

DESIGNING TO MANAGE RISK

By: Dennis J Doherty, P.E., F.ASCE, Haley & Aldrich

Risk is inherent in underground construction using trenchless technology methods, with many risks associated for both new installation and rehabilitation projects. These risks include failure to perform by the contractor, failure due to unforeseen obstructions or changed subsurface conditions, the consequences of failure affecting third parties, and impacts to the public in general due to poor planning. The consequences of risk generally do not occur until the construction phase of the project. However, most of these risks can be alleviated ahead of time with proper planning, design techniques, and incorporation of special procedures into contract documents. These include preliminary design, field and desk top investigations, determining potential for ground movement, and identifying hindrances to both rehabilitation and new installation methods.

The consequences of failure (or risk) are generally in the form of financial impacts to the project owner or contractor, and sometimes third parties. In underground construction, it is often said the owner owns the ground and the contractor owns the method. There are many who believe it is the contractor who controls the construc-

tion method and is solely responsible for control of risk. However, it is the Professional Engineer's duty to provide the owner with a design that protects the owner and helps the contractor manage risks.

RISK ANALYSIS & MANAGEMENT

The risk analysis and management process should answer the following questions:

- What are the risks?
- What is the probability of loss that results from them?
- How much are the losses likely to cost?
- What might the losses be if the worst happens?
- How can the losses be reduced or eliminated?
- What are the alternatives?
- Will the alternative produce other risk?

In engineering and construction, the best strategy is to assign the risk to the party best able to manage the risk. This requires designing projects with managing risk in mind. The engineer must understand the capabilities and limitations of the proposed trenchless method and match these to the existing conditions (both below and above ground), understand the proposed function of the utility being installed by the trenchless method, and understand the material science of the rehabilitation material or pipe being installed by the trenchless method. For example, when rehabilitating a pipe by either slip lining or cured-in-place pipe, the chemicals within the pipe flow stream or in the surrounding ground may be detrimental to the long-term strength of the material. Another example is the cost



Manmade obstruction to microtunneling

associated with handling and disposing of contaminated ground, groundwater, or pipe sediments.

FIELD INVESTIGATIONS

In addition to the engineer being cognizant of the capabilities and limitations of each of the trenchless methods and existing conditions, the owner must also understand the need for and be willing, to pay for the extra field investigation during the design process to identify the existing conditions that may affect the selection of the trenchless method or reduce risk, extra insurance, if you will.

There are many field investigation techniques that can be used during the preliminary and final design:

Ground Penetrating Radar (GPR) can be used to identify potential obstructions to micro tunneling, HDD or other new



Broken HDD drill stem pipe

installation method. This method can also be used to locate other utilities that may not be mapped.

Magnetic Abnormalities Scan and Side Scan Sonar can be used to identify potential submerged or sunken material that is metallic and may interfere with tracking of HDD drills under rivers and other water bodies, especially for salt water bodies where GPR will not work. Side scan sonar can also assist in finding submerged or sunken material that is not metallic.

Roto-Sonic is a subsurface exploration method used to retrieve rock cores or large samples of dense soils. It can also be used to obtain boulder and cobble sizes in glacial geology to determine hardness of boulders and to approximate their size.

In-Pipe GPR is a relatively new technology that uses ground penetrating radar technology from within an existing pipe. The In-Pipe GPR can be used to determine the potential for voids outside of the existing pipe, and wall thickness and type of construction for older cast-in-place concrete or brick sewers.

3-D Laser Profiling uses laser technology to determine exact interior pipe dimensions. The 3-D laser profiling technology can be used to determine the exact dimensions of non-circular asymmetric pipes when designing a trenchless rehabilitation method. This includes liner thickness.

Sediment testing of in-pipe sediments can be crucial to the short term construction cost (or change orders) and long term structural integrity of pipe rehabilitated by a trenchless method. The testing should be conducted to determine the potential of existing hazardous material in the pipe sediment, and a chemical analysis of the sediments can determine if there are compounds that could reduce the long term strength of the new liner material.

Historic drawing review can be critical in determining a number of design factors. In urban environments, the review of historical drawings may indicate changes in street patterns or identify abandoned underground infrastructure. The changes in street patterns can mean abandoned building foundations under what otherwise may appear to be a clear street. Knowing the existence of abandoned underground infrastructure will allow the designer to specify measures to handle it.



Example of use of historic drawings. Red is new microtunnel alignment in St. James Ave. Boston. Notice former railway station in alignment - this required changes in method and alignment.

CHOOSING THE RIGHT TRENCHLESS METHOD AND RIGHT TOOLING

Selecting the correct trenchless method, whether for rehabilitation or new installation requires that the designer have a detailed understanding of the capabilities, limitations, construction logistics, and materials of the trenchless methods under

consideration. The designer must also consider the existing site conditions such as site layout and geological conditions, as well as the intended use of the installed product, and environmental conditions including contaminated ground or pipe sediment.

For example, in a glacial till, when a gravity sewer needs to be installed at a precise line and grade, auger boring may not be the appropriate method because the line and grade



What glacial till can do to an improperly tooled microtunnel head

tolerances are +/- 1% of the drive length. Therefore, over a 200-foot drive, the alignment may be off by 2 feet up or down, left or right. The presence of boulders and cobbles make it more difficult to control line and grade, and can also be detrimental to microtunneling cutter heads if the correct tooling for the head is not selected. Another example is the potential for material degradation of plastic pipe or CIPP liners where the existing pipe being rehabilitated passes through a zone of soil and/or groundwater highly contaminated with a hydro-carbon like fuel oil or gasoline. Both the new installation and rehabilitation methods chosen in the above examples can be costly to the owner: the first due to possible rework and/or required change in method, and the second due to reduction in the life of the liner thus affecting the life cycle cost.

Understandably, most designers leave it up to the contractor to select the right tooling on a specific trenchless method. However, specifying specific tooling requirements may assist in controlling risk, as in the following three examples:

1. Specifying allowable surface settlement caused by overcut for microtunneling in a specific geology may assist in control of potential settlement that could cause unacceptable movement of nearby sensitive structures.

2. Specifying or requiring downhole pressure monitoring during HDD will reduce the potential for frac-outs due to design depth or geology.

3. Requirement for use of a gyroscope in HDD alignment control where the horizontal alignment is within an easement, and there are nearby steel structures and/or overhead power transmission lines that may affect the magnetic steering controls of more conventional HDD tracking devices.

The designer should still be careful to not over specify the methods and tooling to be used. It is better to specify what will not be allowed, or to specify specific tolerances that need to be met.

CONTRACT DOCUMENTS

The designer needs to consider the various risks associated with existing site conditions, including geology, surface staging areas and the specified trenchless method. The risks should be listed in a table known as a Risk Register. An example of a Risk Register for a microtunnel project is shown above in Table 1.

TABLE 1.

RISK	CONSEQUENCES	PARTY BEST SUITED TO HANDLE	METHOD OF MANAGING RISK
Settlement	Movement of sensitive structure	Contractor	Specify allowable settlement. Specify Geotechnical Instrumentation Plan to be implemented by Contractor during construction. Engineer and Contractor to monitor.
Obstructions	Stoppage of forward motion. Potential rescue shaft.	Owner	Provide measurement and payment item with specific clauses for handling obstructions when encountered.
Movement of Adjacent Sensitive Utilities	Compromise structural integrity	Owner	Stabilize via ground modification or rehabilitation prior to microtunneling.
Shaft Movement	Affects alignment and drive distance	Contractor	Contractor selection of shaft support system. Owner specified tolerances.

Language should be included in the contract documents requiring a shared risk approach. This results in more equitable outcomes for both the owner and the contractor. For example, the shared risk approach requires the contractor to submit an auditable unit cost (after award of the contract) for down time of specified equipment and manpower if the microtunnel drive is stopped by an obstruction.

Specifying allowable materials will not only ensure longer life and lower life cycle cost, but also ease of installation or reduced capital construction cost. For example, it may be cheaper to allow for longer pushed-in slipline rehabilitation, and thereby less shafts, by specifying stronger slipline pipe material (or disallowing weaker material).

PRE-QUALIFICATION

If the project is technically challenging, and requires highly experienced microtunnel, HDD, pipe bursting, or other trenchless technology specialty contractors, then contractor pre-qualification should be used. Pre-qualification of specialty contractors should be used if the project is in a highly urbanized area with challenging subsurface conditions where inexperienced contractors are more prone to errors. The owner must allow time in the overall project schedule for the prequalification process, which could add 2 to 8 weeks to the overall project schedule depending on the project complexity.

There are several qualitative factors used in prequalifying contractors, including:

- Corporate experience with similar work
- Financial stability
- Technical approach
- Personnel experience, skills, and competencies
- Risk management process
- Applicable tools, templates, and processes
- References for similar work

A weighted scoring algorithm should be employed to assess these qualitative factors.

FIELD MONITORING

Success of a particular trenchless method not only depends on quality contractors, it also depends on contractual requirements for quality control and monitoring of the quality control testing. A field monitoring program is an established method for controlling risk on new installation trenchless projects.

For example, in microtunneling, movement of adjacent soil masses needs to be limited to prevent subsidence or heaving at the surface, and the subsequent movement of nearby structures and utilities. These movements can be monitored for deformation by establishing a pre-construction survey of critical locations, structures, and other utilities, then monitoring movement during microtunnel operations using

inclinometers, vibration monitors, and groundwater observation wells. If conditions approach or exceed predicted values, then microtunnelling is halted until the cause is determined.

It is during the field monitoring process that the contingency planning established at the beginning of the construction phase may be implemented. The monitoring has a preset limitation which will trigger a response. The specific response is predetermined by the contingency plan.

OTHER CONTRACTUAL TOOLS

Other contractual tools, including contractor incentive programs, and partnering are recommended for trenchless technology projects. These methods have been used successfully on many projects. Contractor incentive programs should also be considered by the project owner/sponsor. Incentives or disincentives can be for positive or negative performance by the contractor

Partnering between the project owner/sponsor, the contractor, and the engineering consultant is also a contractual tool for controlling risk. Partnering is a voluntary process and results in a "team" atmosphere where the common goal is to provide a finished product that all members can

"THE CONSEQUENCES OF RISK GENERALLY DO NOT OCCUR UNTIL THE CONSTRUCTION PHASE OF THE PROJECT, HOWEVER MOST OF THESE RISKS CAN BE ALLEVIATED"

point to as a success. The partnering team should consist of the project manager and chief resident engineer, the design project manager, the construction manager from the project owner/sponsor, and project managers and field superintendents from the prime contractor (and specialty contractors when necessary).

Projects utilizing partnering as a risk control method have improved contract administration, reduced claims, and increased the value of the completed project. It also allows an expedient resolution to unforeseen risk events. Before committing to partnering, owners should consider all legal and practical issues, procurement and logistics, including establishing clear lines of responsibility.

CONCLUSION

It is the responsibility of the Professional Engineer working in the trenchless industry to assist the Owner in identifying risk and risk mitigation methods, and hence

overall project cost, for the Owner. It is also the duty of the Professional Engineer to provide the Contractor with contract documents that are realistic and buildable. Conversely, the Contractor should be responsible and work with the Owner and Engineer to construct a successful project that adheres to risk mitigation plans in place. Although it is the Contractor's means and methods that make the Engineer's design a reality, the Engineer usually has more detail knowledge on the existing conditions along with detailed knowledge of the decisions made during the design process that identified risk and methods for avoiding them.

Ultimately, it is the responsibility of the Engineer and the Contractor to deliver a successful project economically and on schedule to the owner. Equally important, they have an obligation to the trenchless industry generally to recognize and manage risk in a responsible and professional manner. 📌

ABOUT THE AUTHOR:



Dennis J Doherty is Senior Consultant and the National Practice Leader, Trenchless Technologies, at Haley & Aldrich, applying a total trenchless approach on microtunneling and HDD projects for private sector energy clients. An ardent proponent of the benefits and value of trenchless methods, Dennis has a unique understanding of risk management as it relates to trenchless design, having worked on a number of innovative projects in the Greater Boston area. He serves on the NASTT No-Dig Show Program Committee and is a Technical Program Session Leader. Dennis is proud to be Chair of the new NASTT-NE Chapter.



HDD Frac-out control in an emergency situation in sensitive waterway.