, sustainability and advancement (Yao 2013, 2). In today’s urban city a multi-stakeholder approach towards the built environment necessitates a joint cooperative of all built environment disciplines to achieve the desired outcome. By working together these various disciplines can contribute towards a positive outcome in the creation of sustainable underground tunnel infrastructure for our modern urban cities. In all such cases consideration of fundamental sustainability principles should be undertaken as early as possible, preferably at the project conceptualisation stage of underground tunnelling. This should then be followed through during the design process, the construction process, and the commissioning process. In achieving sustainability as an integral component of infrastructure tunnelling stakeholders can achieve a beneficial outcome economically, environmentally, politically, and also socially, thereby creating a potential win-win situation for all.

References


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