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Liveable cities and urban underground space

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ABSTRACT

As populations grow in dense urban city centres, so too does the demand for space and natural resources. An option to combat this problem, all too often, has been to build denser and taller buildings in addition to transporting an ever-increasing abundance of resources (e.g. raw materials, water, energy and food) into the city whilst moving waste back out. This has major implications for liveable cities (LC), which in future policy terms might be considered to include aspects of (i) wellbeing, (ii) resource security (i.e. 'one planet' living) and (iii) carbon reduction (now enshrined in international law). An option that has been overlooked, and one which could add significantly to this LC agenda, is wider adoption of urban underground space (UUS).

This paper looks at how UUS has been, or could be, used within cities now, and in the future, and investigates the implications for achieving more liveable cities, which includes cognisance of the potential for radical transformation rather than adaption. It is concluded that wider adoption of UUS brings with it many benefits; however to avoid many of the dis-benefits an improved system of management, planning provision (which includes integrated mapping frameworks that consider more readily the future) and policy application is required.

1. Introduction

UUS can be defined as a space beneath urban areas that has the potential to provide direct services to a city (e.g. groundwater supply or geothermal energy). UUS encompasses natural geological formations of rocks and soils, anthropogenically altered soils and manmade structures, as well as caverns of various origins. When considering liveability there are four basic UUS resources: space, materials, water, and energy (Parriaux et al., 2007), each of which has different degrees of renewability dependent upon the way and/or rate they have been exploited (Sterling et al., 2012).

UUS has been used for thousands of years and yet the role of UUS in addressing urban development issues was raised just over a century ago by Hénard (1903) and since this time has been re-examined intermittently by a range of authors and institutes (Utudjian, 1952; Utudjian and Bernet, 1966; Fairhurst, 1976; Duffaut, 1977; Parker and Daly, 1981; Carmody and Sterling, 1993; Godard and Sterling, 1995; Hunt and Rogers, 2005; Jefferson et al., 2006; Parriaux et al., 2006; Rogers and Hunt, 2006; Simpson and Tatsuoka, 2008; Bobylev, 2009; Sterling et al., 2012; International Tunnelling Association – ITA, 1987, 1991a, 1991b, 1991c, 2000, 2002). Acceptance that it is an extremely valuable, irreplaceable resource has never been considered as readily as it is today (Parriaux et al., 2007; Bobylev, 2009; Sterling et al., 2012).

UUS functions in the role of a dynamic medium through which anthropological systems and ecosystem services interact and impact each other. Recognition that this interdependency exists is vital to understanding sustainability (as it pertains to civil engineering) in respect of how it impacts on urban systems' functionality. A burgeoning consensus points to the fact that future urban interventions that progress development and 'liveability' for humankind, and readily embrace the principles of sustainability and resilience, must be considered at the planning and design stages of any infrastructure construction project (Godard, 2004; Jefferson et al., 2006; Braithwaite, 2007; Simpson and Tatsuoka, 2008; Hunt et al., 2008; Rogers, 2009; Rogers et al., 2012).

This paper surveys the development in urban underground space (UUS) usage and the typical absence of planning for coordinated use. It seeks to explore the fundamental case for a more demanding and better designed utilisation of this space, moving us towards rather than away from a more liveable environment.

1.1. Underground space in cities

By 2009, in excess of half of the global population was living in cities (Besner, 2002; Parker, 2004). Moreover, the projected growth

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in urban centres in developed nations is expected to increase to 700,000 km^2 by 2030 (from 300,000 km^2 in the year 2000), with similar increases in emerging nations (from 250,000 km^2 in 2000, to 820,000 km^2 by 2030 – Angel et al., 2005). According to Godard (2004), the manifestation of this continuous growth will increase densities in our towns and cities, because they are a preferred space for development. Fig. 1 indicates that urban populations are increasing globally and it is reported that global physical city area expansion (276% by year 2030) will take place at a much higher rate than global population growth (66% by 2030 – Sterling et al., 2012). The pursuit of additional space in large urban areas is a global phenomenon as urban sprawl is restricted and buildings reach ever-increasing heights at considerable cost. This is accompanied by a number of challenges associated with provision of infrastructure, which grows proportionately with the size of the city (Hunt and Rogers, 2005; Rogers and Hunt, 2006; Hunt et al., 2009; Admiraal, 2010) and impacts liveability therein. In addition to the pre-existence of heritage and cultural resources, which need protection, retrofitting new infrastructure systems is a particular challenge for UUS construction into existing city contexts. In contrast, for 'up-and-coming' cities (Fig. 1), in which underground construction projects are being undertaken for the first time, the process is more straightforward, although there should be an emphasis on getting it 'right first time' in terms of foresight and planning to avoid inherent legacies that can restrict future planning options. Indeed, these areas offer an exceptional opportunity for prudent planning and evaluation of UUS infrastructure development policies (Bobylev, 2009) and thereby avoid the mistakes of older cities, where a lack of holistic planning combined with insufficient (or inappropriate) governance for UUS has created the current difficulties.

1.2. Planning for UUS in cities (Fig. 2)

It might be considered that high population densities and building stock densities already constitutes increased development of UUS (Horvat et al., 1998; Monnikhof et al., 1998; Chow et al., 2002; Evans et al., 2009). However, the fundamental difficulty in realising appropriate organised planning and development of UUS appears to lie in the *'business-as-usual'* approach manifested

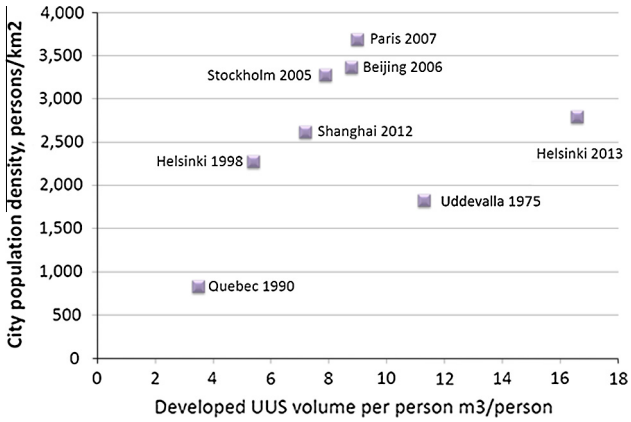

Fig. 2. Relationship between population densities in urban areas and volumes of urban underground infrastructure (Bobylev, 2016).

over hundreds of years and, under ordinary circumstances, being seemingly invisible to planners, policy makers, and the public *per se* (Sterling et al., 2012).

Increased uses of UUS gain in importance when basic human needs in major cities have to be met in order to make them not only habitable, but both liveable and thriving. For example, Hanamura (1998) asserts that it is fundamentally inconceivable for a modern city to exist or be sustainable devoid of UUS water distribution and sewerage conduits. Set against this need for greater UUS usage, exploitation of UUS is routinely hindered by the 'first-come, first-served' tendency of pre-existing usage, whether for underground physical structures or resource exploitation (Jefferson et al., 2006; Sterling, 2007; Rogers, 2009). The main lesson for 'up-and-coming' cities is for all planners and policy makers to be aware of the opportunities and threats to use of UUS to enhance city liveability, and to put in place well-thought-out systems of underground planning. This proactive approach is essential if conflicts (e.g. reduction in carbon vs. increasing infrastructure capacity for greater demand of dwindling resources) are to be avoided before they arise and before wellbeing is unduly impacted. This also offers supreme opportunities for significant radical

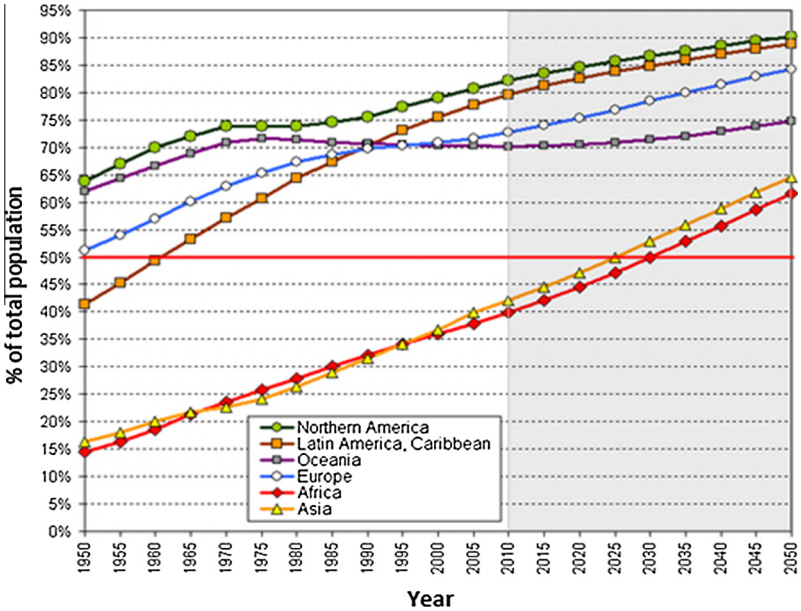

Fig. 1. Urban population by major geographical area (United-Nations, 2010).