The Future Use of Underground Space in Malaysia: A Literature Review

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Abstract

Today, more than half of the world population lives in urban areas and it is expected that this figure will grow rapidly to reach 85.9% in 2050. People will keep on migrating from inland to village, city, and metropolis and the number is increasing year by year. Cities are increasingly overcrowded and congested. The rapid developments in urban area to meet human needs are found to be inconsistent with the principle of sustainable development. Besides, space is highly demanded with great pressure especially for housing and infrastructure. This results in other problems such as greater traffic congestion, air pollution, and lack of green space for development. Due to these circumstances, the other consideration is using none other than going to the third dimension of city as a final frontier in urban development and possible path to sustainable urban form. In Malaysia, the use of underground space started with the establishment of shop lots below the Merdeka Square, sixteen years ago, then followed by Petronas Twin Towers, Light Rail Transit, Storm water Management and Road Tunnel (SMART), and the most recent is an on-going project of Mass Rapid Transit (MRT). Looking on positively for the underground development for infrastructure, this paper attempts to review and discuss the present and future use of underground space in Malaysia. The paper also explores the potential planning and challenges of underground development. This is done by reviewing successful underground developments around the world in order to suggest the potential planning for underground space in Malaysia. The investigation attempts to address the possibility of developing a sustainable underground development in Malaysia as a step forward.

***Keywords*:** urban underground space, planning and utilization, sustainable development

1.0 Introduction

Infrastructure is important to the vitality and the experience of a contemporary metropolis. As we move into the twenty-first century, one of the primary roles of urban design is the reworking of movement corridors as new vessels of collective life(Wall, 1999).Explosive growth of cities in developing countries and, thus, the demand for improved liveability and environmental protection has created a strong demand for new underground development. The population of the world in urban areas keeps increasing year by year due to urbanization. In 1970 as many as 1,353 million people live in urban areas and the number increased to 3,632 million in 2011 (United Nation, 2012). This was an increase of 37% and in 2050, it is expected that the number will reach 6,252 million. Urbanization percentage in most of developed countries is increasing due to the increasing number of urban population (Table 1). By referring to Table 2, urbanization percentage in 1970 was only 66.6%, but the number increased to 77.7% in 2011 and will continue to increase to almost 85.9% in 2050.By then, the world can be categorized as urban area.

Table 1. Total Population in Urban Area, 1950-2050

	Population (millions)				
Major area	1950	1970	2011	2030	2050
Urban Population					
Africa	33	87	414	744	1,265
Asia	245	506	1,895	2,703	3,310
Europe	281	412	539	573	591
Latin America and the	69	163	472	585	650

Caribbean					
Northern America	110	171	286	344	396
Oceania	8	14	26	34	40
Total	746	1,353	3,632	4,983	6,252

Source: United Nation (2012)

Table 2. Percentage Urbanisation by Development Group, 1950-2050

	Percentage Urban (%)				
Development Group	1950	1970	2011	2030	2050
World	29.4	36.6	52.1	59.9	67.2
More developed regions	54.5	66.6	77.7	82.1	85.9
Less developed regions	17.6	25.3	46.5	55.8	64.1

Source: United Nation (2012)

The above statistics shows that rapid growth and development around the world demand more spaces especially in urban areas. Increasing demand for surface space has led to development on marginal land, including soft soils, slopes, waterfronts, and brown field sites (Chow *et al.*, 2002). Space is highly demanded especially for housing and infrastructure, besides for other problem solutions such as traffic congestion, air pollution, and lack of green space for development (Maire *et al.*, 2006; Parriaux *et al.*, 2006).

As many mega cities show, there is a limit of how far cities can sprawl(Knights & Admiraal, 2009). One way of dealing with the problems of urban space scarcity is by building upwards. Indeed, high-rise buildings have for years been the manifesting example of how to create more space on a limited amount of land. However, office space or living space is not the only demanded space in cities. A prime example of a city which carefully needs to consider how space is used is the city state of Singapore. Other than that, we can go deeper into discussing underground space. Underground space refers to a space that is situated below the ground level (Ronka *et al.,* 1996). According to National Land Code 1965, Section 92A, underground land can be defined as land which lies below the surface of the earth. It means anything below the surface land can be considered as underground land. Due to these circumstances, the other consideration is using none other than going to the third dimension of the city as a final frontier in urban development and possible path to sustainable urban. Underground development will create more space above ground for many purposes especially for recreation and social activities also development of new green fields and residential area. Looking back, the underground space has been exploited for thousands of years, for strategic and military purposes, for religious building, for water and sanitation conveyance and military purposes (Maire *et al.*, 2006). It is only later than that the underground has been deeply used for transportation, commercial building and other infrastructure, such as tunnelling and integrated railway transport.

Malaysia is also not excluded from urbanization issues. Based on the number of urban density and urbanization as shown in Table 3 and Figure1, the urban development in Malaysia is growing rapidly. It means the consideration for using urban underground space for development must be given a full attention.

Table 3. Population Density in Malaysia

Year	**2000**	**2010**
Population	23.3 million	28.3 million
Density(persons/sq. km)	71	86

Source: Department of Statistics Malaysia (2010)

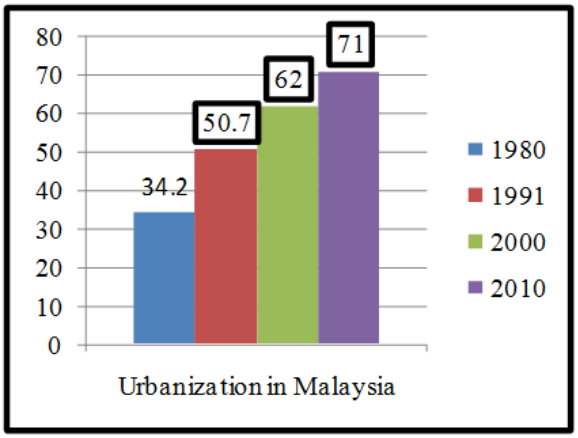

Figure1. Percentage Urbanization in Malaysia, 1980-2010
Source: Department of Statistics Malaysia (2010)

Malaysians may still not be familiar with underground space development, but the establishment of shop lots below the Merdeka Square sixteen years ago, followed by Petronas Twin Towers, Light Rail Transit, Storm water Management and Road Tunnel (SMART) (Ghazali, Rasid & Alias, 200)and the most recent Mass Rapid Transit (MRT), Malaysia has,in fact, already participated in underground space development. However, being a new form of land development for the country, several problems have arisen including the legal implications to the landowners above the developments and the technical problems pertaining to building structure and the safety of the occupants.

Underground utilization pattern varies in different urban contexts, depending on the local culture, geographical situation, social environment, and economic needs (Carmody and Sterling, 1993).This article focuses on the existing and future use of underground space in Malaysia. With the present comprehensive laws and regulation on the disposal of underground space but an absent planning guideline of underground space, underground space development practices vary between different parts of the country. Therefore, the aim of this article is to highlight the potential of urban underground space development in Malaysia. It explains the present situation of underground space utilization and identifies the possible future uses for sustainable urban underground space development in Malaysia.

2.0 Why Go Underground?

Since the recent centuries and particularly during the last decades, numerous reasons have encouraged mankind to use and develop underground space. For a good understanding of these reasons it is necessary to keep in mind certain fundamental characteristics of underground space (ITA-AITES, 2002). Firstly, the underground medium is a space that can provide the setting for activities or infrastructures that are difficult, impossible, environmentally undesirable or less profitable to install above ground. A fundamental characteristic of underground space lies in the natural protection it offers to whatever is placed underground. This protection is simultaneously mechanical, thermal, and acoustical. On the other hand, the containment created by underground structures has the advantages of protecting the surface environment from the risks and/or disturbances inherent in certain types of activities. Lastly, one important feature of underground space is its opacity. Thanks to the natural visual screen created by the geological medium where an underground structure is only visible at the points where it connects to the surface.

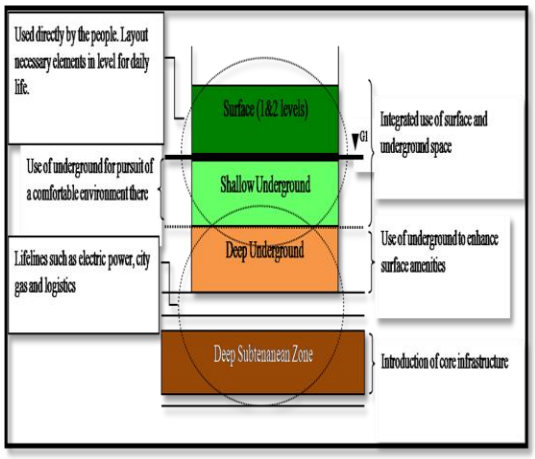

Figure 2: Use of Surface and Underground
Sources: Ikeda and Yokosuka, 2009 in Zhang. *Et al.* (2011)

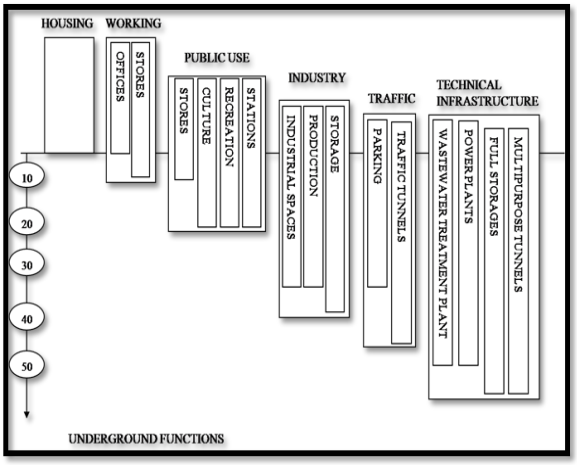

Figure 3: Feasible Depth of Underground Development
Source: Ronka*et al.* (1996)

There are links between surface space and underground space. The usage both in surface and underground must be integrated in order to maximize its benefit. Figure 2shows the usage of surface and underground space. Usually the underground space can be categorized into three parts; shallow underground, deep underground and deep subterranean zone. The development surface space will always have the usage integration with underground space

The utilization of underground space will not only depend on it usage, but there are other aspects that need to be considered, especially the legal and administrative, economic, social, safety and health, technical and also geo-environmental issues. Not all underground structures are suitable for many sites, functions and building programs, but it can be possible alternative for development when conditions are appropriate (Carmody and Sterling, 1983). Figure 3illustrates the feasible depths of different activities involved in the surface and underground space development (Ronka et al., 1996).

From the above figure, the need and importance of underground space as a part of development are undeniable. Working and public use category will definitely focus more on surface development. Underground space is developed only for car parks, shop lots, and service facilities. Meanwhile, for other categories such as industry, traffic and technical infrastructure, underground space plays a major role in development. Most of the infrastructure such as subway, road, pipeline and others are buried underground to maximize land use.

As our land includes surface and underground space, it has many resources that need to be explored for development. Therefore by going underground, the resource that lies beneath our feet will lead to utilization of underground space. However, underground utilization pattern varies in different urban contexts, depending on local culture, geographical situation, social, environment and economic need (Carmody and Sterling, 1993). There are many reasons for and benefits from going underground for development as follows:

(i) Land use and location (Parriaux *et al.*, 2006)

In many cases, underground space use results from a lack of surface space. The use of underground space allow a facility to be built in a location where a surface facility is not possible because building a surface facility in that location may notbe not acceptable to the community. There are many types of facilities that are best or necessarily placed underground because their physical presence on the surface is unwanted, such as public utilities, storage of less-desirable materials, and car parks.

(iii) Environmental preservation (Durmisevic, 1999)

The ground also provides a variety of advantages in terms of protection of environment. These are notably important aspects in designing facilities with a low environmental impact.

(iv) Topographic reason (ITA-AITES, 2002)

In the hilly or mountainous areas, the use of tunnels improves or makes feasible various transportation options such as roads, railways, canals, etc. Tunnels are also an important option in river, straits, and harbour crossings. Underground space use offers many advantages with regard to the layout of facilities and infrastructures. These advantages derive essentially from the freedom within the geological, cost, and land ownership limitations to plan a facility in three dimensions and from the removal of physical barriers on the land.

(v) Aesthetic (Chow. F.C, *et al.*, 2002)

By going underground, it helps in removing unattractive structures such as car parks, roads, and tunnels. In line with that, we can save more surface space for other developments.

3.0 Possibilities of Developing a Sustainable Underground Development

The drive towards a sustainable future means that planners are looking for new ways to allow for economic growth while preserving the natural environment. The best sustainable way of maximizing the usage of underground and above-the-ground resources, is through proper planning. The potential of underground space development should be exploited in a right way to maximize the benefits to the environment, society, and economy. Underground development can only be realized if it is socially and politically acceptable, economically viable and legally possible (Parriaux *et al.*, 2006). Therefore, a study of urban underground space development should be done, focusing on the above elements. To ensure that all elements can contribute to sustainable development, Figure 4 shows some questions that need some answers.

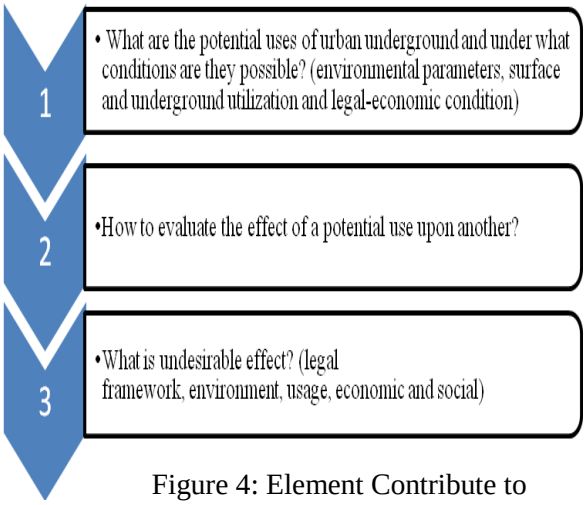

Figure 4: Element Contribute to Sustainable Development
Source: Maire, *et al.* (2006)

More extensive use of the urban underground can help cities to reach the goal of sustainable development, but this can only be achieved under the conditions of a long term planning. Therefore, more research should be conducted in order to help define the potential use of urban underground resources and to evaluate the effect of a use upon another, considering space and time.

Table 4: Urban Underground Space Development in the World

AUTHOR	COUNTRIES	APPLICATION
Chow (2002); Fabillahand Junji, (2006)	France	• The Louvre • Versailles(Innovatie road tunnels) • De France City • Development
Chow(2002); Zacharias(2000)	Canada	• Montreal City
Chow (2002); Fabillahand Junji (2006)	USA	• Boston City Big Dig
ITA-AITES(2012)	Netherlands	• Underground Trash Collection
ITA-AITES(2004)	United Kingdom	• Hindhead Tunnel • Cross London Rail Links
ITA-AITES(2004)	India	• Delhi Metro Project • Dhauliganga He Project
Fabillahand Junji(2006)	Japan	• Tokyo Underground Drainage Network • Nagoya Sakae Park Oasis (Bus Terminal Annex, Japan)
ITA-AITES (2004); Chandrasekaranand Hong(2006)	Singapore	• Underground Science City, Singapore • Kallang Paya Lebar Expressway • Deep Tunnel Sewerage System
Mangkoesoebroto (2005); Fabillahand Junji (2006)	Indonesia	• Nusantara Tunnel • Mass Rapid Transit

4.0 Successful Urban Underground Development Example around the World

Understanding the importance of underground space utilization requires an awareness of urban development trends and the course that contemporary planning is taking. In such a way, there is a growing rationale for increased underground space utilization because of urban growth worldwide, the need for infrastructure renewal in older cities, the need for basic infrastructure in developing countries, congestion and deteriorating utility and transportation corridors, and current improvements in underground construction technology. It is expected that the continued development of current trends will hopefully bring technological resolution of problems that continue to plague underground construction. Table 4 lists the examples of successful development of underground space that can be found around the world.

Below are details and explanation of example of urban underground space development in the world:

1. Montreal City, Canada

Montreal has the world's largest underground city containing 31 km of passageways, 10 metro stations, a railway station, bus terminal, more than 1600 shops, 200 restaurants, 40 banks and 30 cinemas, as well as hotels, offices, swimming pools and theatres. The construction begun in the 1960 apparently was based on an idea of Leonardo de Vinci, the 'city under the city'. The idea then grew as developers realized the importance of linking into the underground network and the metro system. The subterranean world protects the citizens from the snow, rain, wind and heat, providing a climate that is 'eternally spring' and an environment that is free from traffic and road-related accidents (Chow, 2002)

2. Kallang Paya-Lebar Expressway (KPE), Singapore

As Southeast Asia's longest underground expressway, KPE enhances transportation infrastructure and serves the growing residential, commercial and industrial needs of the Northeast. Costing $1.7 billion to build, the KPE is part of the Government's commitment to build roads to support Singapore's growth. Stretching from East Coast Parkway (ECP) to Tampines Expressway (TPE), the full 12km KPE opened to traffic on 20 September 2008. The KPE serves the growing residential, commercial and industrial needs of the north-eastern corridor and is expected to reduce journey time in the northeast corridor by up to 25%. This benefits motorists travelling between the north-east sector and the city, as well as improves connectivity between the ECP, PIE and TPE (Singapore Land Transport and Authority, 2011).

3. The Nusantara Tunnel, Indonesia

The Nusantara Tunnel™ links Sumatra and Java -two major islands in Indonesia with 80% of the total population. The development of this physical linkage between the two Islands will integrate many interests among Indonesians who are well-known for their richness in social and cultural dimensions. Moreover, this connection will further integrate natural resources that are found on these two major islands. Certainly, the connection will eventually combine most of the Indonesian potentials.

5.0 Present Use of Urban Underground Space in Malaysia

Since city centres are densely built areas, building underground can accommodate many functions, relieving pressure on the surface and it can be an attractive solution for solving traffic problems and increasing mobility. Users of urban underground space can be divided into two categories; functional infrastructures and passing and living spaces (Li, 2011).Functional infrastructures here relate to urban daily functions such as public utility, storage facility, and energy exploitation system. Meanwhile, passing and living space mostly relates to spaces for human activities such as transportation network and underground commercial centre. Usually, underground development supports the utilization of the underground space of urban areas, as an integral part of physical planning and zoning, for the alleviation of the surface problems and the improvement of the quality of life and the environmental conditions(Mavrikos and Kaliampakos, 2007).

Underground space development helps to contribute partial solution to the urban problems in terms of necessity, construction, and social objectives. The use of underground space as an underground subway system, an underground road tunnel, or parking space is the most common. According to Fabillah and Nishi(2006), Japan has since 1995 listed actual solutions of urban problems by underground space use (Table 5).

Table 5: Solution of Urban Problems by Underground Space Use

Main Theme	**Solution**	**Underground Space**
Urban Planning and Green Space	Open Space Arrangement	• Osaka City Grand, Gymegium, Japan
Urban Function Ability	Court less City	• Montreal Underground Pedestrian Road Network, Canada
	Eliminating Wall Segregation	• Boston City Big Dig, USA
Urban Planning and Space Development	Underground Space Effective Usage	• Korakuen Geopolice (Underground Space Design, Japan) • Nagoya Sakae Park Oasis

		(Bus Terminal Annex, Japan)
Urban Transport System Joint Development	Underground Parking Access Route	• Motomachi Parking Access, Japan
Urban Planning and Private Participation	Management by Non-Profit Organization (NPO)	• Shiodome Seaside Town Management, Japan
Urban Development and Safety Treatment	TV Monitor and Security Control	• Montreal Subway Station, Canada • Tokyo Underground Drainage Network, Japan
Attractive Urban Space Use	Urban Authentic Protection	• Montblanc Parking Area, Swiss
Urban Livelihood Improvement	Underground Housing Facility	• De France City Development, France

(Source: Fabillah and Nishi, 2006)

The above urban problems and solutions are also applicable to Malaysia. An example of successful urban underground development to help solve urban problems is the innovative Storm water Management and Road Tunnel(SMART).The project provides a storm-water diversion scheme including flood-water storage and a 10km, 11.8m diameter bypass tunnel, sufficient to save a city from flooding in the foreseeable future. With no major flood events over most of the years, the dual-use tunnel was engineered, with double -road decks built into the central three-kilometre section, relieving traffic congestion by providing 2x2 traffic lanes for cars connecting the city centre to the southern gateway, the KL-Seremban highway (Klados, *et al.*, 2007).

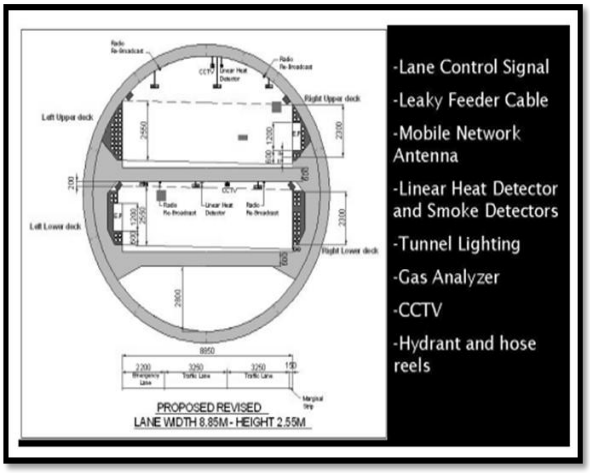

Figure 5: Road Deck Configuration in SMART Tunnel with E&M Equipment indicated
Source: Klados *et al.* (2007)

Other than focusing on public utility, urban underground space development in Malaysia can be exploited for various uses such as underground commercial centre and underground water storage tanks. In 1990, Malaysia already developed an underground shopping complex, Plaza Putra, situated at the Merdeka Square. With an area of 6510 square meters (70,073 square feet), the area was leased out by the Mayor of Kuala Lumpur at that time to Landgen Property Management Sdn Bhd for 42 years. One of the conditions given by the Mayor to Landgen Property Sdn Bhd before the construction of Plaza Putra was maintaining Merdeka Square as one of the historical area in Kuala Lumpur. Plaza Putra in the form of 'dumb-bell' (rectangle) comes from the 461 parking spaces, security, electricity and water supply and air conditioning system (Salleh, 1997). Unfortunately, major floods have occurred in Kuala Lumpur in 2003 causing flood water to be trapped under the Merdeka Square for a week. This has resulted in the total destruction of all of the shop lots and other properties in Plaza Putra (Zainudin, 2004). At that time, the existence of expertise in urban underground space development was lacking. Nowadays, research on urban underground space has advanced globally. It is possible today to develop urban underground space for underground commercial centres since the trend

now is moving towards maximization of space use whether on surface or underground. Through the development of underground commercial centres, open spaces can be utilised as well as having the potential to reduce the cost for land acquisition.

6.0 Sustainable Urban Underground Space Development in Malaysia

Instead of using underground waste-water treatment such as Underground Industrial Plant in Helsinki Finland, Malaysia can use underground space for water storage tanks to benefit some sectors such as residential. Underground water storage tanks in a residential area can be used as part of a rainwater harvesting system. Instead of having to preserve more open space, it can help the environment to use rainwater for daily usage. Country like USA has been using underground water storage tanks as one alternative to save the environment. Underground rainwater harvesting help in collecting rainwater from rooftops and store it for laundry, shower and baths, toilet flushing, gardening and even for car cleaning. Figure 6shows how underground water storage tank in residential works.

Figure 6: Underground Rainwater Harvesting
Source: http://www.pipeco.com.my (2012)

Malaysia can follow the example from Almere, Netherlands which utilizes urban underground space for trash collection (ITA-AITES, 2012, Honkio, 2009). It has an extensive network of pipelines with a total length of about 8 kilometres to help transport garbage out of the city. Using a suction method, garbage is transported at a speed of 70km per hour to a collection terminal, where it is divided into different containers. Filled containers are automatically replaced and a signal is sent to garbage trucks to take the full containers to the incinerator. The use of this system has reduced pollution throughout the city and the absence of the garbage trucks has reduced noise and smell.

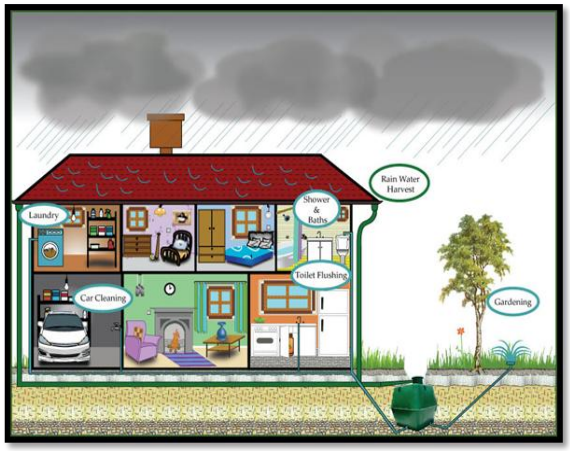

Figure 7: Underground Trash Collection
Source: Honkio (2009)

Tunnelling is not focusing only transportation but also utility usage. Utility tunnelling or known as utilidors helps to reduce density development in tunnelling because it is multi-functioning (Curiel-Esparza *et al.*, 2004). For example, in Ashgabat, Turkmenistan, a tunnel for underground cable has been combined with a large-scale drainage syste

2012). The drainage system dis
subsurface water into the nearby desert for use in an irrigation project. At the same time, the tunnel functions as a sewage main and cable tunnel for the city centre and major government buildings. With the rapid growth of development in Malaysia, especially in urban area, the utilidors concept can be applied since the need for fresh water, energy usage, electricity and telecommunications are increasing year by year. Underground space is the only solutions in bundling all components in service ducts or tunnels (ITA-AITES, 2012).

Figure 8: Utilidors in Turkmenistan
Source: ITA-AITES (2012)

Figure 9: Jalan Petaling Area Source:
http://mile.mmu.edu.my (2012)

Moreover, other major cities are considering subsurface to provide more than just solutions for transport and utility. A major benefit of underground buildings is their low visual impact, making them particularly attractive as visitor centres and museums at historic sites. A notable example is the education centre and museum built in 2007 at George Washington's Mount Vernon estate, near Washington, DC (Evans *et al.*, 2009). In Malaysia, there are several areas of potential historic sites that can be developed. The most appropriate example is Jalan Sultan/Jalan Petaling in the heart of Kuala Lumpur. The Jalan Sultan/Jalan Petaling area is a vibrant and unique retail area drawing tourists to the area not only to shop but to experience the hustle and bustle in a historical part of the city. The area known as KL's Chinatown is the earliest commercial area of Kuala Lumpur and generally consists of double-storey shop houses carrying out retail and trading activities. There are also numerous temples that dot the area. Many buildings from the early 20th. Century deemed to have significant architectural heritage value are present in the area. Therefore, to preserve this area as one of the historical areas, MRT station, provisionally called the Pasar Seni Station, will be located underground the Jalan Sultan/Jalan Petaling area.

Based from the above potential planning and future use, Malaysia is not yet exploiting the use of urban underground space to its limit even though the awareness about it started to emerge as early as the 90's. It is time for us now to move one more step forward in urban development by providing urban underground space. Before we truly develop it, a comprehensive feasibility study that should touch on various categories and aspects is carried out in order for a sustainable urban underground space be developed. The rate, scope, and forms of urban underground utilization significantly vary around the globe in accordance with specific economic, demographic and geographical conditions.

Hence, in developing our underground space in urban areas, Malaysia must promote a holistic approach which considers not only the geological and environmental effect but also the economic efficiency and the social acceptability of underground development. Through this holistic approach, cities have been able to make more extensive use of their urban underground without compromising the use of their resources for the future generations.

7.0 Conclusion

The need for urban underground space in Malaysia is not that critical compared to other developed countries. However, awareness about the possibility of using urban underground space as a new type of development must be considered. Due to rapid growth of development, the demand for land also increases

and in the future, Malaysia seems to utilize all surface and underground spaces for achieving sustainable development. It is rather futile to develop underground space without sustainable elements associated with it.

Therefore, underground space use must conform to the sustainable development in urban area because it will give impact on the physical, social and environment at the surface area. Urbanization must always take into account underground space as an important element of development and sustainability. A three-dimensional concept of the city and land planning should constitute the basis for a long-term management of resources. Underground space is tied to the sustainability of an urban area because the use of underground facilities can positively impact on the extent to which human occupancy of a land area affects the surface environment. Finally, the development of urban underground space must conform to a required standard of sustainable development since it has impacts on the physical, social, and economic environment of the surface area. Suggested future research in this context must touch on the legal aspects, planning policy, urban underground resources, and other related issues.

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