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# Urban Uses of Underground Space around the World

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## INTRODUCTION

Underground space has been used by humankind since the beginning of time. Caves were used by our ancestors to provide protection from inclement weather, from wild beasts, and from unfriendly humans. As our societies have evolved, it has become common to put things which we wish to shield from view - either for security or esthetic reasons - in the subsurface. However, it is a relatively new phenomenon to use the subsurface to enhance our urban areas and accommodate the need for usable space. Effective use of underground space provides an opportunity to balance society's needs for space, infrastructure and services against the equally pressing need for agricultural land, open space, habitat, and wilderness.

## WHY UNDERGROUND SPACE ?

The last decade has been a time of significant underground space development due to the confluence of three factors ; The evolution of underground construction technology ; the economic feasibility of underground development ; and the cultural acceptability of underground space use.

The following are several reasons why decision-makers and urban officials are exploring and utilizing underground space as their cities grow ;

1) The need to meet the requirements of a growing population in existing urban areas ;

2) The desire to preserve or improve the urban landscape ;

3) The desire to protect environmentally sensitive areas and resources ;

4) The desire to enhance the function and efficiency of an urban area ;

5) The desire to preserve undeveloped land for other uses such as open space or agriculture ;

6) The need to provide energy-efficient space ;

7) The need to meet specialized space requirements ;

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8) The need to protect historic or culturally significant areas.

## The need to provide development opportunities in existing urban areas.

Without exception, the older societies around the world reached the capacity of their cities to accommodate the space demands of a growing population many years ago. It is only in the more recently settled countries, such as the United States and Canada, where land is plentiful, that cities have continued to expand laterally to meet the demand for space. However, in many of the older cities in the United States and Canada, the limit of expansion has been reached, and decision-makers are seeking ways to meet new development needs within existing boundaries.

In countries with difficult topography, the habitable area has always been limited. Underground space allows the utilization of land which would be unsuitable for development at the surface. The Scandinavian countries, for instance, which have a mountainous terrain, have successfully placed urban facilities within mountains and hilly terrain near their urban areas, thus accommodating urban space requirements.

In meeting the needs of expanding urban populations, not only must habitation and work space be found, but also space to accommodate the infrastructure systems necessary to support growing populations, such as water and transportation systems, waste collection and removal schemes. Water and waste systems have traditionally been sited underground. However, the scale and complexity of these systems continues to increase with the growth of urban populations.

## The desire to preserve or improve the urban landscape.

In most large urban areas, the relief and beauty provided by open space and parks has often been overshadowed by the need to accommodate more development. However, by using underground space to accommodate some space demands, parks and open space can be preserved or returned to the urban landscape. This will become increasingly important as mankind seeks to balance the need to protect and enhance the natural environment with the need for more developed space.

Similarly, important historic and cultural resources can be protected by providing for expansion or development in the subsurface.

## The desire to enhance the function and efficiency of an urban area.

Initial construction or relocation of certain uses to an underground site can vastly improve the efficiency and function of an urban area. Transportation in general, whether train, auto or pedestrian, can benefit from the grade separation offered by an underground alignment. By removing the potential for conflict between transportation modes, each mode moves more quickly and efficiently toward its destination. The lack of conflict of transportation systems with pedestrian systems, can provide for freer movement at both surface and underground, enhancing the function of each.

In addition to reducing potential conflicts among uses, underground transportation align-ments, whether for machines or humans, can provide all-weather protection. This is especially important in northern climates where long, cold winters may otherwise inhibit citizens ability to travel freely in the urban area.

Some typical urban uses require too much valuable surface land, and should only be considered for underground sites. Parking ramps for automobiles are such a use. Surface car parks are inefficient and represent poor land use.

### The desire to preserve undeveloped land for open space and agricultural uses.

Effective use of underground space in urban areas can allow land at a city's edge to remain either undeveloped for open space or recreational use, or to be used for agricultural purposes. In either case, the relief and diversity provided by these uses is important to the success and function of the urban area, and in the case of agricultural land, may even affect the availability and cost of food products to the urban area.

A related issue is where to site large infrastructure facilities which are necessary to support the urban area, but which are usually located on the surface in outlying areas. A good example is sewage treatment plants, which typically are sited on large tracts of land at the edge of urban areas, Not only do they require land which could be used for other purposes, but the infrastructure necessary to transport effluent from the urban area to the treatment facility is vast and expensive. To the extent that facilities such as these can be sited underground, and closer to urban areas, they preserve open space and reduce the cost of infrastructure.

### The desire to provide energy-efficient development opportunities

Because it is shielded from the varying climatic influences which affect surface development, underground space of all types requires less energy to achieve and maintain a comfortable climate.

It is estimated that underground space uses from 20% to 40% of the energy required for comparable space on the surface.

In addition, to the extent that use of underground space encourages compact urban development, underground space use provides transportation energy savings by reducing the distances necessary to travel within the urban area.

### The need to meet special space requirements.

Because of its isolation from surface climatic influences, underground space offers a unique environment for those uses which require a special environment. For instance, underground space can be essentially dust and vibration free, creating an environment suitable for high tech manufacture and use.

Underground space is also suitable for facilities which require security, as access can be closely controlled. In many cases, such facilities may be sited without widespread knowledge, further enhancing their security.

## EXAMPLES OF URBAN UNDERGROUND SPACE USE

### Les Halles, Paris, France.

Les Halles is a four million square foot (367, 309 square meter) urban underground complex lacated in the heart of Paris, on the Right Bank of the Seine. Construction was completed in 1988.

Les Halles serves several functions ; it provides extensive commercial and retail space, serves as a community center and houses the largest transportation hub in Paris. The following uses are found in Les Halles ;

More than 240 shops
An Olympic-sized swimming pool and adjacent greenhouse
Music practice rooms
The city's film archives
The Cousteau Oceanographic Centre
The largest bookstore in Paris
A private radio station
A 640 seat auditorium for chamber music and quartets
A municipal gymnasium
21 theaters

Les Halles was the site of the original wholesale food market for the Paris region since the 12th century. In the 1960's the market was moved to a site near Orly field for hygienic and transportation reasons. City Planners were concerned that the Les Halles area, which had been a hub of activity, would become lifeless and blighted. The Paris Council embarker on a vigorous revitalization plan for the area.

At about the same time, the need for a major North-South, East-West intersection in the city for the various transportation systems became apparent. The Halles area, with its vast underground potential, became available at just the right moment to accommodate the construction of the largest transportation hub in Paris, with seven railway and transit lines served by five 350-foot-long platforms.

Original plans called for a vast underground complex of shops, pedestrian ways and transit facilities complemented by housing, hotels, and restaurants to be built on the surface.

A five-acre park is laid out before historic St. Eustache church. It is quite common to see people enjoying the park on the surface, while commercial and retail activity takes place in the bustling space below ground.

It is important to note that the level of activity required to maintain the vitality of the Les Halles area would not have been possible if limited to the surface. In addition to the desire to protect many existing buildings, such as St. Eustache church, surface construction in Old Paris is limited to a height of 27 meters. The Paris Council demonstrated significant foresight by siting this major complex underground.

### Osterleden, Stockholm, Sweden.

Osterleden is a proposed underground ring road which will circle the city of Stockholm. The underground alignment has been suggested for two reasons. First, the topography of the area surrounding Stockholm is hilly. Therefore, putting the road underground avoids dangerous, icy hills. Second, the underground alignment was chosen to remove the road from conflicts with other traffic, therefore allowing traffic on the Osterleden to move quickly, and to avoid compounding surface congestion.

A similar sheme, the LASER project, has been suggested for Paris, France, to relieve that city's notorious auto congestion.

### Les Louvre Addition, Paris, France

The new addition at Les Louvre, the pyramid-shaped entry gallery designed by I.M. Pei, serves several purposes. The original Les Louvre buildings are a series of castles constructed since the 12th century by French nobility. Taken together they form a large horseshoe-shaped complex, which prior to construction of the pyramid, was entered by a single door at one corner of the horseshoe. Visitors to the museum who wished to see an exhibit at the opposite end of the museum were required to walk the entire length, and then return to exit.

The pyramid was constructed at the center of the "horseshoe" and forms the major entry into the museum's several buildings. Easy access is provided from this central point to all the major galleries, saving visitors time and energy.

The pyramid also provides space for an expanded museum shop, restaurants and coffee shops, and meeting rooms. An underground access for tour buses is soon to be added, which will bring tourists directly from an underground bus entry into the museums. This will allow the tourists to move more quickly, and also minimizes congestion and conflicts between pedestrians and autos at the surface.

The new pyramid at Les Louvre has improved the efficiency and function of the museum, provided necessary new space for a proper museum shop, and space for restaurants and meeting rooms for the benefit of museum visitors.

The pyramid initially caused great controversy since the disign is not in the traditional Parisian architectural style. However, it has received general acceptance among Parisians, because even though it is of a different style, the design is classic and of a scale which is consistent with other Paris buildings and monuments.

### Underground Pedestrian Networks in Montreal and Toronto, Canada.

The cities of Montreal and Toronto each feature extensive underground pedestrian networks in the heart of their downtowns which have made the cities more pleasant and livable despite their location in an extreme nothern climate.

The network in Montreal extends for 1.4 kilometers through retail and commercial space, linking shops, transit, the trans-Canadian rail system, office buildings, hotels, and restaurants. It is said one can live an entire lifetime in Montreal without ever going outdoors.

The network in Toronto is similar to the underground network in Montreal, providing pedestrians with a safe, grade-separated, all-weather method to move about the city in even the worst weather.

In each city, an ancillary benefit has been the establishment of significant new retail activity at the underground level. Shops have appeared along the pedestrian corridors, creating a vital atmosphere at this level.

### The Smithsonian Underground Museum Complex, Washington, D.C., U.S.A.

Two underground museums were opened in September, 1987 by the Smithsonian Institution ; The Alfred Sackler Museum of Near Eastern Art, and the Museum of African Art. The new museums were constructed to allow collections which had been stored to be displayed for the benefit of the public.

The museums are located behind the original Smithsonian building, "The Castle", on the National Mall in the heart of Washington, D.C. The National Mall is a broad, tree-lined area which extends from the Capitol building to the Washington monument. The decision to build the new museums underground was made to avoid intrusion into the National Mall, and to avoid contributing to an already-dense urban atmosphere.

The only visible structures on the surface are the small entry pavilions above each museum. The remainder of the surface area is covered by the 4.5 acre Enid Haupt Park, a pupular place for rest and relaxation by museum visitors and city residents.

### Post Office Square, Boston, Massachusetts, U.S.A.

Post Office Square is a new park in the heart of Boston, Massachusetts. It covers 2 acres, an entire city block. It replaces a multi-level surface parking garage which was old, inefficient, and out-of-date.

The park at Post Office Square overlies a new underground parking garage which replaced the old one. Not only was the visual blight of the old garage removed, but the capacity of the new garage exceeds the capacity of the old one by 75% - from a capacity of 800 automobiles to a capacity of 1400 automobiles in the new garage. The new garage was built using new "top down" construction technology.

### Marienplatz Underground Complex, Munich, Germany.

The City of Munich, the capitol of the state of Bavaria, is located in southern Germany, near the German Alps mountain range. The surrounding alpine countryside is devoted primarily to agriculture.

The city of Munich features two Town Halls, the newest of which was constructed in the 17th century A.D. In front of this New Town Hall lies the historic square, the Marienplatz.

Several changes - utilizing underground space - were made in the 1970's in Munich to enhance the livability of the city, to improve transportation and to accommodate new space demands.

The first was to close the area surrounding the Marienplatz and some neighboring streets to auto traffic. The second was to provide an underground transit system through the heart of the city. The third was to move some uses from the surface to an underground level directly beneath the Marienplatz, but above the level of the subway system. Today, one finds uses such as a produce market, a furniture store, a variety of boutiques and shops such as a dry cleaner and florist, all at the underground level.

The new, expanded Marienplatz, in the meantime, provides a pleasant pedestrian area where persons can stroll at their leisure, or stop at one of the sidewalk cafes to watch the famous Glockenspidel in the tower of the New Town Hall. Effective use of underground space to house a new transportation system and previous surface shops and boutiques has improved the livability of the city of Munich at its vety center.

### Kansas City Underground, Kansas City, Missouri, U.S.A.

There are nearly 30million square feet of underground manufacturing and storage space in use in the Kansas City area. The underground is the fifth largest industrial site in the Kansas City area.

Underground space developed in Kansas City as a byproduct of mining limstone for construction aggregate. It was recognized that the space left by the mining activity was cool in the summer and warm in the winter. Kansas City is located at the center of the United States. This location made it a logical storage point in the transshipment of fresh produce from the agricultural region of the west to the markets in the east. It also made it a logical distribution point for many items.

Today, many major U.S. food producers such as Beatrice, Hunt, Pillsbury, etc., use major portions of the Kansas City underground for food storage.

In addition, the security of the site attracted the U.S. Postal Service to store their single largest store of postage stock-a very valuable commodity-in the Kansas City underground.

There are major high tech operations located in the Kanasa City underground, as a result of the stability of the subsurface location. And a maior executive office park is being developed in the Kansas City underground.

There are two rail lines which run through the Kansas City underground and semi-trailer trucks drive into the underground to load and unload their products.

A major entertainment complex is located directly above one of the largest underground developments, Hunt Midwest, and a golf course and housing development is planned for the surface overlying another underground complex.

### Underground Use in Scandinavia - Sweden, Norway and Finland

The Scandinavians have used underground space to meet their urban space needs for many years. A major initial consideration was to provide civil defense shelters near their cities for use in the event of war. These shelters were designed to accommodate a variety of uses in peacetime, including sports halls, workshops, libraries, garages and storerooms. Citizens were encouraged to use these facilities on a routine basis, and in the process became very familiar with their location and the entry and exit points. This would have been an important asset in the time of a conflict.

In more recent years, the Scandinavians have continued to put a variety of uses underground for two reasons: their topography is very hilly and rocky; they desire to preserve whatever surface space there is for other uses.

Some of the uses to be found underground in Scandinavia today are: sports halls, churches, museums, hospitals, concert halls, swimming pools, and tennis courts. The newest and most spectacular use of this type is the new Olympic Hockey Rink built for the 1994 Olympics in Norway. It is built beneath a small mountain in the center of the town of Gjovik. It boasts the largest clear span yet constructed in rock, 64 meters.

There are also major infrastructure facilities located underground such as district heating systems, sewage treatment plants and multi-use utility corridors.

## WEIGHING THE COSTS AND BENEFITS OF UNDERGROUND SPACE

Socio-economic analysis is the examination of the social and economic costs and benefits of a given project for all who are affected by it. The direct effects as well as the indirect or secondary effects are identified and measured. The resulting information is intended to aid in the decision-making process.

The analysis requires attaching quantifiable measures to as many aspects of a project as possible. It also involves the definition of "costs" and of "benefits". In addition to the traditional definition given to these words, a "cost" may be defined as a benefit foregone, and a "benefit" as a cost avoided.

There are many direct and indirect advantages to underground construction. Some of them can be easily measured and others cannot. It varies from project to project and between locations around the world.

The easy temptation is to measure just the capital cost when comparing surface and underground alternatives for a project. However, the more complete and accurate measure is to compare life cycle costs for each alternative over the expected lifetime of a project. Lift cycle costs include capital cost, operation and maintenance, energy usage, repairs, etc.

Another important factor to measure when considering a surface versus and underground project is to determine anticipated system performance for each alternative. This is especially important for transportation projects, where the exclusive right-of-way offered by a underground alignment may dramatically improve the performance of the system, thereby increasing usage and operating revenues.

In the report, "The costs and Benefits of Underground Transit Alignments", a working group of the International Tunnelling Association found that transit ridership, and therefore revenues, were considerably higher when transit was sited in an underground alignment due to the improved performance of the system. Transit in underground alignments moved without hesitation from station to station, providing a measure of reliability not possible with a surface alignment. This improved speed and reliability encouraged greater ridership, resulting in increased transit revenues.

A major benefit of underground space use-but difficult to quantify-is its positive environmental impact. Whether the issue is preservation of open space and agricultural land; creation of green space in urban environments; improved transit ridership and therefore reduced auto emissions and congestion; lack of disturbance of natural areas and ecosystems; the environmental benefits are real and becoming increasingly important to each of us. These environmental benefits cannot be ignored, and every effort must be made to measure them in quantifiable terms.

Until the economic value of a pound of Carbon Monoxide saved with increased use of transit can be measured, we must at least insist that unquantifiable benefits be recognized in any costbenefit analysis. We may not be certain of the scale of the benefit, but the contribution must be recognized.

## SUMMARY

As our global population grows each day, it is apparent that we must find new ways to provide space for habitation and the services necessary to support large urban areas. It is no longer advisable nor acceptable to continue to expand our cities on the surface, encroaching on valuable agricultural land and open space. We must also find ways to be more energy efficient in every aspect of our societies.

Effective use of underground space can provide the space necessary to accommodate larger populations and the services necessary for their support in existing urban areas. We can also find new ways to utilize underground facilities to improve urban efficiency and function.

Underground technology has improved dramatically in the last two decades and continues to evolve to meet a great variety of applications. The confluence of available technology, economic feasibility, and greater acceptance of underground solutions with recognition of the need to change the ways we build and use our urban areas and their surrounding environment indicates that we are witnessing only the beginning of appropriate and innovative use of underground space. Future generations will indeed "Think Deep."