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Going underground: An exploration of the interfaces between underground urban transport infrastructure and its environment

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ABSTRACT

With the continued urbanization and densification of cities worldwide the planning, and use of urban underground space (UUS) is of clear interest to urban and transport planners; and asset owners/managers. Effective strategies for the management of UUS and its environment once built are required and critical insight of how current use of these spaces affect and are affected by each other, enables effective planning and asset management strategies to be developed now and for the future.

This paper argues that the management of existing and development of new urban infrastructure and its interfaces with UUS requires consideration of what is/will be there; who does/will own it; and how it must/will be protected. However, there appears to be a gap in the literature relating to how and why these interfaces occur and how they could and should be managed effectively.

Taking the case of existing urban underground metro infrastructure, this paper demonstrates how understanding the *presence*, *property*, and *protection* interfaces of urban underground infrastructure and its environment at different levels of consideration is essential to urban and transport planning and management.

The paper concludes with a challenge to current strategies and proposals for the development and management of UUS and its environment, questioning whether they are fit for current and future demands and changes.

1. Introduction

Urban underground space (UUS) does not occur or exist by itself. It generally requires physical structures, referred to as urban underground infrastructure (UUI), to create that space (e.g. tunnels; floors; ceilings; girders; walls; shafts). These structures interact with the subsoil and other urban infrastructure (buildings; basement levels; other tunnels; transport infrastructure; utilities). Typically, the structures and land can be owned by or be the responsibility of different parties, at different interfaces, within the same footprint, or extend beyond these. For example, the Toronto pedestrian subway system is a network of subways (UUS formed from UUI) owned privately, but used by the general public. They are located under private buildings and property, and extend under the public highway. They also connect with other privately owned subways and buildings (City of Toronto, 2018). Therefore interfaces occur at different locations below as well as above ground. The continued safe presence and operation of both UUI and its environment is dependent on effective asset management. This involves strategies and actions to ensure inspection, maintenance, repair and replacement of assets. It also includes consideration and mitigation of risk through change, which may occur over the whole lifetime of assets. Past changes have direct and indirect effects on the UUI or its environment for the future and thus must also be considered. Having an effective means of determining the interfaces between urban infrastructure and how change has occurred, is an important part of ensuring the safe continuing presence and operation of existing infrastructure as well as for planning future infrastructure.

Effective asset management strategies must ensure that each interfacing party (property owner/maintainer) has a clear understanding of the primary interfaces involved in the operation and management of UUI. Darroch et al. (2016) proposed a conceptual framework (Fig. 1) which described these in basic terms as: what is there (*presence*); who owns it (*property*); how is it protected (*protection*). It is recommended that these be clarified, agreed, and documented between all interested parties, for the whole lifetime of the assets, and beyond their removal/change.

Ongoing research into the application of a conceptual framework to identify and clarify the interfaces between UUI and its environment,

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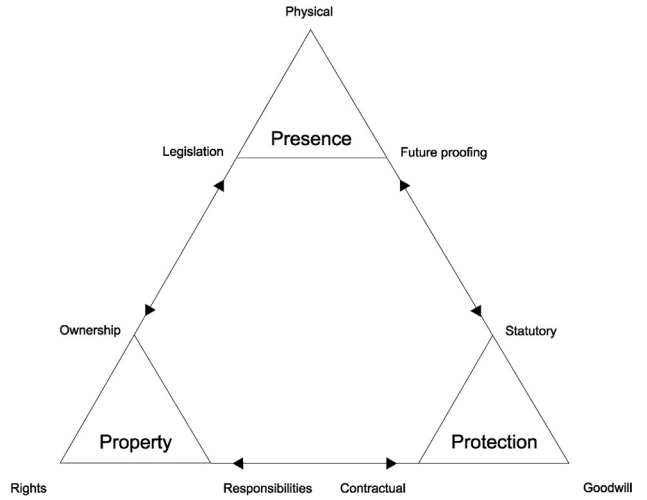

Fig. 1. The conceptual framework developed to assist understanding of the complex relationship between urban underground metro infrastructure (UUMI) and its environment.
Source: based on Darroch et al. (2016)

reported in this paper, has determined that the level of analysis required by the different stakeholders within an urban environment should also be considered. These stakeholders are likely to include: urban/transport planners; utilities/land owners; transport companies/authorities. The different levels of analysis proposed are: holistic (overall area); macro (general interfaces within a specific location); and micro (specific detail of how and why those interfaces occur within a specific site).

From reviews of current literature, it appears that there are few coordinated considerations of the three primary interfaces of *presence, property, and protection* for UUI. There are papers which discuss, propose, and promote development of UUI and policy changes to effect this generally (*presence*) (Hunt et al., 2016; Admiraal and Cornaro, 2016). Others consider division of land and subsoil to enable development (*property*) (International Tunnelling Association, 1991; Groetelaers and Ploeger, 2007). Some professional publications also demonstrate the need to protect UUI (*protection*) (Perry, 2014; Viggiani, and de Sanctis, 2009). But none to date give holistic, macro, or micro examples or case studies of how UUS interfaces with its environment collectively (*presence, property,* and *protection*). This is a concern given both the short and long term impacts uncoordinated proposals for urban and transport construction will have on cities now and in to the future.

Through the practical application of the conceptual framework introduced in Darroch et al. (2016), this paper argues that appreciation, understanding and knowledge of how assets and their environment interact is of direct relevance to research and practice in urban and transport: planning; development; and management (Gov.uk, 2017 GLA, 2018; WSP, 2017a, 2017b; Ashurst, 2017). Additionally, it is suggested that UUI interfaces should be planned, designed, constructed, and managed for their whole life cycle, with the factors of presence, property, and protection clearly documented.

Using examples from existing urban underground metro infrastructure (UUMI), this paper demonstrates how understanding the *presence, property*, and *protection* interfaces of urban underground infrastructure and its environment at different levels of analysis is essential to urban and transport planning and management. The paper is structured as follows:

- Section 2 discusses levels of applicability and analyses applied to the Darroch et al. (2016) conceptual framework;
- It also considers the high level questions to be asked when applying the conceptual framework to any one or group of assets within a specific or general environment;
- Section 3 presents examples from the London Underground (LU) network of physical, property, and presence;
- Section 4 contains a simple case study applying the conceptual framework to an example location on the LU network;
- Section 5 presents two suggested transferability scenarios to further demonstrate the characteristics of the three primary interfaces of *presence, property,* and *protection*.

The paper concludes with a challenge to current approaches towards the development and management of urban underground space, and its environment. The principles proposed in this paper are offered as a means to identify and clarify how existing and proposed urban underground space interfaces with its environment, something which appears to be currently lacking in both the literature and professional practice.

1.1. Explanation of key terms

A number of key terms are used within this paper and are defined as follows:

- Urban environment – densely developed area containing residential, commercial, industrial, retail buildings; utilities; and transport infrastructure.
- Urban underground space (UUS) – the space created within the subsoil of the city not necessarily formed of tunnels or fully underground spaces, but below ground level. It may be enclosed (tunnels etc.) or open to the atmosphere, either at ground level or above (open voids (cuttings); ventilation shafts etc.).
- Air space – the actual UUS created within enclosed or open urban underground infrastructure (UUI); the space above buildings, highways, or railway; it can be above or below ground level (where there is no covering over; e.g. an open cutting).
- Urban underground infrastructure (UUI) – the engineered structures that enable UUS to exist. These can be tunnels, sewers, shafts, passages, retaining walls, girders and rafts.
- Sub-surface – the term used here as between 0.2 and 5 m to the top of the structure forming the UUI (tunnel/covered way). For example, a sub-surface tunnel (0.2–5 m deep), other than a deep tube tunnel (2–33 m deep).
- Sub-surface railway – those railways built between 1860 and 1884 within the Transport for London (TfL) fare zone 1, which are commonly and incorrectly perceived to have been constructed wholly under road and by cut and cover methods.
- Sub-soil – the ground within which the UUI is created to form the actual space. For example, a tunnel is formed by excavating the 'subsoil'. Sub-soil can also mean the surrounding ground around that UUI.
- Tube railways – those railways constructed from the mid-1880s onwards using a Greathead tunnelling shield or some technological development enabling the sub-soil to be excavated at depths up to 35 m underground without substantial disruption to the surface above.
- Urban underground metro infrastructure (UUMI) – the collective term for all UUS/UUI assets and air space within them relating to an underground metro system within an urban area, whether sub-surface or tube. This includes but is not limited to: tunnels; shafts; station buildings; entrances to stations; retaining walls etc.
- General Legislation – legislation that is incorporated within authorising legislation, and provides specific requirements which must be accommodated unless a variation is made within the authorising legislation.
- Authorising Legislation – the Act of Parliament specifically relating to the construction of/land acquisition for/extension of time for/changes to the construction and presence of railway infrastructure.