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A preliminary investigation of underground residential buildings: Advantages, disadvantages, and critical risks

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ABSTRACT

Owing to the dramatically increased population in metropolises recently, the problem of lacking space has become more critical. To address this issue, most metropolises choose promoting underground space development. Lately, a new idea of constructing underground residential buildings emerges and has attracted considerable attention from authorities. The aims of this study are to investigate the possible advantages and disadvantages of underground residential buildings, and to investigate the critical risks in the constructions of underground residential building projects. To achieve these goals, an empirical questionnaire survey was administered to 30 Singapore-based construction companies. Results showed that "space saving" was the most significant advantage of underground residential buildings, followed by "improved indoor thermal comfort," "more resistant to external noises," and "increased level of privacy." Also, results revealed that "limited access to natural light" was the most severe disadvantage, followed by "high construction cost," "climate isolation," "psychological resistance from residents," "environmental issues," and "safety concerns." Additionally, this study disclosed and discussed the top five critical risks of underground residential building projects, including "labor restrictions," "cost overruns," "local contractors' competence in underground construction," "material restrictions," and "economic fluctuations." This study has contributed to the body of knowledge by examining the advantages, disadvantages, and critical risks in underground residential building projects innovatively. The findings from this study are also informative to relevant project stakeholders and policy makers from authorities, as these findings can enhance their understandings of such type of buildings and facilitate their decision-makings accordingly.

1. Introduction

Compared to small cities and rural areas, metropolises are more attractive to people as they can offer people a living environment that is more convenient, medical care of higher-quality, and varied opportunities of education and employment (Hunt et al., 2016; United Nations, 2015b). Thus, over recent decades, a steady flow of population have been moving into the metropolises worldwide. According to the United Nations (2015b), there used to be 126 cities around the world possessing one million population or above in the year of 1970, while in 2014, this number increased to 417 sharply, suggesting a significant growth in the global metropolitan population over the past four decades.

The influx of population can provide metropolises with ample human resources to support their social and economic development (Kaliampakos et al., 2016; Li et al., 2016a), however, it also makes the existing packed metropolises even more crowded and urges the authorities to explore new strategies to create space for those new metropolitan dwellers (Admiraal and Cornaro, 2016a,b; Broere, 2016). Fortunately, the authorities found a good solution, namely developing the underground spaces of the metropolises, and have devoted considerable efforts in this regard (Bartel and Janssen, 2016; Broch, 2016; Durmisevic and Sariyildiz, 2001; Kishii, 2016; Tengborg and Sturk, 2016; Vähäaho, 2016; Zhao et al., 2016; Zhao and Zhao, 2016). Particularly, over the past two decades numerous underground space structures such as underground shopping malls, hospitals, railways, power plants, sewerage systems and depots have been constructed worldwide, which has indeed expanded urbanite's living space and relieved the land use pressure on those densely packed metropolises (Bobylev, 2009; Li et al., 2016b; Ronka et al., 1998; Zhao et al., 2016).

Singapore is a modern, prosperous metropolis, and meanwhile, a densely populated city-state that merely has a land area of 719 square kilometers (Department of Statistics, 2016). According to the United Nations (2015a), Singapore has become the 3rd most densely populated country worldwide with a high population density of 8005 persons per

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Table 1
Potential advantages and disadvantages of underground residential buildings.

Advantages & disadvantages			Explanation	References
Potential advantages	A1	Space saving	Developing underground residential buildings can help constrain the ever-increasing urban sprawl and save space for natural and heritage landscapes.	Alkaff et al. (2016), Bobylev (2009), Broere (2016), Carmody and Sterling (1983), Liu et al. (2015); and Ronka et al. (1998)
	A2	Energy saving	Underground residential buildings can achieve substantial energy savings because such buildings are surrounded by a typical natural insulation material, namely soil, which makes the buildings require smaller heating and cooling loads.	Alkaff et al. (2016), Carmody and Sterling (1983), Chow et al. (2002), Goel et al. (2012), Liu et al. (2015); and Sugai et al. (2012)
	A3	High level of fire resistance	As surrounded by a natural fireproof material, namely soil, underground residential buildings face a relatively low possibility of catching fire.	Alkaff et al. (2016), Carmody and Sterling (1983), Chow et al. (2002); and Liu et al. (2015)
	A4	Less influenced by natural disasters	Underground residential buildings offer a safer living environment in the face of natural disasters such as high winds, hail storms, lightning strikes, tornadoes because such buildings are constructed under the ground.	Alkaff et al. (2016), Goel et al. (2012); and Liu et al. (2015)
	A5	Lower operating costs	The operating costs for underground residential buildings would be lower because such buildings offer substantial energy savings which would be reflected as the reduction of utility fares eventually.	Goel et al. (2012)
	A6	Improved indoor thermal comfort	Underground residential buildings can ensure residents a pleasant thermal comfort, because no matter how extreme the external temperature is, the soil temperature follows with phase delay and significant attenuation, making the temperature inside the building moderate.	Ronka et al. (1998), Roberts et al. (2016), Sugai et al. (2012), Liu et al. (2015); and Alkaff et al. (2016)
	A7	More resistant to external noises	Underground residential buildings are much more resistant to external noises than surface residential buildings as the soil is a solid matter which can prevent the transmission of noise much more effectively than liquid and gas.	Alkaff et al. (2016), Broere (2016), Liu et al. (2015), Roberts et al. (2016); and Ronka et al. (1998)
	A8	Increased level of privacy	Underground residential buildings can increase the level of privacy for residents as the views from the outside are blocked.	Goel et al. (2012)
Potential disadvantages	D1	Limited access to natural light	Comparing to living in surface buildings, living underground would bring residents some difficulties in accessing the natural light.	Carmody and Sterling (1983), Durmisevic (1999), Edwards and Torcellini (2002), Nakhaei et al. (2016), Roberts et al. (2016); and Ronka et al. (1998)
	D2	Psychological resistance from people	Normally, people hold psychological resistance to living underground as they consider underground a place which is dark, damp, confined, poorly ventilated and more related to death and burial.	Alkaff et al. (2016), Durmisevic and Sariyildiz (2001), Edelenbos et al. (1998), Goel et al. (2012), Lee et al. (2016), Liu et al. (2015); and Nakhaei et al. (2016)
	D3	Environmental issues	The construction of underground residential buildings may raise various environmental issues such as changing the hydrologic conditions around the site, producing pollutions, and causing settlement to the adjacent structures.	Attanayake and Waterman (2006), Bobylev (2009), Goel et al. (2012)
	D4	High construction cost	Construction costs for underground residential buildings are higher than that for surface residential buildings as underground residential buildings involve numerous excavation, support, and permanent lining work which are extremely costly.	Chow et al. (2002), Edelenbos et al. (1998), Goel et al. (2012), Kaliampakos et al. (2016), National Research Council and U.S. National Committee on Tunneling Technology (1984); and Sugai et al. (2012)
	D5	Climate isolation	Underground residential buildings are isolated. Therefore such buildings need additional facilities to provide ventilation to reject the heat produced by the equipment and facilities underground.	Carmody and Sterling (1983), Goel et al. (2012); and Roberts et al. (2016)
	D6	Safety Concerns	Underground residential buildings may raise diverse safety concerns to residents, such as structure settlement, flood, shortage of oxygen, poisoning, and entrapment.	Goel et al. (2012), Lee et al. (2016), Ogata et al. (1990), Qian and Lin (2016), Seo and Choi (2008), Sterling et al. (1992), Watanabe et al. (1992)
	D7	Restrictions due to existing structures	The development of underground residential buildings is highly affected by the existing structures.	Goel et al. (2012)
	D8	Lack of a visible facade design	Underground residential buildings have to miss the aesthetics of facade design because of being constructed underground.	Goel et al. (2012), Roberts et al. (2016)