

US Perspective: Challenges for Constructing Underground Facilities in Urban Areas

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ABSTRACT: A number of major underground projects are currently underway in the United States of America (US) and more are planned for a construction start within the next five years. This paper provides a brief overview of some of the more significant challenges that the US civil underground industry is currently facing as cities make increasing use of underground space to address issues of urban infrastructure renewal and development.

INTRODUCTION

In times past, the US urban planner often looked no further than a conventional surface solution to provide the space needed to develop the inner city. “The only way is up” was a commonly used phrase that summed-up many planners’ development philosophy. Elevated transit was common in large cities such as Chicago and New York, when underground construction was technically difficult.

Now, with the city-scape becoming ever-more congested and aesthetic and other environmental concerns growing, street level or aerial solutions, such as the one shown in Figure 1, are no longer the

now facing US cities. This paper describes a variety of challenges facing the underground construction industry in the US, including: site restrictions, funding, construction risk and contracting methods, community relations, and the shortage of graduate engineers. The topics are to be expanded for discussion during the Think Deep Conference Presentation, 2008.

Of course, a good deal of US urban development continues to rely heavily upon the use of multistory buildings, skyscrapers and cut-and-cover structures, but the deeper, tunneled option for transit has now become mainstream, and is clearly visible on every city planner’s “radar screen.” Surface constraints and property values have also made underground parking, office space, and other uses such as museum and concert halls financially feasible.

Particularly in the more densely developed and older US cities, infrastructure projects in particular are more and more moving away from the use of the conventional at-grade and elevated structures that have commonly acted to interrupt and complicate traffic patterns in the congested downtowns. Similarly, the cut-and-cover option, which provides for operational separation from street-level traffic, can be highly problematic to construct, and cause major disruption to road and foot traffic. Figure 2 illustrates the level of construction disruption that typically accompanies the cut-and-cover construction process.

Communities that are directly impacted by infrastructure construction place increasing value on underground options. These communities are more likely to aggressively support underground option selection to better preserve and/or recreate open space and minimize the disruption and inconvenience associated with the construction process itself – not to mention permanent noise and visual impacts of at-



Figure 1, Elevated transit in New York constructed in early 20th century

automatic choice for grade-separated transit. City, state and federal decision makers are now routinely and seriously asking if use of underground areas can provide a more robust and sustainable long-term solution to many of the urban development problems

grade or elevated transportation, and further loss of surface area for development.

Of course residents' preference is not the only factor used by the owner-sponsor in planning for and accommodating city growth. This paper discusses some of the other factors that are currently at work –at cross purposes- to both slow and accelerate the use of underground space in the US marketplace. It also describes some recent improvements in practices by referencing some case histories, on-going research initiatives, and projects some possible future trends. The list is by no means comprehensive, but it is one that is intended to give an overview and insight into the state of the US underground civil construction industry at the beginning of the 21st Century.

1 FINDING SPACE DEEP UNDERGROUND

Engineers in larger US cities are increasingly turning to the use of deep space. Deeper sites are being considered because foundation works, pipes, duct and cable already occupy the shallow subsurface. Trenched, micro-tunneled and tunneled networks commonly lace the city's foundation level and render further large scale excavation at shallow depth highly problematic. These old generations of infrastructure frequently pose formidable obstacles to major new tunnel construction. To avoid the challenges of negotiating these shallow obstructions, proponents of new underground projects are literally being challenged to "think deeper."



Figure 2, Cut and cover construction, Los Angeles, CA

In the US, as elsewhere designers are now studying the geology to deeper depth to find preferred host ground masses for new generations of underground infrastructure and facilities. Looking to deeper alignments to find "virgin ground" for these new structures not only provides planners and designers with a way to avoid interference with existing infrastructure, but can also open-up a wider range of cost-effective construction options to mitigate against

the perennial challenges of the underground; geology, hydrology, topography, right-of-way, and so forth.

Use of deeper underground space has seen significant development in several US cities in the latter part of the 20th century and this trend is likely to continue. Very large infrastructure projects have already been constructed at depth. Projects such as the Tunnels and Reservoir Project (TARP) of greater Chicago were developed in the 80's and 90's to provide a huge amount of additional stormwater retention capacity. The baseline phase of this project was recently completed with over 150 km of deep, large tunnels now in operation. These tunnels were bored in rock at depths in excess of 100m, and at diameters of up to 10m.

There are still however many instances – particularly for metro projects – where subway stations sites must be located where population and work centers demand. It is here that construction solutions for difficult geology must be designed – not avoided. This is also the case for "undergrounding" of existing transportation corridors such as US freeway projects built at grade (or elevated through urban areas) as part of the country's Interstate Highway system in the 1950s and 60s. Some of these are now seen unfavorably, and cities such as Boston, San Francisco and potentially Seattle have made the choice to remove some of these aerial structures in favor of underground roadways or other land uses.

Similar scopes for other infrastructure projects (freshwater, stormwater, mass transit) are now in place or under construction in the service of urban populations including those of Atlanta, Boston, Milwaukee, New York, Los Angeles, Portland, Seattle, Washington DC, and other cities.

2 JUSTIFYING THE CAPITAL COST

The capital cost differential between mined, cut and cover, and aerial solutions may have diminished somewhat over the last few decades with the gradual improvement in underground construction technology. However, recent budget estimates, comparing aerial and tunneled options, generally still indicate that a construction premium will be paid if the tunneled option is adopted.

Unfortunately for underground proponents, the focus on capital cost often governs in the owner-sponsor's decision-making process. Potential operating and maintenance savings, and the indirect benefits of the tunneled solution related to added long-term value to neighboring businesses, land-users, residents, the environment, and operational advantages may be under-estimated within, or excluded from, the decision-making framework.

Within the context of many capital programs there is still no accepted methodology for accounting for these "soft" cost factors in the decision making process. The subjective value of long-term savings or benefits is discounted relative to the more objectively calculable near-term costs of construction. In the US it appears that construction "hard dollars" continue to

3 ACCOUNTING FOR UNDERGROUND RISK

Underground construction generally carries a perceived greater level of risk (uncertainty) than its elevated, at-grade or cut-and-cover counterpart). In the case of underground construction, ground doesn't just serve as a part of the foundation and/or sidewall structures but it is the structure. In assembling a project team for an underground program it is important to combine structural engineering skills with the expertise required to reliably identify and mitigate the particular challenges of underground construction. As noted by Kuesel (Civil Engineering, March '89) "It was mind-boggling to a structural engineer to recognize that ground properties were not fixed in a handbook (like concrete and steel) but varied according to location and time." As underlined by the recent risk management texts generated by British Tunnelling Society, International Tunnelling Association and others it is of paramount importance to include those that know "what can go wrong" in the planning process.

In most cases underground risks can be effectively managed if they have been identified, characterized and mitigated before construction starts. Unfortunately, this has not always been the case. A survey of construction news headlines will serve as a reminder to the urban planner that underground construction programs can go very badly wrong! In hindsight engineering estimates of in situ conditions, construction performance and cost often prove to have been largely optimistic. In the US, as elsewhere, it is not uncommon to read of projects where construction costs and durations have effectively doubled (or more), with protracted disputes and litigation often ensuing. Thus the reported cost overruns on a single project may cause years of debate and delay for the next.

As a result of some hard-learned lessons, owner-sponsors and managers of US underground projects are moving towards the use of more formal risk management strategies. Such strategies allow the owner-sponsors of underground work to develop a better appreciation of their project's risk exposure, expressed in the universal language of dollars and days. Armed with such tools, management is now better able to more rationally evaluate and either act to mitigate problem events before they occur on site or increase construction contingency.

4 REDUCING COST BY SHARING SPACE

Although the point is made here that a fuller accounting of the indirect factors of the underground site may lead to its increased adoption, these factors alone may not be adequate for a decision "tipping point" to be reached. Although the underground structures may have some significant long-term cost advantages over cut and cover solutions, it is possible that in some instances operational, maintenance and decommissioning costs may be significantly higher.

However, there are other practical ways of making the underground solution cost-competitive for infrastructure development. One option for reducing

cost is being investigated by a consortium of US and Finnish researchers. This initiative is aimed at improving the economy of the underground solution by combining multiple utility networks within a single tunnel corridor or "Utilidor", as shown in Figure 4.

The "Smart Space" initiative is a collaborative venture between the Earth Science Division of Lawrence Berkeley National Laboratory, University of California and the Technical Research Centre of Finland (VTT). The researchers are developing monitoring systems, and models that can better support a multi-user programme for providing joint access, occupancy, and maintenance system aimed at improving operational independence and reducing life-cycle costs for the individual utility entities. (www.vtt.fi/proj/smartspace/smartspace_brochure.pdf)

5 PARTNERING WITH THE COMMUNITY



Figure 4, Tunnels utility corridors "utilidor"

Although one could conclude from much of the above discussion that residents living in proximity to a proposed underground project would view it favorably, this is not always the case. Indeed, staunch opposition can be encountered especially in instances where the underground project can promise little or no direct, long-term benefit to the local community. In evaluating an Illinois site for an underground accelerator (Superconducting Super Collider, SSC) in the late 1980's a review committee noted that strong landowner opposition was encountered.

The Illinois site was ultimately rejected in favor of a site in Texas. An Illinois site is now being considered as potential host site for a new underground accelerator, the International Linear Collider (ILC). In light of the past community opposition to siting the SSC in Illinois, the US High Energy Physics Community has begun working with the surrounding community to establish a forum for discussion and resolution of concerns. As part of this early outreach effort, Fermilab, a high energy physics laboratory sited in Northern Illinois, has formed a Citizen Task Force to provide a mechanism for the impacted

community to provide input to the pre-project planning process.

The Task Force provides input to the Fermilab technical design team on a range of design issues, including the siting of the buildings, the alignment of the underground structures and the mitigation of construction impacts. The Task Force and Fermilab are also working to identify the economic and educational benefits of the project and its ability to bring new opportunities to local communities and businesses. (www.fermilabcommunity.org/pdfs/ILCInput.pdf)

The Task Force represents a long term commitment from the surrounding communities and Fermilab to collaboration and communication, allowing for the identification and alignment of purposes and the targeting of mutually beneficial community initiatives. In its membership, the ILC Task Force includes representatives from bordering neighborhoods, business, schools, and environmental, civic, faith-based and youth organizations. Winning and maintaining public support is of paramount importance to any planner of underground facilities.

There are a good number of projects that are more readily supported by the communities than the one described above. If the benefits of an underground solution are self-explanatory it is much easier to convince the neighbor communities that the underground option is the “way to go.” A case in point is a subway system. Although likely to cause some “community angst” during construction, once commissioned, subway systems such as WMATA, Figure 5, rapidly become an integral part of city life with the subway a clear asset for any neighborhood.



Figure 5, WMATA Station

Unfortunately the success of these projects in operation often receives far less publicity than the problems that may have marked its construction. One idea is to hold festivals celebrating underground structures to remind citizens of how effectively their use serves the community and contributes to its quality of life.

6 STREAMLINING CONTRACT PRACTICES

Over the last forty years the US industry has worked diligently to tailor contract practices to address the particular vagaries of underground construction. A number of stakeholders have contributed to the development of these practices including not just the owner and builder, but also the designers, construction managers, insurers, equipment manufacturers and material suppliers. All these players have a significant financial interest and a professional commitment to the success of the underground project.

The US tunneling industry has recently initiated an update of the "Better Contracting Practices for Underground Construction" guidelines to allow for more recent contracting experiences to be reported and used to guide future contract practices. The document is being authored by a broad cross-section of the industry, and covers Planning, Community Relations, Site Conditions, Risk Management, Design Development, Estimating, Scheduling, Changes, Disputes Resolution and Insurance.

The cost performance of the underground construction industry has steadily improved over the past two decades. Construction methods and means continue to evolve with the civil industry adopting faster and more reliable construction techniques – such as use of pressure-face TBMs, and streamlining delivery systems through the use of innovative contract delivery systems. These systems include Construction Manager at Risk and, more commonly, Design-Build. However, Design-Build contracts for underground construction have not gained wide acceptance in the U.S. at this point in time.

A recent trend towards the adoption of multi-national joint ventures has also been noted. These international partnerships are providing increased opportunities for cross-continent technology transfer, with partners all benefiting from the greater degree of shared design and construction expertise.

7 ENCOURAGING INNOVATION

Progress in the US tunneling industry has been evolutionary rather than revolutionary in nature. In the largely low-bid forum in which most public contracts are let, and the risky environment in which construction takes place, owner-sponsors and bidders can rarely afford the luxury of “on-the-job research.” Moving away from “low-bid” by consideration of alternative contracting such as alliancing and incentivized construction management, is now being considered by several agencies and may allow more innovation for underground construction.

Underground research ideally requires dedicated space, specialized staff, task-specific contracting language, and of course time and money! To best accommodate underground research separate, dedicated sites and budgets are desirable. Although not in an urban setting, to illustrate this spirit, the State of South Dakota and the US National Science Foundation are collaborating to create new opportunities for underground research by re-opening

the defunct Homestake Gold Mine in South Dakota and outfitting it to establish laboratory space (Figure 6). The space created will be used to accomplish multidisciplinary research in physics, biology, geosciences and engineering. Known as the Deep Underground Science and Engineering Laboratory, (DUSEL) it will have access to an extensive network of mine tunnels (>500 km) down to depths well in excess of two kilometres. (<http://www.deepspace.org/>).



Figure 6, Homestake Mine Shaft Head House

DUSEL will offer underground engineers opportunities for innovation in many important areas including site investigation, rock mass characterization, ground support testing, methods and means trials and instrumentation. Advances in the state of practice in any one of these geotechnical areas would find immediate application for downstream excavations at DUSEL and in many of the hard rock formations that underlie some major US cities.

At the time of writing, geophysicists and engineers are beginning to install a site-wide network of micro-sensors to study seismic activity induced during the mine dewatering and reentry phases of the project. It is expected that these early studies will provide input to the underground design work, notably relative to geologic modeling and the development of expert systems that can better serve the engineer's needs in site selection and geotechnical characterization.

8 INSPIRING NEW RECRUITS

Although improvements in the reliability of the design processes are likely to continue, the need for engineering judgment is likely to remain a key management ingredient for the foreseeable future. Until a way is found to develop a foolproof design and construction process, the industry will continue to rely heavily upon the skill that the individuals, from the miner at the heading to the manager at her desk, can bring to bear.

The challenges listed above can only be addressed if there is an appropriately qualified and experienced team on site to manage the work. Such teams are proving increasingly difficult to assemble and it behooves the industry to a make renewed effort in to

inspire, recruit and train the next generation of tunnellers, fully equipped to meet the unique and exciting challenges that continue to face our industry.

One of the major challenges we face as a community is to pass on both our enthusiasm and our hard-won knowledge to those that will follow.

9 A BRIGHT FUTURE UNDERGROUND

It has long been acknowledged within our industry that the underground solution represents a smart choice to solve many pressing urban problems. In the US, we are now starting to see that underground space is also becoming more of a strategic necessity.

Even though the long-term cost benefits afforded by the underground site are not always fully accounted for within the decision-making framework, community support and sustainability factors are leading owner-sponsors to the increased adoption of an underground site or alignment.

There have been some well-publicized "problem jobs", but there are also a lot of very successful projects too that serve as good examples of the positive impact that underground projects provide to urban living space. The underground option is continuing to gain in popularity.

We predict growth and exciting times ahead for the US underground community. To fulfill the prediction, we must focus on recruiting and developing a high caliber of underground construction professionals who can meet the needs of our challenging industry.

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