CSCE Annual Conference

Growing with youth – Croître avec les jeunes

Laval (Greater Montreal)

June 12 - 15, 2019

RECENT DEVELOPMENT OF MULTI-PURPOSE UTILITY TUNNELS IN CHINA

Luo, Y. [1,2], Zhang, C. [2,4], Hammad A. [1,5]
[1] Concordia University
[2] Xi'An Jiaotong-Liverpool University
[3] y44luoyisha@gmail.com
[4] Cheng.Zhang@xjtlu.edu.cn
[5] amin.hammad@concordia.ca

Abstract: Repeated excavations of buried utilities cause road congestion and maintenance conflicts. Besides, the interference of buried utilities in limited underground spaces does not meet the requirement of sustainable urban underground development. Multi-purpose utility tunnels (MUTs) integrate all utilities together in one tunnel and can be accessed by humans. MUTs reduce the excavation needs and costs and avoid the traffic congestion caused by excavations. MUTs also provide easy access for inspection and maintenance of all types of utilities inside the tunnel. There are many MUTs in use in Europe and Japan, but the development of new tunnels in recent years is limited and lacks long-term planning. On the contrary, China is making a big progress in MUT planning and construction in recent years because the Chinese government is taking MUT construction as an important urban infrastructure development. The experience of MUT planning, construction and management in China can be very useful for other countries to examine the potential of MUTs as a sustainable option for future municipal asset rehabilitation projects. This paper first reviews the new development of MUTs including MUT history in China and the total planned and constructed lengths. Furthermore, several projects in major Chinese cities are reviewed including basic data on the length, cross-section, utilities housed, and cost analysis. It is concluded that although the initial cost of MUTs is high, they are sustainable and cost-effective infrastructures for underground utilities in the long term. It is hoped that this paper will encourage further research about the usage of MUTs.

1 INTRODUCTION

Most of municipal and private utilities (e. g. water and sewer pipes, electrical and telecommunication cables, etc.) are buried within the right of way under the roads. Repeated road excavation for utility maintenance considerably increases the maintenance costs, and is a common cause for road congestion. Furthermore, the buried utilities can be damaged by being directly exposed to underground environment (e.g. soil and humidity) or being accidentally hit by excavation equipment. Frequent excavation for different utilities is a waste of money especially if utilities under the same road are repaired at different times (Hunt and Rogers 2006). In addition, the limited shallow underground spaces are sometimes not enough for all the conduits in some narrow streets which can cause utilities interference (Cano-Hurtado and Canto-Perello 1999). In short, buried utilities are becoming un-economical, unsustainable and increase the social costs.

Utility tunnel refers to "*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). Multi-purpose utility tunnels (MUTs) refer to more than one utility pipes or cables in one single underground structure system (Su 2007). MUTs reduce the excavation needs and costs, and consequently reduce traffic congestion caused by excavation. MUTs protect utilities from damages and corrosion and they decrease the impacts on the environment (Canto-Perello and Curiel-Esparza 2013; Hunt, Nash, and Rogers 2014). Moreover, MUTs are easily accessible for maintenance and accident prevention. MUTs provide enough shallow underground space, especially vertical space, to avoid utility interference and enough space for new utilities which meets the sustainable development requirements of underground space (Cano-Hurtado and Canto-Perello 1999).

MUTs can be also referred to as Utility Corridors, Utilidors, Common Service Tunnels, Common Utility Tunnels, and Common Utility Ducts (Curiel-Esparza, Canto-Perello, and Calvo 2004). MUTs can be classified into three types based on depth: (a) flush-fitting MUTs which have 0 m cover, (b) shallow MUTs which have 0.5 to 2 meters cover, and (c) deep MUTs which have 2 to 80 meters cover (Hunt and Rogers 2006). In addition, MUTs can be classified into three types based on accessibility: (a) searchable MUTs are tunnels that can be accessible in a selective form by removing the cover, but it cannot be fully accessed because of the reduced cross-section area, (b) visitable MUTs are tunnels that can be fully accessed by man and in the whole length, (c) compartmentalized MUTs provide barriers between each utility type for protection (Canto-Perello and Curiel-Esparza 2001; Hunt and Rogers 2006).

The first MUT designed by Roman engineers integrated sewer system and water pipes with a huge cross-section (Cano-Hurtado and Canto-Perello 1999; Canto-Perello and Curiel-Esparza 2001). MUTs have been applied since the 19th century in London, Paris and other European cities as well as in Japan and the United States (Laistner and Laistner 2012). The first MUT in Paris was built in 1855 with sewage system (Cano-Hurtado and Canto-Perello 1999). The first MUT in the UK was built in 1866 and contained foul water and drinking water. It allows man-access and is still in use. There were more than 50 major MUT projects in the world from 1940 to 2011 with a total length of around 400 km (Hunt and Rogers 2006). Most of them are in Europe and some in Asia. Most MUTs in Europe and the US are either old or short. MUT in Japan started from 1923 in Tokyo, Osaka and Nagoya after the Great Kantō earthquake, and Japanese government issued a special law on MUT construction in 1963 (Shu 2003). In recent years, Singapore is the first country in Southeast Asia to implement MUT on a comprehensive scale. The Common Services Tunnels Bill was passed on March 19, 2018 for mandating the use of MUT as well as the related requirements and penalties (*Channel News Asia* 2018; Seow 2018). In the United States, several MUTs were built in the past, mostly in university campuses. However, very little work has been done in recent years related to MUTs. Most states in the US are interested in MUTs according to a survey. However, the security and operational issues are the main concerns of applying MUT projects (Kuhn et al. 2002). For example, Boston Smart Utility project only proposes small telecom utilidors and electrical duct banks (Boston Planning & Development Agency and AECOM 2017).

Compared to the countries mentioned above which either built MUTs several years ago or have only few projects due to cost and security issues, China is making a big progress and MUT construction has become an essential urban infrastructure development in recent years. The State Council decided to start MUT construction nationwide in 2013 and identified 25 pilot cities to build MUTs (Wang et al. 2018; Ministry of Finance of China 2015, 2016). In 2016, MUT construction length in China exceeded 2000 km including pilot cities and many other cities (MHURD 2016). As a result, it is important to study MUT projects' planning and construction in China, and examine whether the MUT experiences are suitable to be applied in other countries. This paper reviews the new development of MUTs in China focusing on major Chinese cities including basic data on the length, cross-section, technical design, and cost analysis based on the previous data. It is hoped that this review will encourage further research about the usage of MUTs.

2 NEW DEVELOPMENT OF MUTs IN CHINA

China urbanization rate in 2017 is 58.52% which is 1.17% more than that of 2016, and urban resident population is 813.47 million, which is 20.49 million more than that of 2016 (The State Council of China 2018). During the past 20 years, the urbanization process was rapid; as a result, the infrastructure services should be improved to catch up with this process. To improve the municipal utility construction and maintenance, and to ensure utility safety, MUTs were introduced for utility companies in China (Wang 2018). The first MUT in China was built in Beijing in 1958 with a total length of 1.08 km containing water, electricity, telecommunication and heating. The first long MUT, which is seen as a signature project, was built under Shanghai Zhangyang Road with a total length of 11.50 km in 1994 (Ma et al. 2017). One of the longest completed MUTs in Hengqin Island, which is 33.4 km, contains electricity, water and telecommunication, and has extra room for future heating, cooling, grey water and garbage vacuum pipes planning (He 2015).

China has taken building MUTs as an important infrastructure development to improve the resilience of first-tier cities, as well as of new areas or less developed cities. The State Council decided to start MUT construction nationwide in 2013. Several policies and guidelines were announced to encourage MUT planning and construction (Wang et al. 2018). Guidelines for the Preparation of Urban Underground MUT Project Planning and Technical Specification for Urban MUT Engineering were issued in 2015 (Song 2016). The Chinese government identified 10 and 15 cities in 2015 and in 2016 respectively as pilot cities to build MUTs (Ministry of Finance of China 2015, 2016). Pilot city qualifications consist of: (a) high construction density areas with a population more than 200,000, (b) heavy transportation, (c) high demand of underground space development and utilization, such as for subways or cables, (d) MUT length more than 10 km, (e) utility types more than three, (f) suitable geological and hydrological conditions, (g) financial conditions and whether public-private partnership (PPP) investment model is reasonable, and (h) new areas at first and then old important areas (MHURD 2015a, 2015b). For future MUT development by MHURD, the construction rate under new roads in city new areas should be 30% by 2020, and the overall MUT construction rate in cities should be 2% by 2020 (MHURD 2017). In 2016 and 2017, the Chinese government determined the construction planning of 2000 km each year including projects in pilot cities (The State Council of China 2016, 2017). At the end of 2016, 147 cities including pilot cities had started the construction of 2005 km (MHURD 2016).

Based on the completion year, the unit costs of MUT projects are calculated in present value. In Figure 1, the highest MUT costs are in large cities, such as Beijing, Shanghai and Shenyang. Beijing and Shanghai are the two largest cities in China, and the MUTs with highest unit costs are mostly in the areas with high population density or in commercial areas. Shenyang City South Canal MUT project is near the South Canal in the old city area, and the construction has to go below two metro lines and under the expressway tunnel, which increases the construction difficulty and cost (Tao 2017). More factors affecting MUT costs, such as the dimensions of the tunnel cross section, number of utilities, depth, and construction method, are to be examined in the future.

3 MUT EXAMPLE PROJECTS IN CHINA

3.1 MUT projects in Beijing

Beijing is the capital of China and has the second largest population after Shanghai. Beijing has the needs for old city reform, transportation infrastructure construction and development of underground spaces. In addition, the powerful economic status and technology advances are advantages for MUT development in Beijing (Song 2016).

As shown in Figure 2, yellow polygons indicate the projects that have been completed, green polygons show the projects under construction and the red polygon shows the project in the design phase at 2016. The central area in Beijing is the blue polygon with a star at its center, and the right green polygon refers to the subsidiary administrative center in Beijing. There are six completed MUT projects in the central area. There are one completed project and one project under construction in the subsidiary administrative center. Since the city is expanding, several projects are taking place between the central area and the sub-central area and in the north. The total length of the projects shown in the figure is about 36.01 km, in which the length of MUT in the design phase is 3.2 km and the MUT under construction is 5.6 km (Song 2016).

Zhongguancun is in the central area of northwest educational and commercial area in Beijing. The land is extremely limited due to the high population density. In addition, this area has 40 routes of buses and several metro stations including one transfer station. To ease the traffic pressure and the limited above-ground space, the underground development is of vital importance. As a result, Beijing government decided to develop a comprehensive underground structure including underground traffic tunnel, parking, MUT and underground commercial areas (Su 2007).

As shown in Figure 3, the storm water and wastewater pipes are buried under the sidewalk, and the comprehensive underground structure is built under the traffic lanes. The first layer of the underground structure is a traffic tunnel, the second layer is metro passages, parking and commercial areas, and the third layer is the MUT with five compartments which have gas, telecommunication, water and grey water, electricity and heating utilities. The length of the MUT is 1.9 km and it is designed as a closed ring to effectively connect the functions of nearby areas (Su 2007). The cross-section area of the MUT is 12.7 m×2.2 m (Xiao 2004). The design of MUT section was based on the discussion among the property developer, utility companies and design organizations according to the management system, and the design has extra space for future utility planning. To connect the main cables and pipes in the MUT to the nearby areas, the branches were built above the MUT (Su 2007).

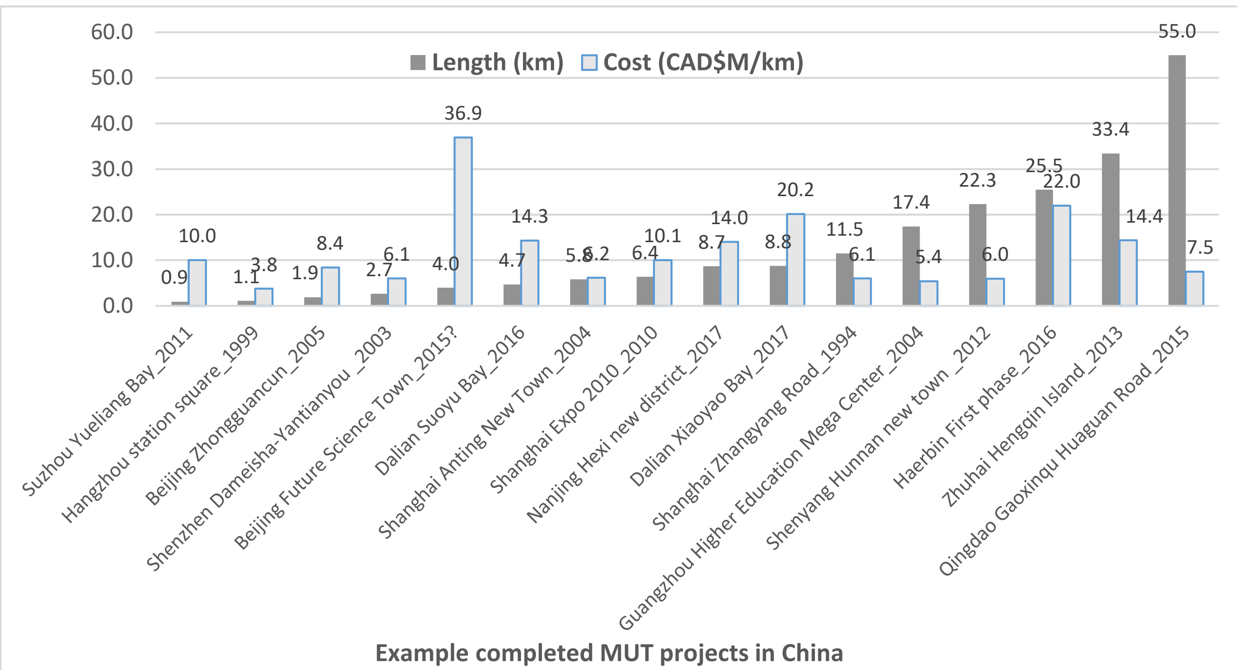

Figure 1: Cost and length of example completed MUT projects in China (Shi et al. 2015; Ye 2001; Su 2007; Xiao 2004; Zhong, Ma, and Guo 2006; Guan 2009; Huang and Chen 2002; Beijing General Municipal Engineering Design & Research Institute, n.d.; Zhou and Li 2015; Liu 2016; Dalian Municipal Design & Research Institute CO., LTD, n.d.; Yan 2015; Zhang 2006; Lv 2011; Qian 2017; Zhang 2014; Chen 2016; Nanjing Hexi New Town Government 2017; Duan and Ni 2017; Zhang 2016; China Government Procurement Net 2017; Wei and Meng 1997; Liu 2015; Wang and Gou 2011; Zhang 2016; CHINAUTIA 2017; Ding et al. 2010; CHINAUTIA 2016; Zhang, Li, and Wang 2015; Ning and Xin 2017; Wang 2017; Harbin Municipal People's Government 2016; CCTV 2017; Zhao 2016; Han 2017; Pan 2017; Liu 2018; Liu 2017; Qian 2017; Chen 2017; Geng 2015; Yu et al. 2013)

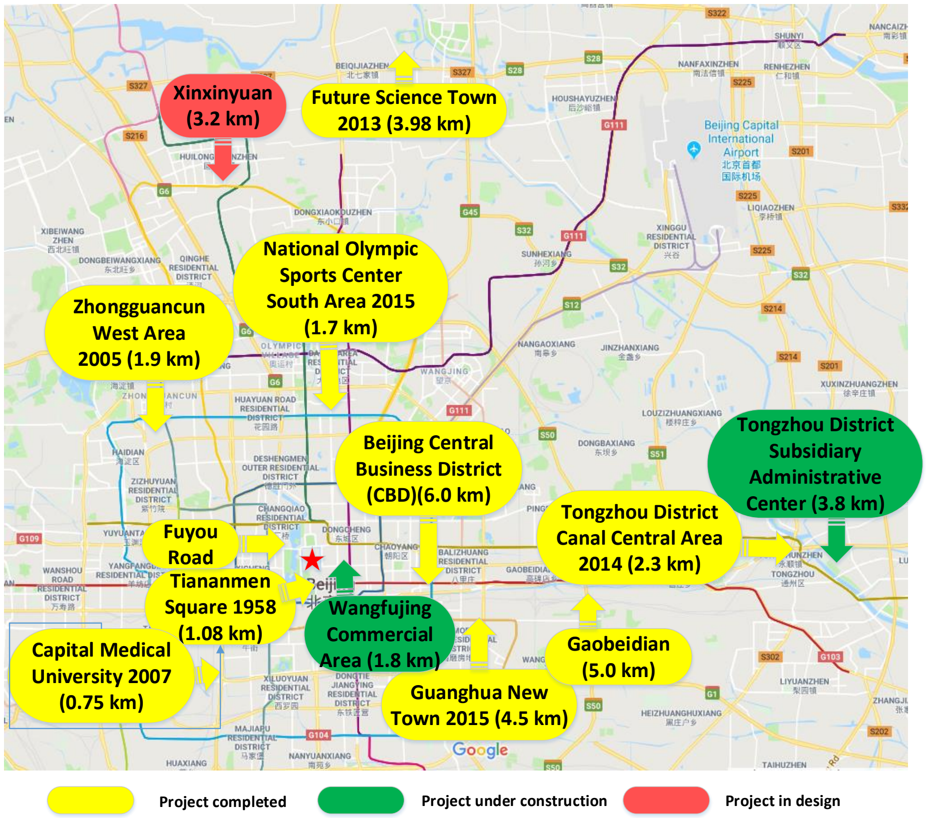

Figure 2: MUT projects in Beijing (Song 2016)

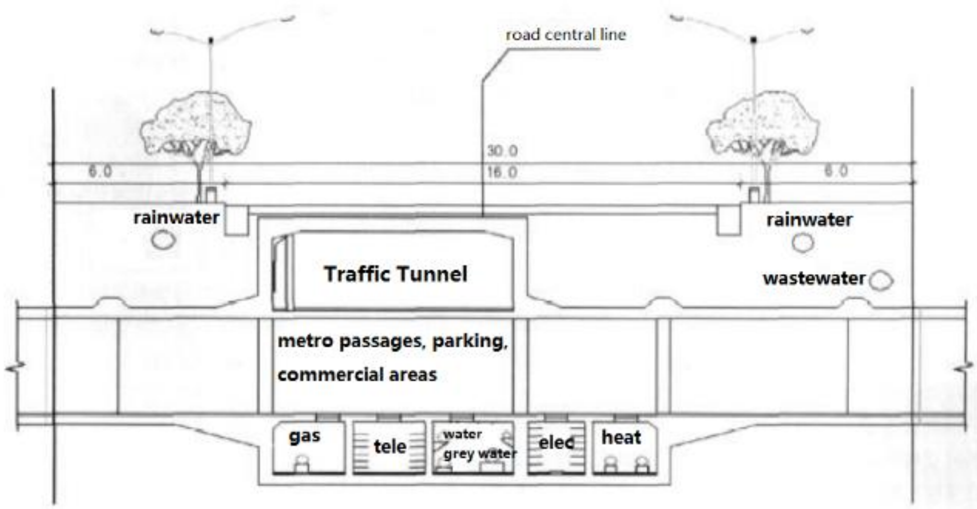

Figure 3: Cross-section of underground layout including Zhongguancun MUT (Su 2007)

3.2 Hengqin Island MUT project in Zhuhai City

This MUT is in Hengqin Island, Zhuhai City, which is near Macau and Hong Kong. Because of the central location of Hengqin Island in the south development area, the central government considers Hengqin as an important commercial development area. The MUT length is 33.4 km and was completed in 2013. It is one of the longest completed MUTs with a cost of about CA$400M (CA$12M/km) (Liu 2018). Hengqin

Island has a large area of rivers and fish ponds with sludges as deep as 30 m. As a result, this project is one of the most complicated MUT projects in China (He 2015). The MUT contains electricity, telecommunication, water, grey water, cooling and garbage vacuum system. As shown in Figure 4, this project includes electricity tunnel and MUT tunnels with one to three compartments' section due to various needs. The cross-section area has several dimensions as shown in Figure 4 (Liu 2018).

As shown in Figure 5, the MUT with one compartment (a) contains telecommunication, water, grey water, cooling and several sensors. The MUT with two compartments (b) contains electricity in the left compartment, and telecommunication, cooling, water and grey water in the right compartment. The MUT with three compartments (c) also contains electricity in the left compartment, water and telecommunication in the middle compartment, and grey water and cooling in the right compartment. The MUT was built under the green belt with 2 m cover. There are also other utilities under the sidewalks and green belt such as heating, gas, sewer and storm water pipes, which are not included in the MUT. For the intersections, a two-level structure was built, with MUT at the top and electricity tunnel at the bottom (Liu 2018).

Figure 4: Layout of Hengqin New Area MUT project (Liu 2018)

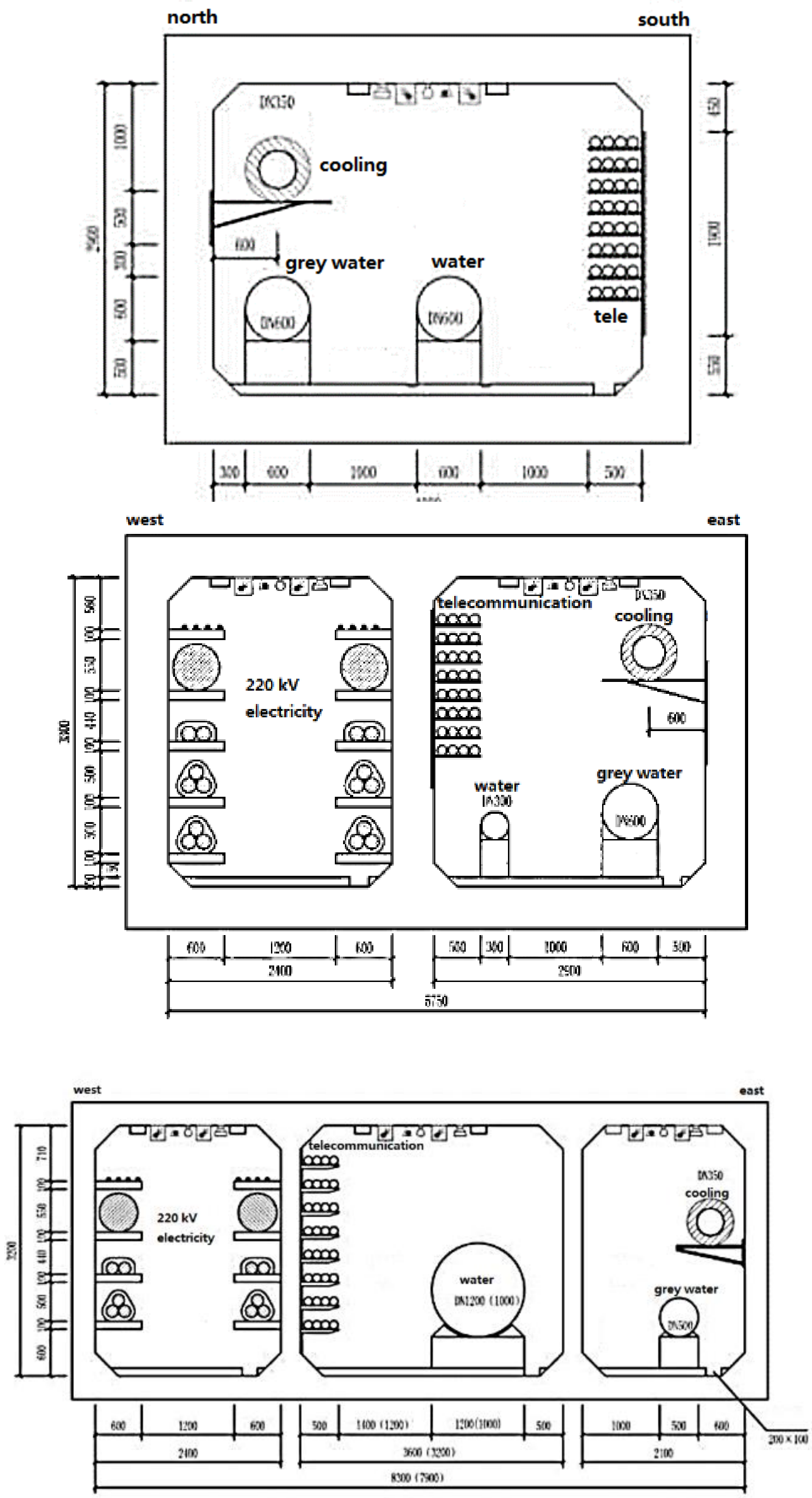

Figure 5: Cross sections of MUT with one, two and three compartments (Lu 2018)

4 DISCUSSION

An obvious decrease of MUT construction in European countries can be observed in recent years (Hunt and Rogers 2006; Laistner and Laistner 2012). MUT has a rapid development in Asian countries especially in China, and some of the recent development of MUT projects in China were reviewed in this paper. Based on the diverse terrain types and soil conditions in China, several MUT projects have unique technological design and materials, which provide good case studies for other countries.

On the other hand, US National Research Council report (National Research Council 2013) mentioned the benefits and obstacles of MUT development in the US. The main obstacles include unavoidable investment abandonment of in-service utilities, operational liabilities concerns, safety issues in a shared utility environment (e.g., gas and electricity), administrative concerns about access of non-related people to MUT, and high initial costs. It was mentioned in this report that "*The viability, value, and benefits of utilidors may be effectively communicated with (1) development of workable scenarios for secure multi-utility facilities; (2) development of workable scenarios for effective transitioning from current configurations; (3) lifecycle cost-benefit analyses comparing separate and combined utility corridors; and (4) demonstration projects. In the United States, utilidors have been built typically as part of major old and new developments or underground transportation improvements (e.g., Disney World in Orlando, Florida, with its extensive underground service "city" and the Chicago freight tunnel network). If the United States is to improve the sustainability of its urban utility services and preserve underground space for more cost-effective sustainability opportunities for future services, then this impasse needs renewed attention*" (National Research Council 2013).

With a clear awareness of MUT benefits, there is a high potential of MUT development in North America that can contribute to the development of smarter, more sustainable and resilient cities. MUT can be equipped with sensors and firefighting systems for better and safer maintenance and management, and they can serve the functions of smart infrastructure systems of the future. In addition, the factors that can reduce the costs of MUT projects (e.g. economy of scale of mass prefabricated production of modular sections) and new financing scheme (e.g. PPP) should be analysed in further studies.

REFERENCES

APWA. 1997. *The 'How-to' Book on Utility Coordination Committees, Report by the American Public Works Association (APWA)*. Kansas City, MO. https://www.apwa.net/Store/detail.aspx?id=PB.AHBU.

Beijing General Municipal Engineering Design & Research Institute. n.d. "Design of multi-utility tunnel in Beijing Future Science Town." Beijing General Municipal Engineering Design & Research Institute. http://www.bmedi.cn/zyly/csdxzhgl/images/4a.jpg.

Boston Planning & Development Agency, and AECOM. 2017. "Smart Utility Standards." Boston Planning & Development Agency. http://www.bostonplans.org/getattachment/621dd21d-a080-4eb8-b8b7-08b92fef0633.

Cano-Hurtado, J.J., and Canto-Perello, J. 1999. "Sustainable Development of Urban Underground Space for Utilities." *Tunnelling and Underground Space Technology* 14 (3): 335–40. https://doi.org/10.1016/S0886-7798(99)00048-6.

Canto-Perello, J., and Curiel-Esparza, J. 2001. "Human Factors Engineering in Utility Tunnel Design." *Tunnelling and Underground Space Technology* 16 (3): 211–15. https://doi.org/10.1016/S0886-7798(01)00041-4.

Canto-Perello, J., and Curiel-Esparza, J. 2013. "Assessing Governance Issues of Urban Utility Tunnels." *Tunnelling and Underground Space Technology* 33 (January): 82–87. https://doi.org/10.1016/j.tust.2012.08.007.

CCTV. 2017. *Kejizhiguang-Multi-Purpose Utility Tunnel-Urban New Veins*. Multi-Purpose Utility Tunnel-Urban New Veins. https://www.youtube.com/watch?v=Dv6axysIisI&list=PLPSsQGZDZiejpxu7E_ICBcBAv7I9TR6eJ.

Channel News Asia. 2018. "Lawrence Wong on Common Services Tunnels Bill," 2018. https://www.channelnewsasia.com/news/singapore/lawrence-wong-on-common-services-tunnels-bill-10057016.

Chen, Q. 2017. “Experience of the Longest and the Most Comprehensive Urban Underground Multi-Purpose Utility Tunnel Construction.” *Chinatunnel Net*, May 9, 2017. http://www.chinatunnel.net/topic/news_detail.aspx?id=540.

Chen, S. 2016. “Advice on the Construction and Management of Multi-Purpose Utility Tunnel.” *Urbanism and Architecture*, no. 20: 377–377. https://doi.org/10.3969/j.issn.1673-0232.2016.20.344.

China Government Procurement Net. 2017. “Social Capital Procurement Pre-Qualification Announcement of Xiaoyao Bay Multi-Utility Tunnel PPP Project.” China Government Procurement Net. http://www.ccgp.gov.cn/cggg/dfgg/gkzb/201712/t20171228_9414716.htm.

CHINAUTIA. 2016. “Hunnan New Town multi-utility tunnel in Shenyang City.” *Urban underground multi-utility tunnel industry net*, October 18, 2016. http://www.chinautia.com/XMZS/show.php?itemid=33.

CHINAUTIA. 2017. “Multi-utility tunnel project in Guangzhou City Higher Education Mega Center.” *Urban underground multi-utility tunnel industry net*, August 18, 2017. http://www.chinautia.com/XMZS/show.php?itemid=46.

Curiel-Esparza, J., Canto-Perello, J. and Calvo, M. A. 2004. “Establishing Sustainable Strategies in Urban Underground Engineering.” *Science and Engineering Ethics* 10 (3): 523–30. https://doi.org/10.1007/s11948-004-0009-5.

Dalian Municipal Design & Research Institute CO., LTD. n.d. “Projects-Multi-Utility Tunnel in Suoyu Bay.” Dalian Municipal Design & Research Institute CO., LTD. http://www.dlszy.cn/project/restaurant-logo/.

Ding, X., Zhang, J., Pang, Y., Xu, Y., Feng, H. and Gong, J. 2010. “Discussion on construction and management of the common trench in Guangzhou University Town.” *Chinese Journal of Underground Space and Engineering* 06 (s1): 1385–89. https://doi.org/10.3969/j.issn.1673-0836.2010.z1.014.

Duan, M., and Ni, M. 2017. “Nanjing City Focuses on the Construction of Multi-Utility Tunnel (MUT)-20 Km MUT in the South New Town.” *Sina*, February 16, 2017. http://jiangsu.sina.com.cn/news/m/2017-02-16/detail-ifyarrqs9855337.shtml.

Geng, L. 2015. “Underground Multi-Purpose Utility Tunnel in Qingdao Gaoxinqu-No Excavations in 100 Years.” Taidongzhen. August 21, 2015. http://www.taidongzhen.com/HTML/News/Qingdao/qdyw/2015/0821/37604.html.

Guan, X. 2009. “Economy comparation of multi-purpose utility tunnel and buried utility construction.” *Construction Economy*, no. s1: 339–42. https://doi.org/DOI:10.14181/j.cnki.1002-851x.2009.s1.016.

Han, L. 2017. “Zhuhai Hengqin Area Invests 2.2 Billion Yuan to Build Intelligent Multi-Utility Tunnel Management System.” *CHINAUTIA*, October 16, 2017. http://www.chinautia.com/news/show.php?itemid=437.

Harbin Municipal People’s Government. 2016. “Harbin City Is Focusing on the Construction of Multi-Utility Tunnel to Make Underground Spaces Connected.” Heilongjiang Province People’s Government. June 21, 2016. http://www.hlj.gov.cn/zwfb/system/2016/06/21/010778998.shtml.

He, J. 2015. “Construction practice and thinking of underground multi-utility tunnel in Hengqin New District.” *Installation*, no. 10: 18–20. https://doi.org/10.3969/j.issn.1002-3607.2015.10.008.

Huang, H., and Chen, Z. 2002. “Introduction to Shenzhen Dameisha-Yantianyou Multi-Purpose Utility Tunnel.” *Municipal Engineering Technology*, no. 4: 61–63. https://doi.org/10.3969/j.issn.1009-7767.2002.04.014.

Hunt, D V L, and Rogers, C. D. F. 2006. “Sustainable Utility Infrastructure via Multi-Utility Tunnels.” In , 11. Calgary, Alberta, Canada.

Hunt, D.V.L., Nash, D. and Rogers, C.D.F. 2014. “Sustainable Utility Placement via Multi-Utility Tunnels.” *Tunnelling and Underground Space Technology* 39 (January): 15–26. https://doi.org/10.1016/j.tust.2012.02.001.

Kuhn, B., Jasek, D., Brydia, R., Parham, A., Ullman, B. and Blaschke, B. 2002. “UTILITY CORRIDOR STRUCTURES AND OTHER UTILITY ACCOMMODATION ALTERNATIVES IN TXDOT RIGHT OF WAY.” Texas Department of Transportation. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.194.5748&rep=rep1&type=pdf.

Laistner, A., and Laistner, H. 2012. “Utility Tunnels – Proven Sustainability Above and Below Ground.” In *REAL CORP 2012*, 12. Schwechat: Selbstverl. des Vereins CORP - Competence Center of Urban and Regional Planning.

Liu, W. 2015. “20-year history of the first modern underground multi-utility tunnel in China-experience and lessons.” *Water and Wastewater Information*, no. 6: 40–42.
Liu, Y. 2016. “Introduction and case study of urban underground multi-utility tunnel construction.” https://wenku.baidu.com/view/432d03c0ba4cf7ec4afe04a1b0717fd5360cb272.html?re=view.
Liu, Y. 2018. “Introduction of Zhuhai Hengqin New Area Underground Multi-Purpose Utility Tunnel Project.” presented at the Development of Macao’s underground facilities conference, Macao, China.
Liu, Z. 2017. “Multi-Utility Tunnel Makes the City Better.” *Xinhuanet*, June 8, 2017. http://www.xinhuanet.com/politics/2017-06/08/c_1121105574.htm.
Lu, W. 2018. “Development of Macau and Civil Engineering and Future of Underground Space Use.” presented at the Development of Macao’s underground facilities conference, Macau, China.
Lv, M. 2011. “Enlightenment of multi-utility tunnel in Shanghai World Expo.” *China Press*, no. 8: 28–28.
Ma, H., Ma, J. Li, Z. and Ma, X. 2017. “The Status and Prospect of Underground Utility Tunnel Construction in China.” *Municipal Engineering Technology* 35 (3): 93–95. https://doi.org/CNKI:SUN:SZJI.0.2017-03-036.
MHURD. 2015a. “Interpretation of Experts for ‘Guiding Opinions on Promoting the Construction of Urban Underground Multi-Utility Tunnels.’” Ministry of Housing and Urban-Rural Development of the People’s Republic of China. 2015. http://www.mohurd.gov.cn/zxydt/201508/t20150812_223245.html.
MHURD. 2015b. “Notice of Organizing to Declare the Underground Multi-Utility Tunnel Pilot City.” Ministry of Housing and Urban-Rural Development of the People’s Republic of China. http://www.mohurd.gov.cn/fgjs/xgbwgz/201501/t20150116_220140.html.
MHURD. 2016. “The underground multi-utility tunnel construction task is fully completed this year.” http://www.mohurd.gov.cn/zxydt/201612/t20161223_230082.html.
MHURD. 2017. “The Thirteenth Five-Year Plan for National Urban Municipal Infrastructure Construction.” Ministry of Housing and Urban-Rural Development of the People’s Republic of China. http://www.mohurd.gov.cn/wjfb/201705/W020170525053420.pdf.
Ministry of Finance of China. 2015. “2015 underground multi-utility tunnel pilot city list publicity.” Ministry of Finance of the People’s Republic of China. http://jjs.mof.gov.cn/zhengwuxinxi/tongzhigonggao/201504/t20150409_1214636.html.
Ministry of Finance of China. 2016. “2016 underground multi-utility tunnel pilot city list publicity supported by the central government.” Ministry of Finance of the People’s Republic of China. http://jjs.mof.gov.cn/zxzyzf/csgwzxzj/201604/t20160425_1964180.html.
Nanjing Hexi New Town Government. 2017. “Nanjing City Hexi New Town Underground Multi-Utility Tunnel.” Nanjing, China: Nanjing Hexi New Town Government. http://www.newtown.gov.cn/xcgh/cgzs/dxzhgl/201703/t20170316_4398703.html.
National Research Council. 2013. *Underground Engineering for Sustainable Urban Development*. National Academy of Sciences. https://doi.org/10.17226/14670.
Ning, S., and Xin, Y. 2017. “Status and Development of Utility Tunnel in Shengyang.” *City & House* 24 (3): 10–14. https://doi.org/CNKI:SUN:CSZZ.0.2017-03-004.
Pan, J. 2017. “Practice and Thoughts of Construction of Hengqin New Area Underground Multi-Utility Tunnel Operation and Management System.” *Shizhengnet*, May 31, 2017. http://www.shizhengnet.org/News_text/?id=1847&qx=168.
Qian, Q. 2017. “To Transform Way of Urban Development by Constructing Underground Utility Tunnel.” *Tunnel Construction* 37 (6): 647–54. https://doi.org/10.3973/j.issn.1672-741X.2017.06.001.
Seow, J. 2018. “Parliament Briefs : Common Services Tunnels Bill Passed.” *The Straits Times*, March 20, 2018. https://www.straitstimes.com/singapore/parliament-briefs-common-services-tunnels-bill-passed.
Shi, W., Li, J., Cai, N. and Tian, D. 2015. “Under the ‘double new’ background urban new district underground multi-utility tunnels planning research.” *Development of Small Cities & Towns*, no. 9: 83–87, 92. https://doi.org/10.3969/j.issn.1002-8439.2015.09.013.
Shu, Y. 2003. “Utility tunnels in Japan.” *Chinese Civil Air Defence* 6: 40–41.
Song, W. 2016. “Beijing multi-utility tunnel planning and construction status and development trend.” *Construction Machinery*, no. 6: 16–21.
Su, Y. 2007. “The application and future of Zhongguancun west area municipal multi-purpose utility tunnel project.” *Road Traffic & Safety* 7 (2): 24–28.

Tao, Y. 2017. “Construction of Shenyang South Canal Underground Multi-Purpose Utility Tunnel.” *Xinhuanet*, 2017. http://www.xinhuanet.com/local/2017-05/06/c_129592211.htm.
The State Council of China. 2016. “Government work report.” *The State Council of China*, March 17, 2016. http://www.gov.cn/guowuyuan/2016-03/17/content_5054901.htm.
The State Council of China. 2017. “Government work report.” *The State Council of China*, March 16, 2017. http://www.gov.cn/premier/2017-03/16/content_5177940.htm.
The State Council of China. 2018. “Our Urbanization Rate Rises to 58.52% Which Can Release New Development Power,” 2018. http://www.gov.cn/xinwen/2018-02/04/content_5263778.htm.
Wang, J. 2018. “Construction and development of urban multi-purpose utility tunnel projects.” presented at the Development of Macao’s underground facilities conference, Macau, China.
Wang, J., and Gou, A. 2011. “The origin and future of urban multi-purpose utility tunnel planning and construction in China.” *Sichuan Architecture* 31 (5): 6–9. https://doi.org/10.3969/j.issn.1007-8983.2011.05.003.
Wang, T., Tan, L., Xie, S. and Ma, B.. 2018. “Development and Applications of Common Utility Tunnels in China.” *Tunnelling and Underground Space Technology* 76 (June): 92–106. https://doi.org/10.1016/j.tust.2018.03.006.
Wang, Y. 2017. “Problems and Counterplan of City Underground Multi-purpose Utility Tunnel Construction.” *New West*, no. 6: 34–35.
Wei, X, and Meng, Y. 1997. “Zhangyang Road, Pudong New Area, Shanghai underground multi-utility tunnel.” *Distribution and Utilization* 14 (4): 6–7.
Xiao, R. 2004. “Connecting Underground Places in Zhong Guancun.” *Construction Science and Technology*, no. 17: 38–39. https://doi.org/10.3969/j.issn.1671-3915.2004.17.017.
Yan, Y. 2015. “Research of the Financing Mode Selection about SuoYu Bay Business District Municipal Composite Pipeline Gallery.” Dalian, China: Dalian University of Technology.
Ye, Z. 2001. “Design of Utility Tunnel under Chengzhan Square in Hangzhou.” *China Municipal Engineering*, no. 4: 61–65. https://doi.org/10.3969/j.issn.1004-4655.2001.04.022.
Yu, D., Lian, X., Li, X., and Lu, G. 2013. “Design Points of Municipal Tunnel in Qingdao Huaguan Road.” *Water & Wastewater* 39 (5): 102–5. https://doi.org/10.3969/j.issn.1002-8471.2013.05.025.
Zhang, H. 2006. “Engineering design of utility tunnel in Shanghai Anting New Town.” *Shanghai Electric Power*, no. 3: 238–42.
Zhang, H., Li, J., and Wang, Y. 2015. “Application of Big Data in the Planning of Municipal Facilities - Taking Hunnan New City in Shenyang as an Example.” In . Guiyang, China: China Urban Planning Association.
Zhang, J. 2016. “Urban underground space development and construction management standards-introduction to multi-utility tunnel in Guangzhou Higher Education Mega Center.” *Civil Engineering & Architecture*, no. 2: 72–86.
Zhang, K. 2014. “Analysis the design work of underground pipe gallery project in the Xiaoyao Bay International Business District.” Dalian University of Technology.
Zhang, Y. 2016. “Green Utility Action Practices in National Ecological Demonstration City: Nanjing Hexi New Town Jiangdong Road Underground Pipeline Tunnel.” *Modern Urban Research*, no. 9: 72–77. https://doi.org/10.3969/j.issn.1009-6000.2016.09.011.
Zhao, S. 2016. “Hengqin Island Multi-Utility Tunnel Takes Effect.” *Hengqin Area Government*, November 28, 2016. http://www.hengqin.gov.cn/office/zwdt/201611/3ee1a3d7928b45f0898e51f45bc03756.shtml.
Zhong, L, Ma, D., and Guo, H. 2006. “Investigation on construction of municipal utility tunnel in Beijing.” *Chinese Journal of Underground Space and Engineering* 2 (8): 1287–92. https://doi.org/10.3969/j.issn.1673-0836.2006.z2.002.
Zhou, D, and Li, Z. 2015. “Multi-utility tunnel in Beijing Future Science Town is under construction.” *China Guanjing Net*, 2015. http://www.zgguanjing.com/news/guonei/gn132.php.