

Use of Underground Space in Seoul and its Foreseeable Future

Seung Ryull Kim¹

¹ESCO Consultant and Engineers Company, Korea

ABSTRACT

The City of Seoul has become one of the most heavily populated human settlements on earth. No other city has experienced such a rapid and condensed expansion, particularly during the past forty years. Along with these remarkable changes, considerable infrastructure was developed underground, besides on the surface, to provide inhabitants with a better living environment. The history of underground space development for the public use in the Seoul conurbation is relatively short and was triggered by the construction of Seoul subway Line 1 in 1970s. Thereafter, a large amount of underground space has been developed for further subway lines, roads and shopping malls. The intent of this paper is to provide a holistic view of the use of underground space with some technological aspects in the Megacity of Seoul. Furthermore, it contains some informative schemes that are under consideration or may possibly be launched in the foreseeable future.

1 INTRODUCTION

The City of Seoul is located at the central part of the Korean peninsula, and is the capital of the Republic of Korea. At the dawn of the twentieth century, its inhabitants numbered merely about two hundred thousand (200,000), while neighbouring Tokyo had grown into a metropolis with over a million (1,000,000) inhabitants. During the last one hundred years, however, the area of the City of Seoul increased about thirty fold (605km²) and the population grew about fifty fold (10,500,000), making it a megacity with more inhabitants than London, New York and Tokyo (SDI, 2003).

By 1989, Seoul was already home to ten million six hundred thousand (10,600,000) or twenty five (25) percent of the population of the entire country within a land surface area of 605km² or 0.6 percent of the total territory of the country. It has become one of the most densely populated cities in the world due to the heavy urban migration of people during the last thirty years between the 1960s and 1990s. During these periods, the population of Seoul increased by eight million. There is a strong view that the concentration of people in Seoul had almost reached its peak in 1992 with approximately eleven million inhabitants. Soon after its peak, it slightly decreased over the last two decades to ten and a half million. Nevertheless, no other city encountered such fast, condensed growth as Seoul in the world. Figure 1 shows the surface area expansion of Seoul during different time periods. Dramatic increases in area are clearly seen in this figure. The present boundaries were set in 1963 encompassing a total area of 605km².

To mitigate the concentration of people into the Seoul administrative boundaries, several satellite cities originally based on existing towns were developed. In all, sixteen cities are located around the City of Seoul boundaries as seen in Figure 2. All of them are situated within a 50 kilometre radius from the centre of Seoul. Together with about thirteen million from the satellite cities, the Seoul conurbation comprises of twenty-three

million people, which accounts for half of the total population of the country; thus, they are residing in a comparatively very small area. This concentration of people obviously required the construction of various types of infrastructure interconnecting the individual suburban areas.

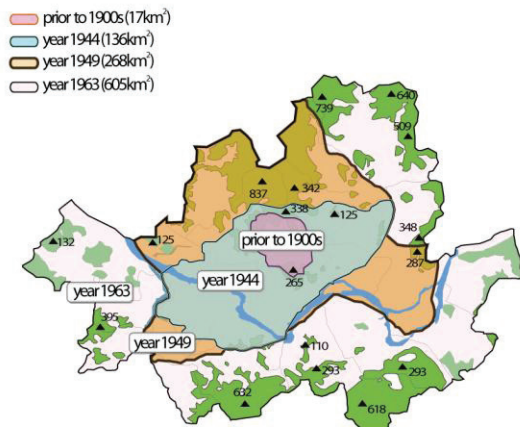


Figure 1 Area expansion of Seoul according to date

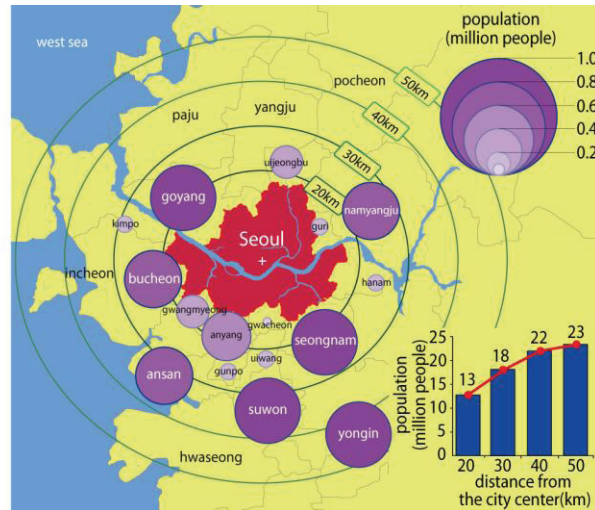


Figure 2 Number of inhabitants in Seoul and its vicinity

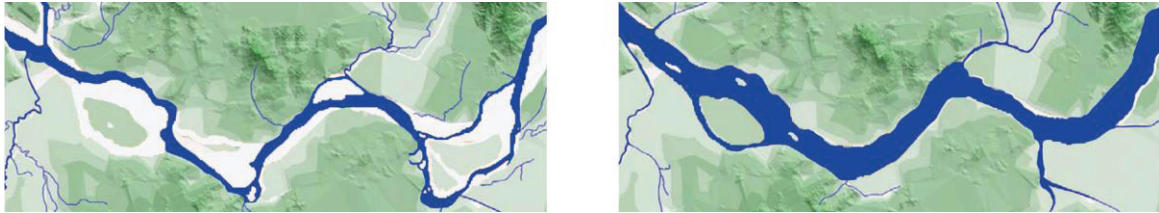
2 TOPOGRAPHIC AND GEOLOGIC CONDITIONS OVER THE SEOUL AREA

2.1 Overview of topography in Seoul

The Seoul basin is not flat, and many hills and mountains are scattered throughout the City of Seoul. However, the area is surrounded by two distinct belts of mountains. The central part, encircled by four inner mountains and their ridges, consists of low flat lands. The highest peak among inner mountains is 342 metres. Mountains forming the outer belt, in contrast to the inner mountains, rise higher than those of inner mountains. The mountain ridge is composed of lots of peaks higher than 600 metres above sea level. This belt roughly limits the Seoul boundaries, and the highest among them being 837 metres (see Figure 1). The many artificial changes that have taken place from a topographical point of view throughout the long history of Seoul make it difficult to recognise the original topography of the capital. However, the character of the original topography has been determined through various landmarks and well-known areas. The Han River, one of the most beautiful landscapes of Seoul, flows westwards dividing Seoul into the north and south. It collects the waters from several tributaries originating from the surrounding mountains. This natural river system, running through the centre of the capital, has accumulated considerable extents of alluvial deposits throughout the Seoul area in long periods of times.

As the population of Seoul increased, the river system began functioning as drainage for rainwater, even wastewater and sewage. The original features are hardly recognisable nowadays since streams have been covered to construct the roads and acquire new lands for other purposes. Meanwhile, Seoul had worked intensively on the development of the Han River. In fact, this was a signal of the opening up a new era of people's urban life. The riverside roads were first built as a part of the Han River development program between the late 1960s and early 1970s. After completion of the artery roads along both sides of the Han River, the overall Han River development program was launched in 1983 and completed in 1985 for the purpose of restoring the Han River, providing recreational areas along its banks whilst considerably easing the

traffic congestion at the same time. As a consequence this project drastically changed the original landscape of the Han River as can be seen in Figures 3(a) and 3(b).



(a) Plan view in 1915

(b) Plan view in 1985 and thereafter

Figure 3 Plan views of waterway and waterfront of the Han River

Since the surrounding Seoul's landscape is hilly and the Han River and its tributaries are flowing through the City centre, about thirty seven percent of its whole area is occupied by mountains and waterways, so-called, non-residential areas. This means that only sixty three percentage of the area can be developed. Seoul, therefore, actually has a population density of 27,548 persons per square kilometre, categorizing Seoul as the second most densely populated city in the world, following Cairo, Egypt (SDI, 2003).

2.2 Overview of geology in Seoul

Figure 4 shows the geological formation in the Seoul basin. The base rock of Seoul consists mainly of gneiss and granite which are beautifully exposed in most places of the mountainous regions. Gneiss formations spread dominantly in the east-westerly direction, and form a broad bandwidth along the Han River flowing westwards. The north-eastern areas and the south-western areas, where the higher mountains are located, consist of granite, mainly biotite granite. These base rock formations easily form sandy soil layers which drain well once they are weathered. Substantial areas are covered with the alluvial deposits as well, particularly along the Han River and its tributaries. Clayey soil layers exist, although in a very limited area, in the westernmost area of Seoul.

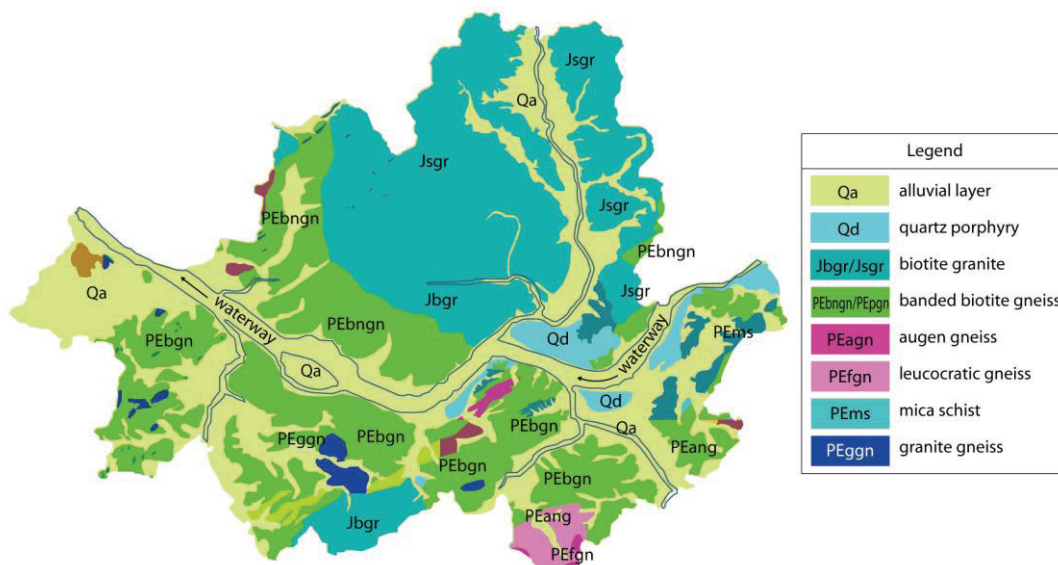


Figure 4 Geological formations in the Seoul basin

Typical geological profiles of the Seoul area are shown in Figure 5. Generally, bed rocks are covered with the weathered layers composed of weathered soils and rocks. These zones are usually overlaid by such deposits as silt, clayey soil and gravel. The general structure, therefore, of the stratum in the Seoul area is four fold, which includes fills, alluvium, weathered soils and rocks (weathered zones), and bed rocks from the surface.

The surface stratum is made up ground of artificially filled deposits. Its thickness is not more than five metres in general. Most of the layers are loose to medium dense and they contain trash and gravel. This layer is commonly encountered from place to place indicating that previous works had been constructed here before.

Alluvium is dominant in the areas adjacent to the rivers and the streams. Thickness of this layer varies location by location, and their wide ranges of relative density are also obvious. These layers are pervious, and their average coefficients of permeability are order of 10^{-4} ~ 10^{-5} m/sec. In some places it develops to a depth of twenty metres with a significant negative effect on underground work.

Weathered stratum consists of weathered soil and weathered rock according to the degree of weathering. The weathered soil is partially apparent, while the weathered rock is widely spread across all of the urban area. These layers are very stable in nature; however their states are vulnerable when exposed to the air and water. The weathered stratum is underlain by the bed rock whose unconfined compressive strength is 25 to 220 Mpa.

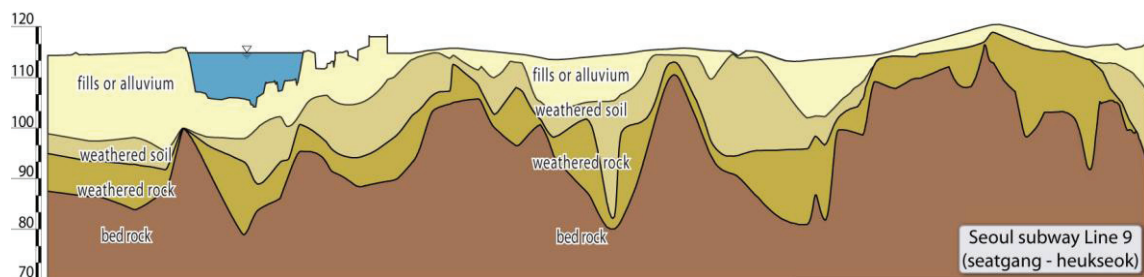


Figure 5 Typical geological profiles in Seoul area

3 STATISTICS OF UNDERGROUND SEOUL

3.1 Generals

Seoul encountered such a rapid and drastic expansion over a very short period of time that it also faced numerous urban problems at the same time. In other words, the changes that have been taking place are so intense in an unusually compact condition that Seoul embodies one of the most acute contemporary urban challenges.

In order to mitigate traffic congestion, roads were aggressively widened and extended, and often elevated at the cross sections, and a great number of pedestrian overpasses and underpasses were built to prevent pedestrians from impeding traffic flow with little attention to the beauty of the landscape. Despite these efforts, it was revealed that the on-surface measures had inevitable limitations. Consequently, attention was given to the utilisation of the underground space to ease the public transportation system and to provide more green areas on the surface.

Underground spaces of Seoul have been extensively used for the past thirty years. There exist various types of underground structures, such as underground roads, subways, utilities (telecommunication and electricity), underground water supply and sewerage as well as shopping malls. Collecting the statistic data at hand reflecting all the features of underground space use for a megacity like Seoul was not an easy task. It is

estimated that at least more than thirty million (30,000,000) cubic metres of underground space were created for only the Seoul metro as of 2010.

3.2 Subways

Generally, subway tunnels are constructed as near to the surface as possible. This is primarily because of convenient access to the system for passengers and lowering the cost of expenses not only in terms of capital, but also in terms of operation and maintenance, including the cost of facilities such as lifts and escalators. For this reason, subway construction is often conducted in relatively soft ground conditions, such as alluvial deposits, silty or clayey soils and weathered soils, in which substantial lengths of Seoul subway lines have been laid.

Two main construction methods, namely the cut-and-cover method and the bored method, were frequently employed for Seoul subway construction. In case of bored tunnelling, the drill-and-blast method was a quite commonly adopted excavation method, while the shield TBM method was applied in a limited capacity so far. Since Seoul is a densely populated area, it was inevitable that the subway routes were aligned beneath existing buildings or residential areas, even under the river or streams with a relatively shallow over burden, which were the most technically and environmentally demanding tasks. Figures 6 and 7 are typical profiles of the Seoul subway tunnels and station.

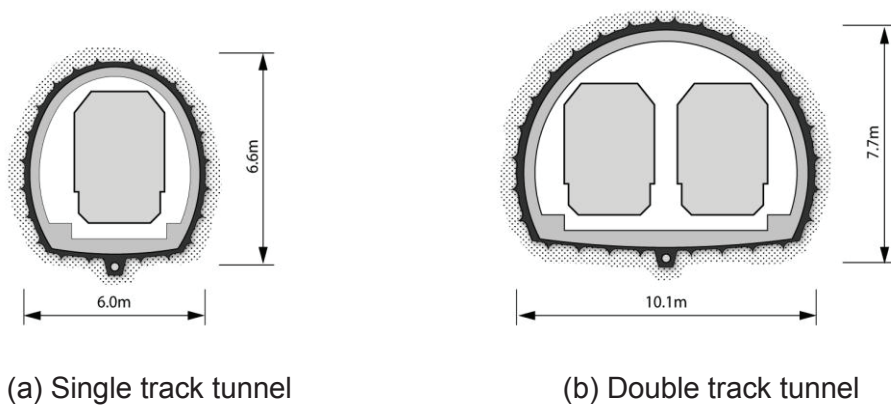


Figure 6 Typical profiles of the subway tunnel

The Seoul subway networks have three hundred and thirty eight (338) stations within the City boundaries. Among them, two hundred and eighty seven (287) stations were built underground. Subway stations were placed at approximately one to one and half kilometre intervals. With rising use of subways, the areas around subway stations became new commercial areas. Many underground shopping centres that connect to or combine with the subway stations were constructed. These trends obviously brought about structural changes in the urban space. Furthermore, spaces were designed to reflect the geographical or historical features of the area, and thus subway stations are no longer just a transit facility but also have become spaces for people's daily life.

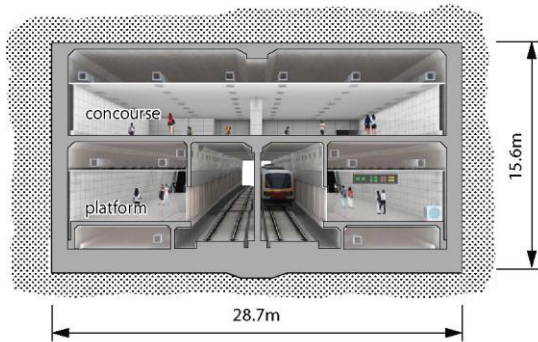


Figure 7 Schematic view of the typical subway station

3.2.1 Seoul subway networks

During the late 1950s up to the end of 1960s, buses and trams were the two major means of mass transportation in Seoul. Up until the early 1980s, the number of buses operated in Seoul steadily grew to eight thousand (8,000), comprising more than sixty percent (60) of all public transportation. However, after the subway came into use since the mid 1970s, this rate has decreased significantly.

The Seoul subway system was categorised into three phases according to the construction stages. Lines 1 to 4 belong to Phase I, while Lines 5 to 8 are part of Phase II. All the lines constructed after Phase II make up Phase III. Seoul subways in use as of 2011 are summarised in Table 1, and the networks are shown in Figure 8, respectively.

Table 1 Summary of the Seoul subways

Phase	Subway Line	Construction Period (year)	Total Length (km)	Construction Method(km)				Tunnel Depth (m)	No. of Stations (under-ground)
				Drill-and-Blast		Cut-and-Cover	TBM		
				ASSM	SC & RB				
I	Line 1	1971~1974	34.4*) 9.5	-	-	9.5	-	average	36(10)
	Line 2	1978~1984	57.3	5.2	-	32.9	-	13.7	51(38)
	Line 3	1980~1985	41.6	4.7	10.7	20.8	-	maximum	34(32)
	Line 4	1980~1985	34.6	0.6	8.2	18.4	-	36.1	26(21)
II	Line 5	1990~1996	57.9	-	33.5	21.9	1.9	average	51(51)
	Line 6	1994~2000	36.1	-	15.6	20.2	-	17.6	38(38)
	Line 7	1990~2000	45.6	-	21.9	21.7	-	maximum	42(39)
	Line 8	1990~1999	19.7	-	5.3	12.9	-	78.4	14(14)
III	Line 9	2002~2009	27.0	-	6.9	14.7	1.8	-	24(23)
		2008~2013	(4.5 ⁺)	-	3.4	1.1	-	average	5(5)
	Bundang Line	1990~2010	9.8	-	8.5	1.3	-	16.7	8(8)
	Shinbundang Line	2008~2013	(6.6 ⁺)	-	4.6	1.1	0.9	maximum	5(4)
	2005~2011	9.1	-	8.6	0.5	-	90.7	4(4)	
Total			382.6	10.5	127.2	177.0	4.6	-	338(287)

* total length of Line 1=43.9= Seoul subway Line: 9.5 + Korail Line : 34.4

⁺ length which is presently under construction

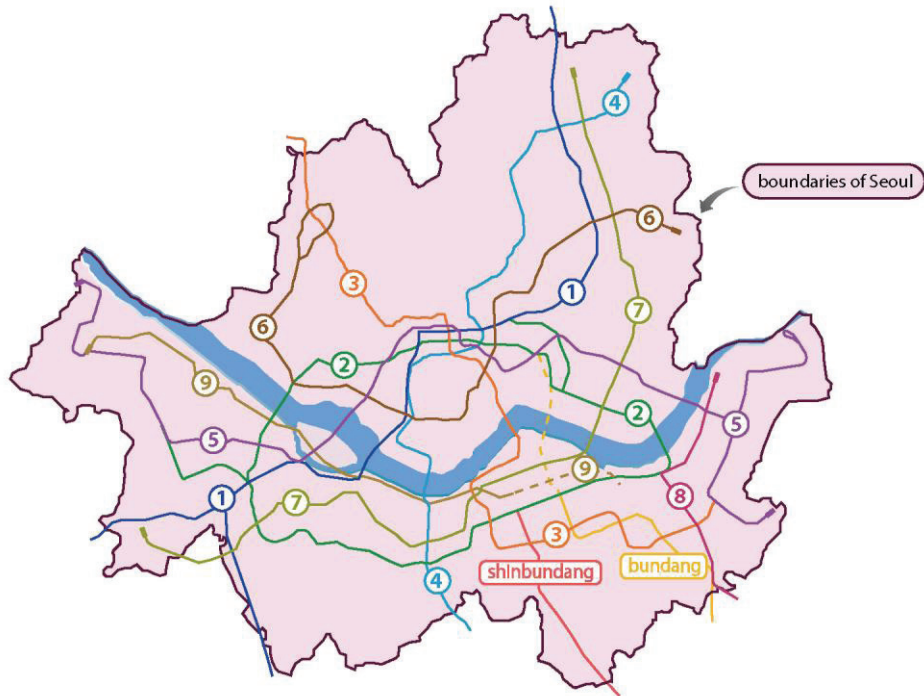


Figure 8 Seoul subway networks

The construction of subway Line 1, stretching nine and a half (9.5) kilometres, began in 1971 and was open to public use in 1974. Whole length of it was laid underground, and it connected to the existing Korail-line (34.4 kilometres) running on the surface. Successful operation of Line 1 spurred the following subway construction: Line 2 in 1984, and Lines 3 and 4 in 1985, which resulted in a shift in the major means of transportation from bus to subway. Phase II of the subway system, of which its total length stretches about one hundred and fifty nine (159) kilometres, was completed in the 1990s. The operation of the Phase II subway lines opened a new era of the Seoul subway, and diminished the role of buses drastically, in terms of urban transportation. As of 2011, Phase III subways are all in use.

Presently, the total length of the subway networks operating in Seoul approximates to three hundred and eighty three (383) kilometres, and it will be three hundred and ninety four (394) kilometres by 2013. Among them some three hundred and nineteen (319) kilometres (eighty three percent of total length) have been built underground. Four different excavation methods as illustrated in Figure 9 were used for the underground work: cut and cover method, American Steel Support Method (ASSM), conventional method with shotcrete and rockbolt, and tunnel boring machine (TBM).

It is interesting to note that the maximum depth constructed increased as the number of subway lines were added (Figure 9). The deepest subway in Phase III was ninety one (91) metres deep, while that in Phase I was only thirty six (36) metres deep. Accordingly, the usage of the cut and cover method decreased from seventy four (74) percent in Phase I to thirty five (35) percent in Phase III, respectively. Subway excavation using TBM was limited to a mere four thousand six hundred (4,600) metres.

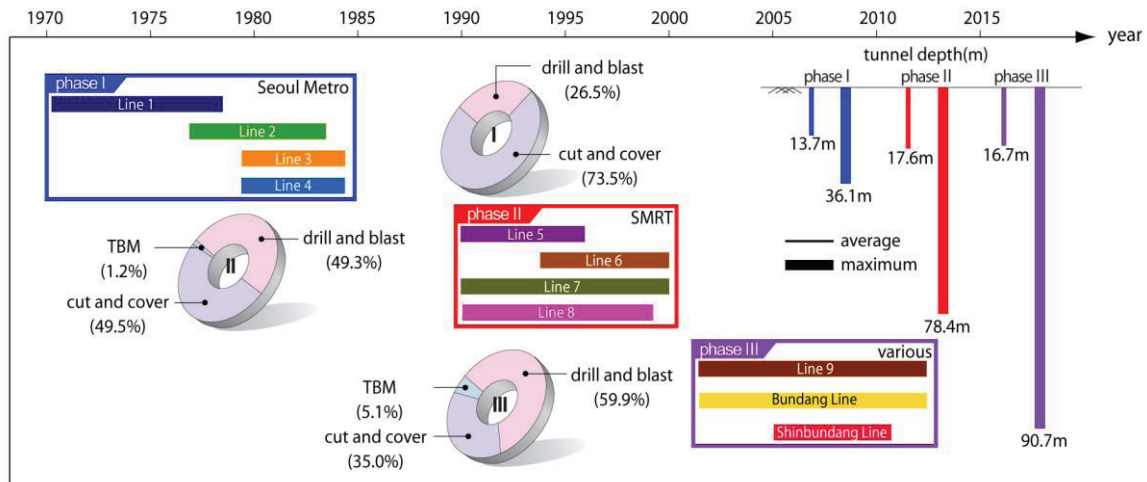


Figure 9 Construction methods and burial depths of Seoul subway in Phase I, II, III

As the economy of the country grew, the number of daily traffic passengers in Seoul has grown tremendously for the past three decades from 1980 to 2010. It is projected that it will approach to nearly forty-million per day in 2025 (Figure 10). This daily city's passenger load is currently shared by means of three major transportation modes such as subway, bus and private automobile. Figure 10 indicates that the city's passenger load carried by subway was merely one percent in 1975. It rapidly increased however to nineteen percent over a fifteen year period. As of 2010, thirty five percent of the total passenger load is carried by subway. On the other hand, twenty eight percent use buses, which will probably be reduced to thirteen percent by 2025. This is vivid evidence that the underground can provide very sound solutions for megacity problems.

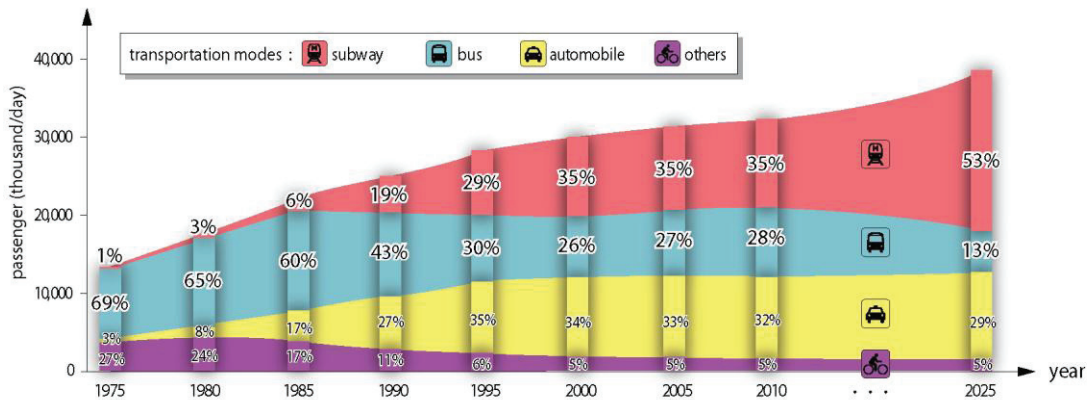


Figure 10 Transportation modes and passenger load shares

3.2.2 Spatial configuration of subway station

As of present, two hundred and eighty seven (287) underground subway stations were constructed in the administrative area of the Seoul Metropolitan Government since 1974, when Seoul subway Line 1 began operating. In the early stages, subway stations were normally designed to meet minimal requirements. Obviously, the spatial configuration was simple and monotonous as seen in Figure 11. A station was considered simply as a place providing the functions for passenger's getting on or off. Convenience and comfortableness had not been considered a priority. Under these circumstances, passengers were easily exposed to a sense of closure in the subway station due to lacking of openness.

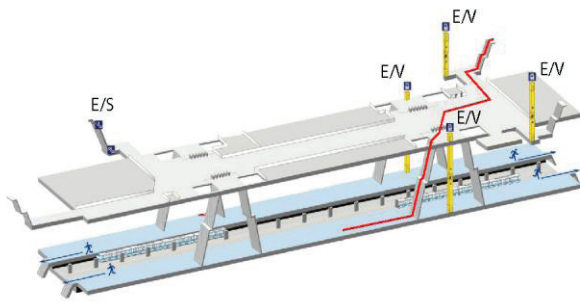


Figure 11 Schematic configurations of subway station at early stage

As the subway system grew, some other functions such as cultural space, rendezvous points, and convenience stores were added to the ordinary station system. Subway stations thus became a multifunctional and multipurpose underground space. In addition the height of each story was increased, open space was added as much as possible, and safety functions of the station were improved. It is quite common nowadays that underground subway stations effectively use natural light as well. Subway stations are no longer stuffy spaces, but rather fascinating and comfortable underground spaces as seen in Figure 12.

For the passenger's easy access and comfortable use, several additional subway stations were constructed on the old subway lines without infringing their daily operation. It was indeed technically demanding underground work. Figure 13 illustrates the construction schemes of a new subway station in conjunction with an old subway line in operation.



Figure 12 Spatial configuration of multifunctional subway station

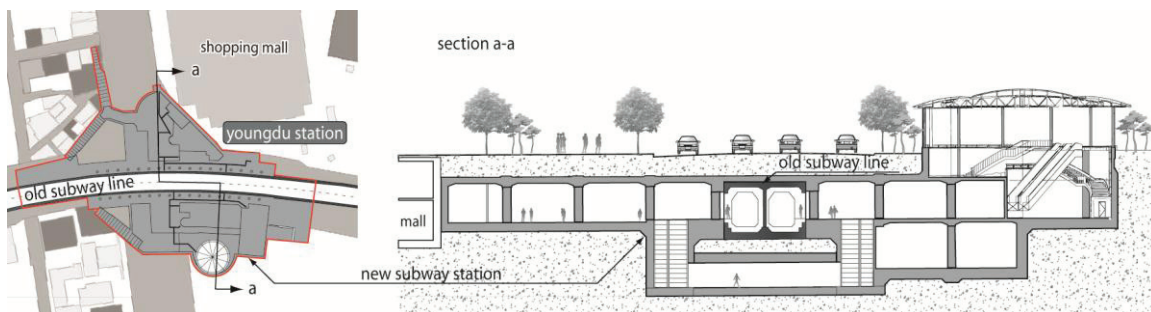


Figure 13 Construction of new subway station joined with old subway line

3.3 Road tunnels

Prior to 1960 road networks covered only existing urban districts, as shown in Figure 14(a).

They rapidly and extensively extended together with the regional expansion of the City of Seoul, as Figures 14(b), 15(a) and 15(b) show respectively. Roads were constructed taking the basic frame of road networks into consideration, established in 1966: four ring roads and thirteen radiating systems of roads. Several long road tunnels were constructed in Seoul because of topographical features of the area.

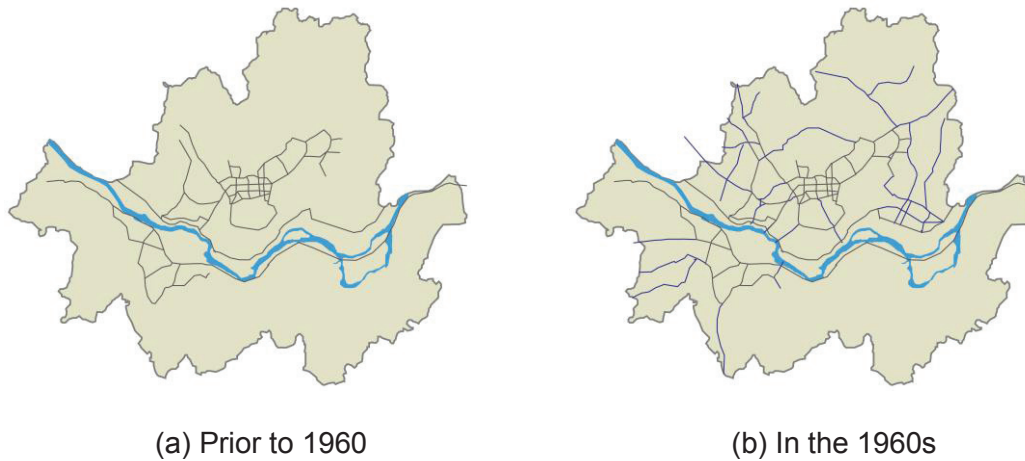


Figure 14 Networks of road in Seoul before 1970

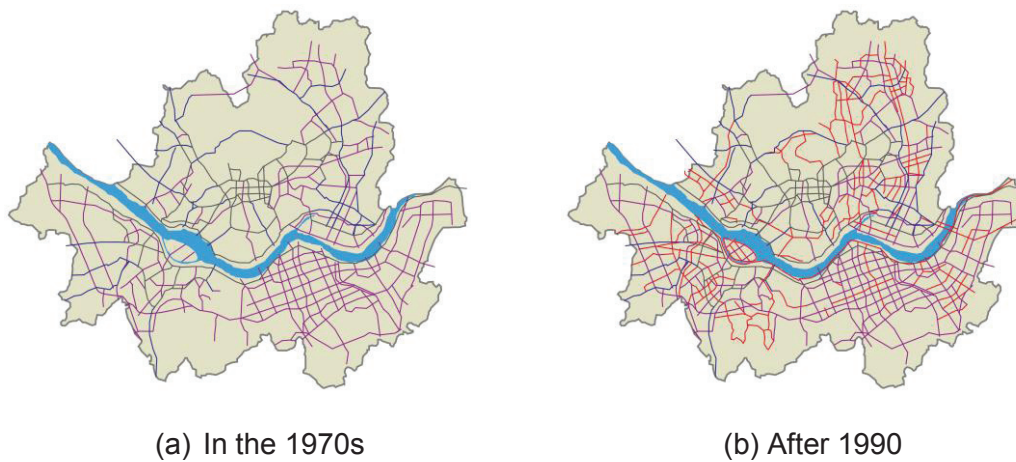


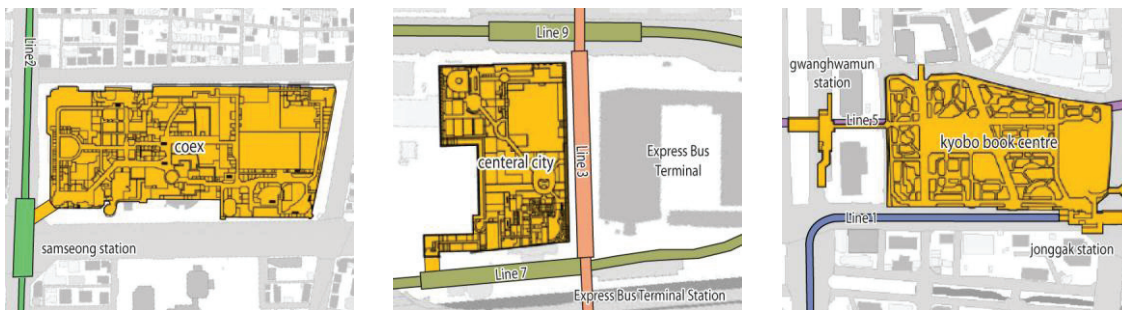
Figure 15 Networks of roads in Seoul after 1970

Road tunnels play an important role in maintaining appropriate functions of the cities and are themselves transportation structures utilising underground space. They are also needed as underground space to provide inhabitants easy access to transportation and convenient travel throughout a hilly urban area like the City of Seoul. Long tunnels serving as a part of the urban highway networks are shown in Figure 16, and number of tunnels and its accumulated lengths at various dates are also shown in the same figure.

some underground space development in Seoul. Since the City of Seoul has been developed with one centre and five sub-centres within its administrative boundaries, the strategic plan for underground space development was proposed based on the characteristics of the City's growth in 1993 (Figure 19).



(a) Linear-underground space development



(b) Area-underground space development

Figure 18 Two types of underground space development

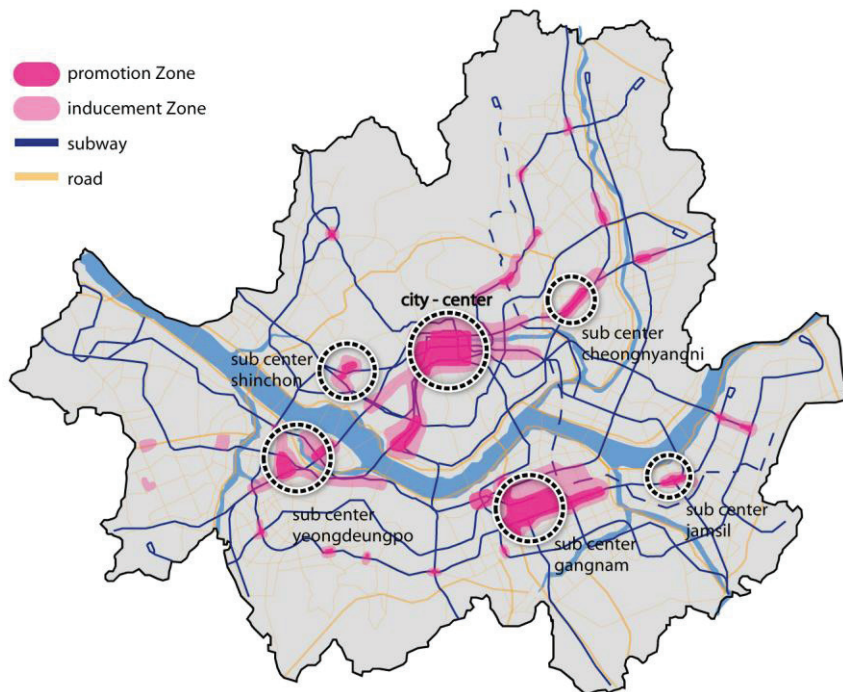


Figure 19 Strategic plan for the underground space development in Seoul (1993)

In the early stages of the urbanisation, buildings, roads and other facilities were constructed on the surface. Underground spaces began to be used with the construction of high-rise buildings and subways. The patterns of development of underground space in Seoul shifted as illustrated in Figure 20. Currently the underground space has an immense importance, and has been developed in a form of city in extent and in volume, particularly in densely populated areas. Citizens' demands to have more green areas on the surface were realised by relocating the above ground facilities that did not need to be on the surface and moving them underground.

Figure 21 is an example of underground space use in Seoul these days. Five underground shopping malls (Figure 21(a)) built in a highly concentrated city centre will be connected together (Figure 21(b)) to improve their functions and to provide convenient access for people. The old ones will also be modernized and modified to accommodate more amenities.

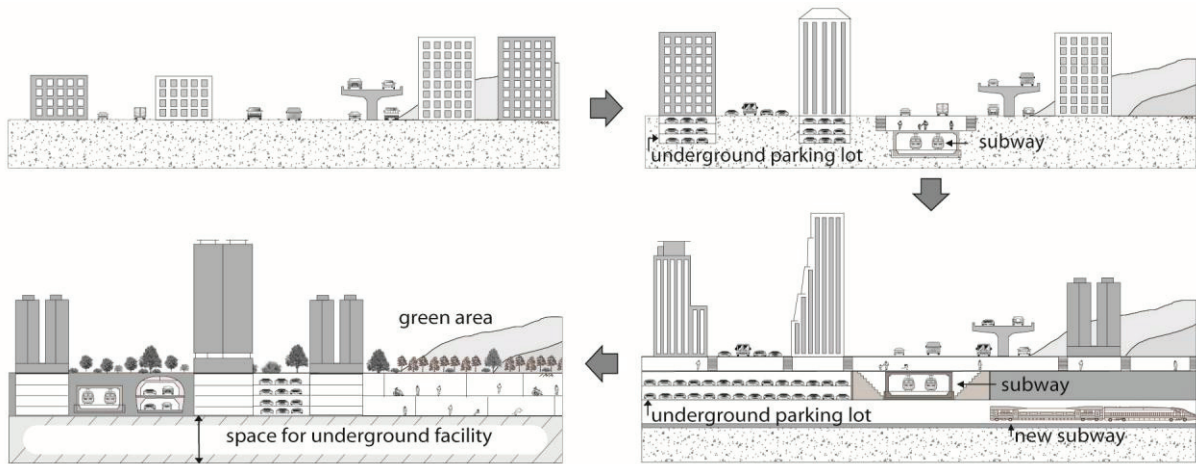
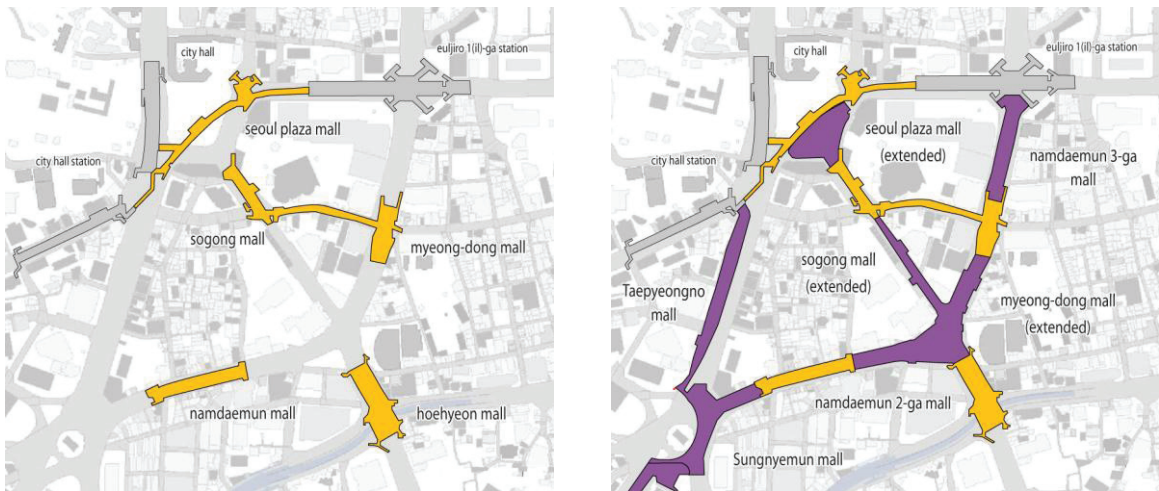


Figure 20 Underground space use and development in Seoul



(a) Malls located individually

(b) Malls connected together

Figure 21 Underground shopping malls in the downtown area of Seoul

In terms of systematic underground space development in Seoul, three zones were set vertically from the ground surface: the depth shallower than twenty metres was defined as 'shallow zone', while the depth deeper than forty metres was defined as 'deep zone', and the zone between these two zones defined as 'middle zone', respectively.

Almost all of the spaces deeper than forty metres in Seoul remain intact. Moreover, the sound bed rock formation is not far below the ground surface, which means that there are plenty of safe and cost-effective spaces for the construction of underground facilities in Seoul. This underground resource draws keen attention as an appropriate solution for the current urban problems in Seoul.

4 SOME EXPERIENCE IN CREATING UNDERGROUND SPACE IN ADVERSE GROUND CONDITIONS

4.1 Generals

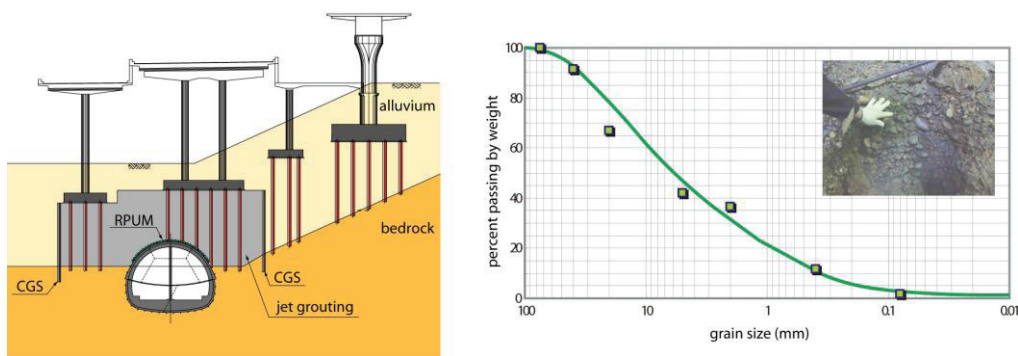
Efforts have been made to alleviate surface traffic congestions in various ways. The level of connectivity between different regions increased with the improvement in the transportation system by utilising the underground space. As stated in the previous chapter, significant lengths of subways and road tunnels, and even underground malls, were constructed for the past four decades in Seoul. Substantial lengths have been laid within poor ground conditions. Consequently, this means that large numbers of geologically challenging projects were carried out throughout the City of Seoul. Some of the experiences learnt from a few of them are introduced in this section.

Grouting techniques were commonly adopted to strengthen the weak ground and to prevent groundwater infiltration. These regions, where tunnelling was successfully achieved, consisted mainly of alluvial geo-materials deposited adjacent to the rivers and the streams. Pre-grouting was also used in the hard rock tunnelling to seal the passage of water inflow causing an adverse impact on tunnelling. The drill-and-blast method has been frequently used for underground rock excavations since the use of Tunnel Boring Machine (TBM) has not been competitive so far.

4.2 Heading through the tips of foundation piles in the gravelly ground

Some piers of the flyover bridges had been founded on gravel ground at the confluence of the Han River and its tributary Banpo Stream. Foundation piles were expected to lay their entire shanks within gravel-like-soil which possessing the average value of hydraulic conductivities order of about 10^{-2} m/sec. It was revealed from the site investigations carried out on site that groundwater in this area directly was influenced by water level of the Han River.

The vertical alignment of a newly constructed subway line (Line 9, CL912) was planned to conflict with sixty-seven foundation piles of the existing flyover bridges. Typical cross section and the gradation curve of the concerned ground are illustrated in Figure 22.



Prior to tunnel excavation, intensive jet grouting was carried out against the ground and foundation piles underneath the footing of piers not only to prevent groundwater inflow, but also eliminate any possible sources of instability related to the tunnel and flyover bridges during the excavation of tunnel. Figure 23 shows the tips of foundation piles exposed during the sequential excavation in the face of tunnel. Settlements of the flyover bridges monitored through the comprehensive monitoring systems were found to be negligibly small. No significant infiltration of groundwater was observed.

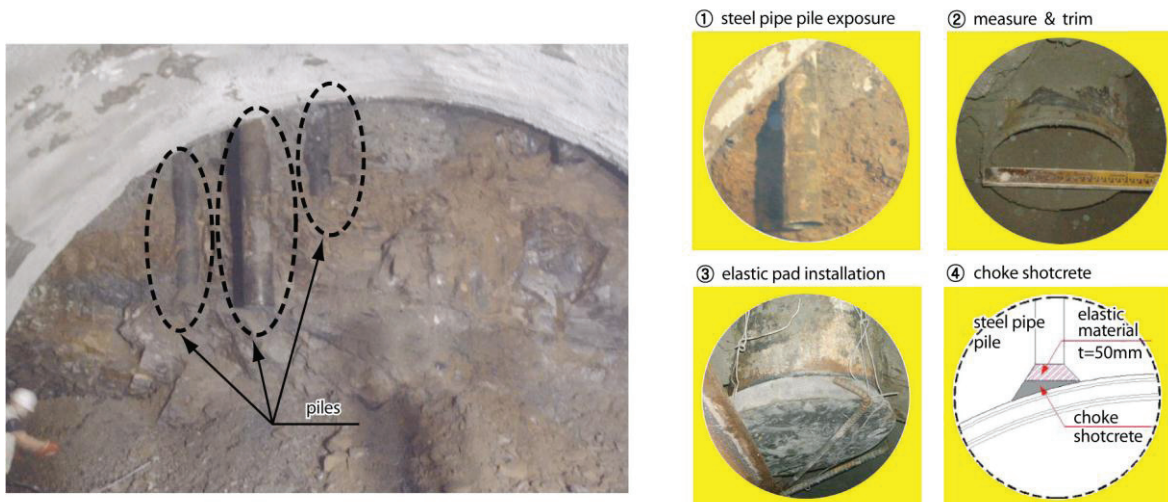


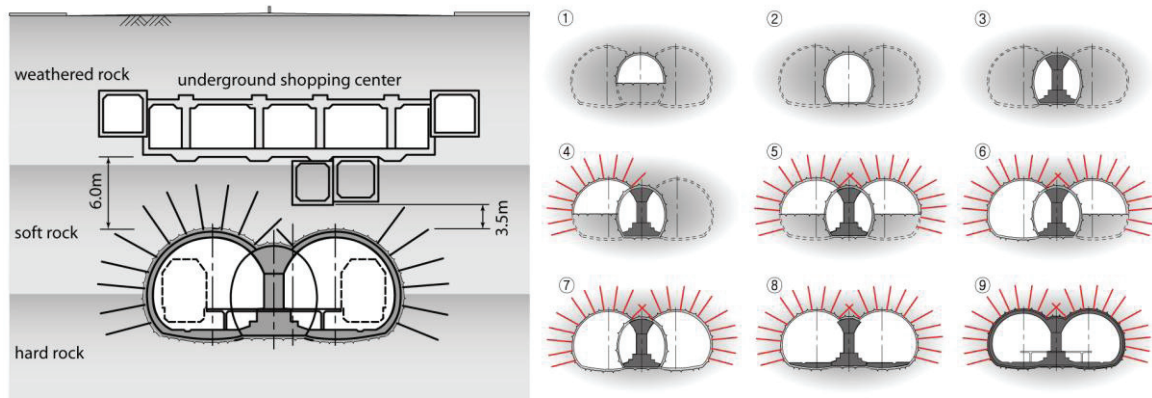
Figure 23 Tips of foundation piles exposed at tunnel face

4.3 Station tunnels under the existing shopping malls

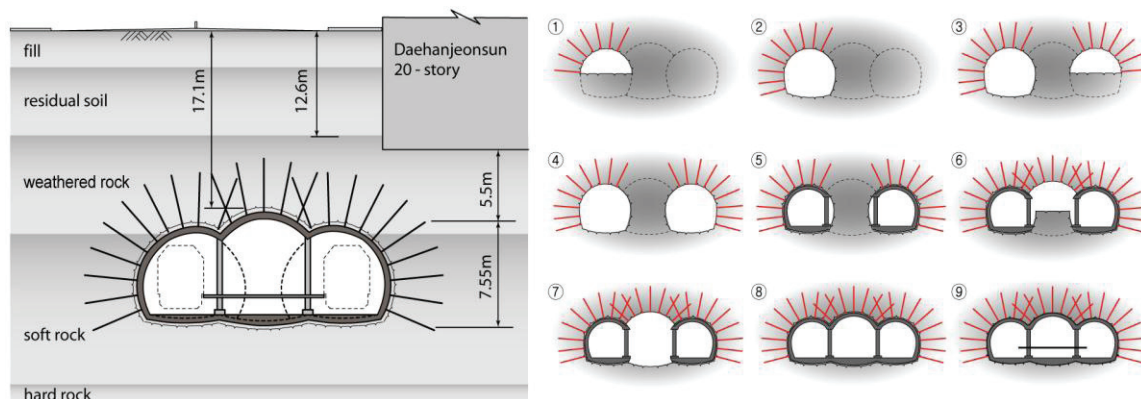
4.3.1 Two-arch and three-arch station tunnels

Cross-sectional configurations of two-arch and three-arch station tunnels are shown with their schema of sequential excavation in Figure 24. Both tunnels were constructed underneath the existing underground structures with minimal cover at three and half (3.5) metres and five and half (5.5) metres, respectively.

In case of Myeongdong Station, the middle part of the whole cross section was excavated first and after that concrete columns were placed along the whole length of the station tunnel prior to the excavation of the side regions. On the other hand, in case of a three-arch tunnel (Hoehyeon Station), excavation was more complicated. Two side tunnels were first excavated as paralleled individual tunnels with the bench excavation less than fifteen-metre long. Central portion of the station tunnel then was excavated after the installation of concrete linings and central columns spaced at five-metre intervals longitudinally. Both station tunnels are in good condition and have been in service since 1985.



(a) Myeongdong Subway Station



(b) Hoehyeon Subway Station

Figure 24 Two-arch subway station and three-arch subway station

4.3.2 Single arch station tunnel underneath old shopping malls and subway

The express bus terminal station belongs to Line 9 of Seoul subway networks was located under the old shopping mall and subway Line 3, which were opened to the public in 1979 and 1985, respectively. Cross-sectional configurations of this station tunnel and adjacent underground structures can be seen in Figure 25. The composition of ground exposed at the tip of the steel pipe installing along the periphery of the crown area of the station tunnel is shown in the same figure.

The subsurface ground condition was composed of three primary features: fills, alluvium and weathered rock formation of gneiss from the surface. The alluvial layer persisted up to a depth of about eighteen metres, where the crown of the station tunnel was situated. The shallowest cover between the existing subway and newly constructed station tunnel was one metre only. The gravel size in the alluvium layer varied in the range between 0.05 metres and 0.2 metres. The thickness of weathered zone was relatively thin at less than one metre.

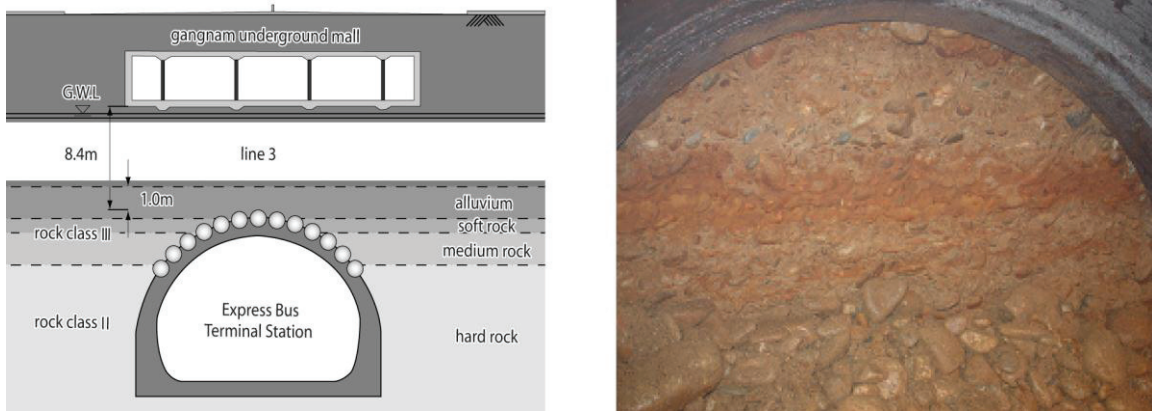


Figure 25 Cross-sectional features of the station tunnel and existing structures with ground conditions at the area of tunnel crown

Since newly the constructed station tunnel was located closely to the existing underground structures, maintaining the stability for those structures was the top priority. A total of thirteen (13) steel pipes, two (2.0) metres in diameter and one hundred and fifty nine (159) metres in length each were inserted along the periphery of the crown of tunnel. Support beams were then constructed at every five metres interval longitudinally. Once the cellular arch was completed by placing reinforcement and pouring of the concrete inside the all pipes, the sidewall galleries were excavated for the construction of supporting walls of the cellular arch, finally the central parts of the ground were removed after sidewalls were completed as the process shown in Figure 26.

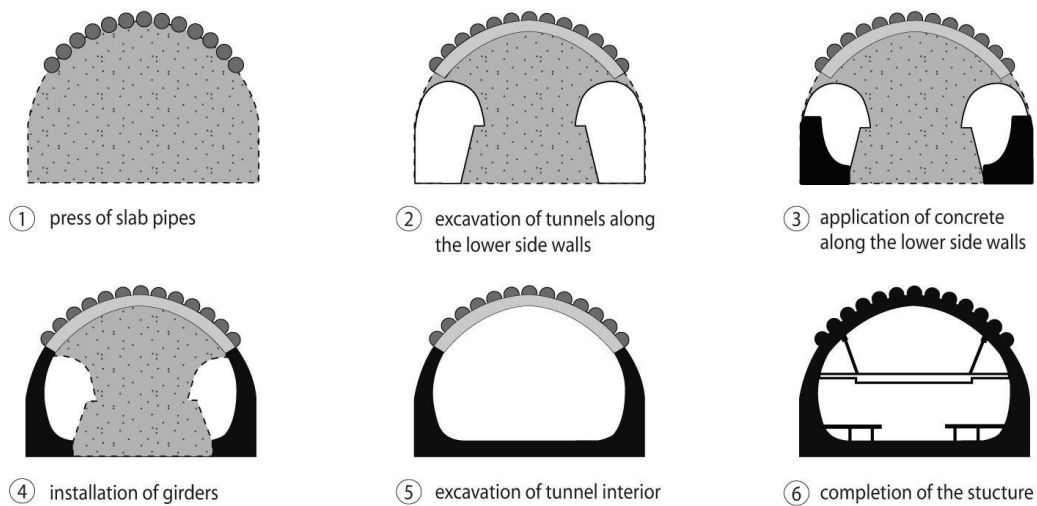


Figure 26 Construction process of the cellular arch method for station tunnel

5 USE OF UNDEGROUND SPACE IN THE FORESEEABLE FUTURE

5.1. Generals

Although the statistic figures quote the accumulated lengths of roads which are wider than four metres in width within the administrative boundaries of Seoul reaches eight thousand one hundred and forty two (8,142) kilometres (as of 2010), the present road network systems are not acceptable to cope with the gradual increase in number of vehicles. In addition, the necessity to widen existing roads or construct new roads is

increasing to ease surface traffic congestion. However, both tasks are very difficult to implement since the surface development of the City of Seoul has almost been completed at the moment.

Above all, the areas of the road are absolutely insufficient when considering the number of inhabitants and vehicles running on them. In order to alleviate these serious surface traffic congestion problems, which incur tremendous economic losses daily, new underground road network systems, such as the so-called U-Smartway, were proposed, and are now on the table for the discussion.

5.2 Outlines of new underground road network systems

Newly proposed underground infrastructure networks, totalling one hundred and forty nine (149) kilometres, are considered as a technically feasible solution which will ease the traffic congestion problems. Most of these networks are planned to be built below a depth of forty metres from the ground surface, firstly, to reduce construction costs and secondly, to mitigate complaints from the public.

Figure 28 below shows the six routes road of proposed network: three are running generally in a north-to-south direction, whilst the rest are running in an east-to-west direction. This network has thirty seven (37) entrance structures and thirty three (33) exit structures. The two inner circles formed by the crossing of routes SN1&2 and EW1&3, respectively are intended to connect sub-centres of the City of Seoul. Moreover, they will take on the role of major roundabouts to the traffic flow from the underground belt roads. It must also be pointed out that each crossing point is planned as an underground junction. Therefore, the suggested underground network can effectively reduce the traffic volume, particularly in the central part of the city, by taking vehicles on the surface and dispersing them rapidly towards the outskirts.

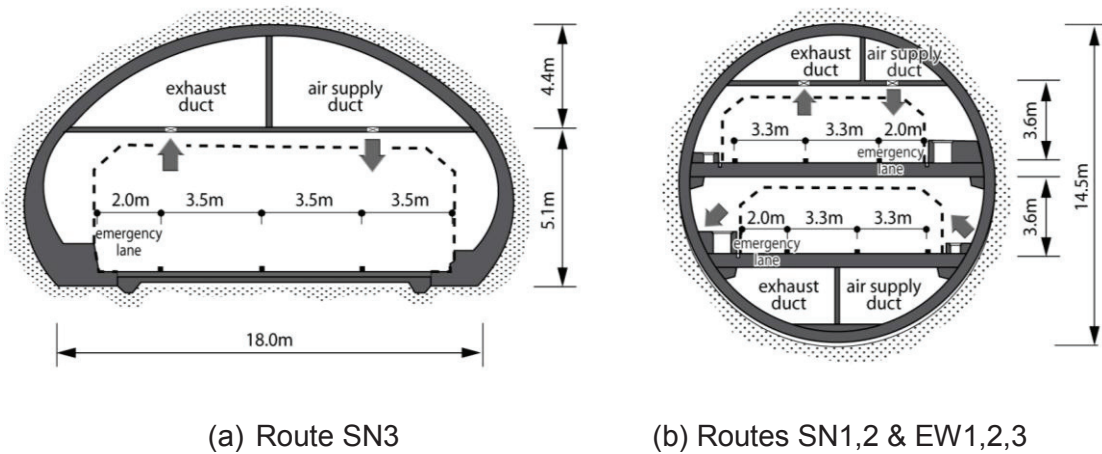


Figure 27 Cross-sectional configurations of U-Smartway tunnels

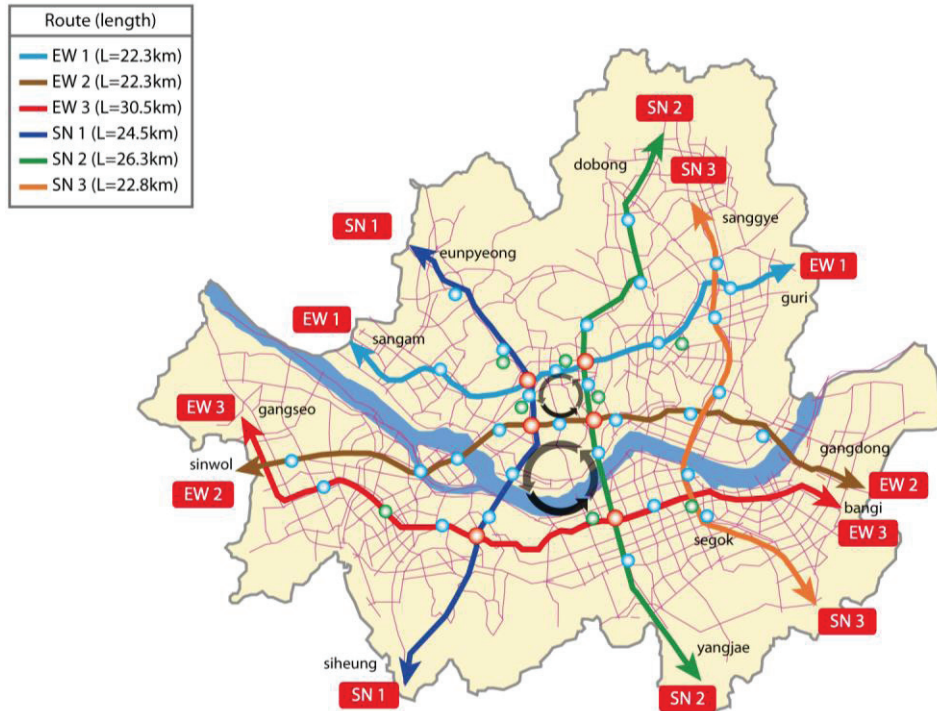


Figure 28 Proposed underground road tunnel networks in Seoul

The most easterly route (SN3) among the north-to-south routes is planned to carry all kinds of vehicles (Figure 27(a)). On the other hand, the remaining routes are planned as compact car only routes. Cross-sectional configurations of these road tunnels are a duplex type as shown in Figure 27(b). Roads were originally planned basically with two lanes going in each direction. However, the belt roads were designed to have three lanes for the smooth change of direction at each junction.

To enhance the egress and ingress of traffic system, all roads have emergency lanes of two (2.0) metre width at the right-hand side along the entire length of underground roads. The systems will be equipped with various emergency facilities such as fire detecting and extinguishing system as well as egress systems for various emergency scenarios etc. Transverse ventilation systems will be applied and all the polluted air inside will also be filtered prior to discharge into the atmosphere.

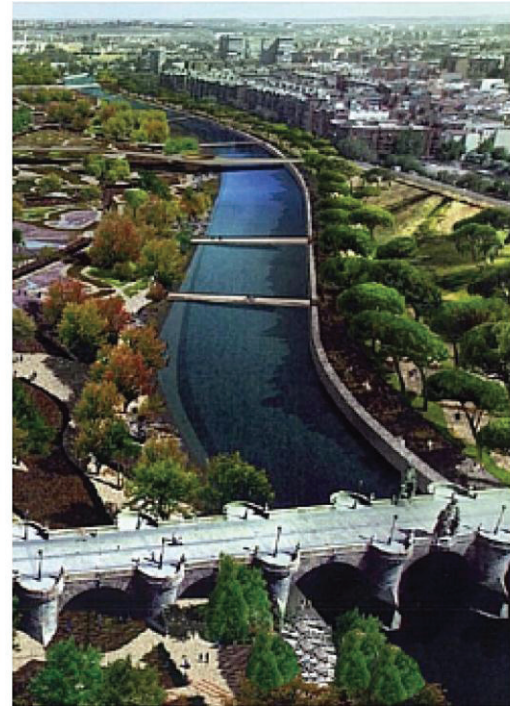
Underground road network systems are expected to reduce the surface traffic volume by about twenty percent, and consequently provide an increase in average speed of about eight kilometres an hour. Greenhouse gas is also expected to be reduced in significant amounts as a result.

5.3 Parks on the existing urban highways in service

During the rapid urbanisation and growth of Seoul, numerous roads and buildings were also constructed as high priorities, with little attention to the requirements of the inhabitants' urban life, both in terms of spatial and recreational area. Nowadays, people in Seoul are demanding more green spaces in their vicinities. In line with these trends, it is proposed that substantial lengths of urban highways, passing through the high-rise apartment complexes be covered over with concrete slabs and overlain again with grasses, flowers and trees. It is interesting to address also that one of the urban arteries running beside along the stream have been proposed to replace with a green space by relocating the road underground. Figure 29 shows the landscapes of the concerned region before and after the completion of such project.



(a) Present urban highway



(b) Landscape to be after relocation of urban highway underground

Figure 29 Landscape to be made on the existing urban highways in service

5 CONCLUSIONS

The City of Seoul is surrounded by several mountains and developed on the gneiss and granite formation providing a landscape that is hilly and beautiful. The Han River, wider than a thousand metres, flows westwards passing through the centre of city. Its tributaries, which are obviously producing plenty of alluvial deposits, are developed throughout the administrative boundaries. Alluviums are, consequently, spread over large extents adjacent to the river and streams. However, sound bed rock formations exist not far below the ground surface.

Seoul has grown fast and tremendously during the past four decades to become one of the most densely populated human settlements on earth. Simultaneously, Seoul embodies one of the most acute urban challenges, particularly serious surface traffic congestion. This drew attention to the utilisation of underground space to ease the public transportation system and to provide more green areas on the surface.

Up until now, large volumes of underground space have been created in Seoul and used for the construction of underground infrastructures, such as subways, roads, utilities and malls. Holistic pictures of the underground space use in Seoul are presented focusing mostly on the underground transportation infrastructures and malls. Utilization of underground space can make sustainable development possible in a megacity like Seoul. Development of underground space should be carried out systematically with thoughtful insights since it is a very important resource for the new future.

Currently, the City of Seoul is confronted with a necessity of underground space utilisation in deeper regions. The time is now right to update the comprehensive Master Plan of Underground Space Development for the City of Seoul for the future.

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