

## ENVIRONMENTAL ISSUES & BENEFITS OF TUNNELS & UNDERGROUND SPACE

by  
**Harvey W. Parker**  
*President, International Tunnelling Association (ITA)*

### ABSTRACT

Tunnels, and underground space in general, are, and always have been, good for the environment. Their use reduces energy demand and there is a reduced demand on resources. Because of the inherent benefits, it is expected that a substantial portion of future demand for tunnels, and underground space in general, will be for environmental and sustainable development reasons. Accordingly, the underground is good for the environment and the environment is good for the underground industry. The underground also provides the public with increased environmental safety and personal safety. This paper addresses the environmental and some safety aspects of the underground.

### INTRODUCTION

Underground Works and Underground Space, which are referred to in this paper as “the Underground” are ideal means for improving the environment and supporting the principles of Sustainable Development. Sustainable Development is defined by the United Nations and most other organizations as:

*Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*

Sustainable development and environmental awareness will be part of our way of life for a long time to come. Everyone seems to be involved in the environmental and sustainable development movement. Most disciplines and industries have embraced sustainable development. Engineers have both an opportunity and a challenge to work toward a sustainable environment. Fortunately, the attitudes, concepts, and methodologies used to embrace the environment are the same as those necessary for increased awareness to risk management, quality and safety all of which enhance our industry and its public image.

### WORLD POPULATION AND THE UNDERGROUND INDUSTRY

In October, 1999, the world population passed the 6 Billion mark and the prediction is that by 2030 the world population will be 8.1 Billion. This in itself will generate an enormous demand for infrastructure. However, an even more alarming fact is that, in the future, most of the world’s population will live not in rural areas but in urban cities. By October, 1999, about ½ of the 6 Billion people lived in urban areas and it is predicted that, in 2030, about 60% or 4.9 Billion people will live in cities.

The United Nations and other world bodies are giving special attention to those cities where more than 10 Million people live, the so-called Megacities. In 2001, there were only 19 Megacities but by 2015 it is estimated that there will be about 60 megacities and most of these cities will be in the Developing World.

Infrastructure must be constructed not only for these cities to be sustainable, but just for them to survive. Fortunately for the underground industry, if the environment and sustainable development are considered, the underground will be the preferred method of choice for much of this essential infrastructure. However, it is essential that those of us in the industry be pro-active to inform the city officials and planners of the importance of the underground to sustainable development and to quality of life at the very earliest stages of a city's growth.

### **ENVIRONMENTAL BENEFITS OF THE UNDERGROUND**

The underground already plays a dominant role in our standard of living and in the preservation of the environment but the advantages of the underground are taken for granted by almost everyone. At least within developed urban cities, every time someone turns on a faucet or flushes a toilet, an "environmental tunnel" is put into use. Yet the average person almost never makes this connection; even members of our industry take clean water in and wastewater out for granted because our tunnels have been doing such a good job for such a long time with so little maintenance that they are invisible to sight and to mind. As urban centers develop, the underground will play an increasing role in improving the quality of life. Some of the numerous environmental and societal benefits that are inherently associated with the Underground are given in Table 1 (Parker, 2004).

Table 1

#### Benefits of the Underground for Society & Sustainable Development

- Tunnels play a vital role by conveying clean water to urban areas and by conveying waste water out. Most major urban areas depend on tunnels for these services, which function with a minimum of maintenance
  - The usable space off a parcel of land can, in some cases, be almost doubled by adding transport or other communication lines, floor space or bulk storage below the ground surface.
  - Life-cycle cost and benefit methodologies are expected to reveal the underground alternatives to be much more competitive with surface facilities.
  - Underground space generally has a very long life; some have been in continuous use contributing to sustainable development for centuries significantly improving life cycle costs
  - Long life & little maintenance not only reduce life-cycle costs but also reduce demand for renewable & non renewable resources
  - It has been demonstrated by several recent events that tunnels behave very well in earthquakes. If urban planners want an important lifeline to survive earthquakes, they should go out of their way to use tunnels.
  - The underground is the only safe location for storage of nuclear waste and other hazardous or undesirable materials.
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- In transit systems, tunnels provide safe, environmentally sound, very fast, and unobtrusive transportation for people in all walks of life in both developed and developing countries.
- Underground space is being used increasingly for industrial, office and even residential facilities.
- Underground space for bulk storage of food, liquids, and gas has gained increasing acceptance in various areas of the world.
- Congestion in urban areas has been dramatically reduced by the use of the underground.
- Underground space inherently conserves energy. Because they are removed from climatic influences, underground facilities provide significant energy savings and conservation of energy
- Underground space is inherently energy efficient. Severe fluctuations of temperature are non-existent allowing more efficient control of temperature and energy.
- Underground space requires little maintenance
- Use of the underground permits preservation of open space for habitat, environmental, and scenic values
- The Underground provides strong protection from natural hazards

### **SUSTAINABLE CONSTRUCTION IS BETTER & SAFER CONSTRUCTION**

Many papers and articles have been written about the fact that embracing sustainable development makes good business sense in terms of the bottom line. This fact that attention to sustainability generally also results in improved business and more profits should be recognized by our industry. Done properly, your society and country will benefit by improved environmental quality and your company or agency will reap financial benefits and other benefits as well.

Embracing the concepts of Sustainable Development requires a change in attitude from just accepting that the environment is important or important enough to warrant consideration. Instead, it requires an agreement to look at planning, design, construction, and operation in an entirely different light; that of actively looking for ways to conduct business that supports the principles of sustainable development. It is this new attitude toward the construction process that makes projects safer and more profitable and the final product better and safer for society.

Cities, especially in developing countries, tend to grow haphazardly. Accordingly infrastructure can not be constructed at the optimum time where construction can be efficient. To the contrary, infrastructure must be thrust onto an existing urban fabric. Underground construction provides ways that these essential services can be constructed beneath existing facilities with a minimum of disruption to the surface and to the public. Clearly this is an advantage for the tunnel industry, and especially for microtunnelling methods, all of which will flourish in the future.

### **RELATIONSHIPS BETWEEN COST, DEMAND, ENVIRONMENT & SAFETY**

The author believes that the bulk of future tunnel demand can be attributed in some way or another to a desire by society and decision makers to improve the

environment. Our industry needs to fully embrace the environment and consciously use the strong benefits of tunnels to be the driving force in selecting the below-ground alternative. There will always be competing surface options which, initially, may appear to a decision maker to be less expensive.

Unfortunately, our industry has not yet developed a convincing quantitative database illustrating just how important the Underground is to the environment and to the true long term life cycle cost of infrastructure. Mere suggestions that tunnels contribute to improve sustainable development will not be enough. It is essential that our industry develop Life Cycle Cost and Benefit Methodology to take advantage of the fact that tunnels last longer than surface structures and to take an equivalent financial advantage for the numerous environmental benefits that they contribute to a project and to society. With Life Cycle Cost and Benefit methodology, the author believes that the underground will be shown to have a lower relative cost that is competitive with surface facilities, and certainly the Underground will be in the “competitive range.”

This is especially true where there is an urgent demand for infrastructure and where the demands on infrastructure are so massive that the least expensive initial capital cost will likely be the deciding factor on whether to use the underground or not. Of course these considerations must be adapted to everyone’s local financial and cultural environment.

Our industry must begin to identify the specific quantitative sustainable development and environmental benefits of the Underground and collect and publish case histories that confirm these benefits giving specific quantitative environmental benefits. This would be in terms of how much less 1) pollution, 2) noise, 3) energy demand, and 4) space needs, etc. can be expected if the underground alternative is chosen. Life cycle cost & benefit methodology should also take in to account a credit for the use of the surface (even if it is a park) and for increases in property values because the infrastructure has no adverse visual impact. Particularly for water and wastewater, our industry needs to quantify just how much better the standard of living is and how much better health is improved by the use of the Underground. We need to aggressively market the Underground as being the alternative that should be selected because of its superiority for sustainable development and the environment.

With respect to safety, two major factors will continue to threaten safety during construction: 1) the high construction cost may encourage “cutting corners” and taking chances to reduce costs and 2) the urgency to bring infrastructure into service faster may also result in less attention to safety. Neither of these is acceptable. Proper implementation of Risk Management methods throughout design and construction are essential.

## **EXAMPLE UNDERGROUND ENVIRONMENTAL SUCCESSES**

The benefits of the Underground are listed in Table 1 but, for traditional infrastructure, they mostly involve the following:

- Lower energy used
  - Flatter grades

- Shorter distances
- Often less energy demand during operation
- Reduced noise
- Reduced air pollution
- Multiple use of land parcels
- Longer Life
- Lower maintenance
- Reduced long term demand on renewable & non-renewable resources

A few selected examples will be given in the paragraphs below. These are merely examples because the worldwide opportunities for greater use of the Underground for Environmental and Sustainable Development and for Life Cycle Cost and Benefit reasons are endless.

**Transportation** The environmental and societal benefits of transportation tunnels are widely known and accepted. Overcoming obstacles such as topography or built up areas with less visual and aesthetic impacts are the major reasons for locating transportation underground. This provides more available space for other purposes and better utilization of space. The indirect advantages include reduced noise and pollution as well as significant time savings and much reduced congestion both of which translate directly to reduced energy usage.

There will be a huge demand for underground transportation projects especially if the criteria properly include life-cycle costing methods which take into account equivalent cost savings that account for the longer life of tunnels and for the financial advantages tunnels provide for the environment and sustainable development.

**Water & Wastewater** Water and wastewater is where our industry shines. Many major cities in the world have a major tunnel supplying water to its inhabitants and even more urban centers manage wastewater by a network of tunnels. The rapid development of the megacities will need abundant new tunnels to meet this demand because tunnels are the best infrastructure for this purpose<sup>11</sup>. As cities develop and mature, they will need improved and expanded wastewater infrastructure. Older cities will need projects to expand and/or rehabilitate the existing water/wastewater tunnels. Since there is a need for tunnels of all sizes and capacity this future demand will be good not only for the traditional large tunnel industry but also for the microtunnel industry.

**Utility Services and Utilidors** The utilities segment of our industry makes the most extensive use of the Underground worldwide and probably one of the strongest in support of sustainable development. The expansion and replacement of utilities is a multibillion dollar annual market worldwide<sup>17</sup>. This demand will also challenge the microtunnelling and directional drilling industries. Placement of several different kinds of utilities in a common underground conduit, sometimes called a utilidor, is a goal of many city engineers but there are many legal and other constraints that prevent more common usage of utilidors<sup>17,3</sup>.

**Bulk Storage** The Underground has been used for storage of food for centuries. There are many types of underground bulk storage including wine, frozen food products, grain, materials, fuels, equipment etc. A compilation of various uses of the

underground for storage of products is given by <sup>2,11</sup> also describes facilities for water storage and for storage of flood waters. Bulk storage of liquids, food, materials and equipment is an ideal situation where the underground provides obvious enormous benefits to the environment and to sustainable development while at the same time providing a large potential market for the underground industry. TA<sup>8-9</sup> has made two proposals to the UN for the reduction of poverty in rural areas that involve food storage. Examples of bulk storage underground are also described well by<sup>17</sup>.

**Energy Production, Storage, and Sharing** In addition to bulk storage, there are a variety of special uses of the Underground that support sustainable development and conservation of energy. There are numerous uses of the underground in hydroelectric projects which are still an essential tool in development. These include power tunnels and underground power caverns. Hydroelectric and water transfer tunnels for hydroelectric and irrigation schemes are excellent examples of a good and environmentally sensitive ways that the underground improves the environment and contribute to sustainable development. Various energy-saving and energy sharing underground schemes are described well by <sup>17</sup>.

**Waste Disposal** The Underground is the safest and most likely place to dispose of many hazardous wastes, especially nuclear waste. These projects are huge underground projects that address environmental and sustainable development issues directly.

**Living and Commercial Spaces** Underground construction for living and commercial space is not new and, in fact, enjoys an ancient legacy. They range from individual residences and small facilities to large complex underground living, office and industrial spaces. These facilities are well described by <sup>1,13, 7, 17</sup>.

**Preservation of Archeological and World/National Heritage Sites** There are many archeological and World and National Heritage sites that may need to be protected from modern day development and tourism. Examples include the Louvre extension as well as the Stonehenge Tunnel which provides a by-pass for the archeological site, and many others <sup>5</sup>.

## **ROLE OF ITA IN THE ENVIRONMENT AND SUSTAINABLE DEVELOPMENT**

ITA and its journal, Tunnelling and Underground Space Technology (TUST) have been active in the environmental and sustainable development fields for a long period of time. Over the decades, there have been numerous articles in TUST addressing environmental issues and sustainable development. They are far too numerous to list but selected ones include: <sup>4, 12, 15, 16, 14, 5, 13, 6</sup>.

ITA has actively promoted the advantages of the Underground to sustainable development and the environment to the United Nations for over a decade. ITA is recognized by the United Nations as a very active Non-Governmental Organization (NGO) in Consultive Status II.

In 2003 & 2004, in response to a request for suggestions on how to reduce poverty in the developing world, ITA prepared proposal to the United Nations which recommended use of underground shelter and food storage <sup>13</sup>. Each of these proposals

made it clear that the sophistication of earth-sheltered structures and underground space in general, can range from simple habitats to highly sophisticated high-tech complexes or communities depending on the needs and resources of the users.

## **THE FUTURE: SUSTAINABILITY, QUALITY, RISK MANAGEMENT, AND SAFETY**

It is possible that if all the infrastructure projects that need to be constructed in these new megacities were undertaken, that the demand for tunnels may exceed our industry's current capacity to design and build them. An even greater challenge is to accomplish this construction while improving sustainability and maintaining quality and safety. ITA Working on Quality (Working Group 16) has recently published a report which emphasizes the absolute necessity of controlling and maintaining quality<sup>8</sup>.

There are many ways to address quality, one of which is the concept of Risk Management. ITA is strongly promoting risk management as part of our overall program to assure quality. ITA Working Group on Research (Working Group 2) recently published a report in TUST<sup>9</sup> that addresses the complex and very important task of identifying risks in advance and adjusting designs and construction methods to reduce risks to a minimum. There are initiatives within our industry to increase our industry's awareness and use of Risk Management to reduce risk and, thus, improve quality<sup>16</sup>.

Nothing is as important as safety. Too often there is a tendency to slightly relax safety precautions when programs are rushed to meet a completion deadline. ITA has emphasized safety from the very beginning of the association. ITA re-published an updated booklet called "Safe Working in Tunnel" which is ideal for toolbox discussions of safety as well as safety presentations in general (ITA, 2005). The booklet is available from your national ITA Organization in your home country and/or can be downloaded free from the ITA website. The booklet is mostly illustrations of good safety practices as well as bad safety practices to be avoided. It is ITA's desire that each nation translate this safety booklet into their native language.

## **CHALLENGE TO OUR UNDERGROUND INDUSTRY**

There are costs and secondary effects for every move toward a cleaner environment and sustainable development. Those of us in the underground industry must understand that this is not all bad. Some costs are really "Investments" and often the secondary effects are beneficial. It is the job of the leaders of our industry to be proactive at the earliest stage of any project, even when it is only an "idea," to keep a positive image of the underground option in the forefront of planners mind. To do so, we must develop, for the use of decision makers, a credible Life Cycle Cost and Benefit Methodology to take advantage of the benefits of the usual longer life of tunnels and the financial benefits over the years of the savings and improvement to the environment. This is even more challenging when projects must be designed and built quickly to satisfy overwhelming urgent demand to put infrastructure into service.

As the growth of cities, particularly the megacities, continues, they will all need abundant infrastructure and the demand for the Underground will be enormous. In

fact, even if a fraction of the needed infrastructure is funded, the capacity of our industry will be challenged. We may not be able to build the required infrastructure fast enough. There simply may not be enough planners, designers, and contractors to do the work.

We can not afford to wait for decision makers to become aware of the environmental and sustainable development benefits of the Underground. Instead we must be proactive and let the world know that:

***The Underground is Good for the Environment***

***Sustainability is Not Possible without Infrastructure and that, often, the best form of sustainable infrastructure involves the underground, and***

***Safety and quality are essential in order to improve the image of the Underground and to provide the abundant infrastructure required for development.***

**REFERENCES**

- 1- Bennett, David J. (2004) “*Beyond Sustainability: The Case for Environmental Architecture,*” < <http://djbarchitects.home.att.net/sustainablebase.htm> >, 16 pp
- 2- Broch, Einer (1993), *Norwegian Underground Storage*, edited by Einer Broch, Publication No. 9, June 1993, Norwegian Soil and Rock Engineering Association, 108 pp
- 3- Cano-Hurtado, J. J. and Canto-Perello, J (1999), Sustainable Development of Urban Underground Space for Utilities, *Tunnelling and Underground Space Technology*, Vol. 14 No. 3, pp 335-340
- 4- Celik, Aliye P. (1996), “Challenge of Sustaining our Habitat in the Twenty-First Century,” *Tunnelling and Underground Space Technology*, Vol. 11, No. 4, October, 1996, p 377-379
- 5- Craig, R. N. (2004), “Environmental and Sustainable Development Reasons for Going Underground,” *Tunnelling and Underground Space Technology*, Special Issue, Vol. 19, No. 4-5
- 6- Goddard, J.P. (2004) “Urban Underground Space and Benefits of Going Underground,” *Tunnelling and Underground Space Technology*, Special Issue, Vol. 19, No. 4-5
- 7- Hall, Loretta (2004), *Underground Buildings: More than Meets the Eye*, Quill Driver Books, World Dancer Press, inc., Sanger, California, 215 pp
- 8- ITA (2004a) Quality in Tunnelling: ITA-AITES Working Group 16 Final Report, *Tunnelling and Underground Space Technology*, Vol. 19, No. 3, pp 239-272

- 9- ITA (2004b) "Guidelines for Tunnelling Risk Management: International Tunnelling Association Working Group 2," in *Tunnelling and Underground Space Technology*, Vol. 19, No. 3, pp 217-237.
  - 10- ITIG (2006), Code of Practice for Risk Management of Tunnel Works, International Tunnel Insurance Group
  - 11- Nordmark, A. (2002) Overview on survey of water installations underground: underground water-conveyance and storage facilities, Report of ITA Working Group 4, Subsurface Planning, in *Tunnelling and Underground Space Technology*, Vol. 17, No. 2, pp 163-178.
  - 12- Parker, Harvey (1996), Tunnelling, Urbanization and Sustainable Development: The Infrastructure Connection, Editorial in *Tunnelling and Underground Space Technology*, Vol. 11, No. 2
  - 13- Parker, Harvey (2004), "Underground Space: Good for Sustainable Development, and Vice Versa," *Tunnelling and Underground Space Technology*, Special Issue, Vol. 19, No. 4-5
  - 14- Ray, Kalyan (1998), Tunnels and infrastructure for metropolises: the Habitat Agenda Perspective, *Tunnelling and Underground Space Technology*, Vol. 13, No. 3, pp 313-315
  - 15- Roberts, Don V. (1996), Sustainable Development and the Use of Underground Space, *Tunnelling and Underground Space Technology*, Vol. 11, No. 4, October, 1996, p 383-390
  - 16- Sellberg, Bjorn (1996) Environmental Benefits: A Key to Increased Underground Space Use in Urban Planning, Editorial in *Tunnelling and Underground Space Technology*, Vol. 11, No. 4, October, 1996, p 369
  - 17- Sterling, Ray and Carmody, John (1993), *Underground Space Design: A Guide to Subsurface Utilization and Design for People in Underground Spaces*, VanNostrand Reinhold, New York, 328 pp
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