The growth and acceptance of trenchless technology as an alternative construction method has made great strides in the past 20 years. Owners and the public are demanding trenchless methods be used because of its many benefits. Many engineers are jumping on the bandwagon, especially in adopting new installation methods. Unfortunately, many of these engineers do not fully understand the issues and problems that can arise due to their limited technical understanding of a specific trenchless installation method (such as horizontal directional drilling or microtunneling) or other new installation methods under development. A detailed understanding of the geology, pipe material, work zone requirements, crossing length, and how each method actually excavates and stabilizes the ground are required.

Too often, engineers draw “a line on a piece of paper” without understanding the implications of the line, and then state, “It is up to the contractor to figure it out.” This is not an acceptable approach for professional engineers as designers, and needs to be stopped for the good of the industry. Trenchless crossings are “engineered products,” not a directive to make the contractor build it no matter what the conditions. This approach puts the owner and contractor at risk. This paper explores the use of risk-based engineering to reduce the risk of just drawing a line on a piece of paper.
Figure 1 – Driving risk down. The intent of risk-based engineering is to drive cost down from red to orange to yellow to green by driving risk down to more manageable levels.

INTRODUCTION

The design and construction of projects using one or more trenchless installation methods is more than just a line on a piece of paper. It does not require just a good survey plan, it requires an understanding of the geological conditions, an understanding of just how the selected trenchless method excavates and removes the ground and installs the pipe, and the required equipment within a specific work zone. It also requires an understanding of a of existing “other issues.” For example, other issues can include contaminated ground and the need to understand how to identify and plan for handling and disposal of contaminates. Another example is understanding that former and existing building foundations exist and can be impacted by or impact the project. The most common issue is knowing where and the type of other utilities in the ground, traffic volumes on surface streets, the all-important egress/ingress points to local commercial, public and private properties. What is often overlooked but just as important are the local social issues and stakeholder issues and how to manage them.

It also requires an understanding that there is risk and that not all risk is equal. The cause and effect, or trigger, of the risk event occurring for a specific trenchless method are dependent on engineering and human error from operations in engineering and construction that can be controlled through changes in the design and/or construction operations. These risk events can include ground settlement, ground heaving, creating large voids, movement of sensitive buildings, inadvertent returns, changed ground conditions, broken downhole tooling, damage to third party property, damage to other utilities and structures and even loss of life. So, it requires managing the risk. The risk to the owner to pay for legitimate change orders due to defective designs or changed conditions; the risk of contractor financial losses caused by defective work or underestimating production rates or use of incorrect tooling for the ground conditions; and the risk to third parties caused by settlements of pavements or rails, the movement of ground under or near sensitive structures, or even the loss of life. Someone has to pay for the risk. Not all planned capital construction cost and administrative cost to the owner include cost of risk which could substantially increase the cost of the project if not controlled.

It really comes down to: “Pay me now or pay me later,” to which should be asked, “Which is more expensive?”

Risk-Based Engineering

Risk is defined as the chance or probability of an event that exposes something or someone to a specific level of danger and peril. For each event, there is a cost associated with it. These costs can be monetary, affect schedule, or affect finished product, or in project management terms, cost, schedule, and scope.

Engineering is defined as using the knowledge of science and technology to construct or modify the environment for the benefit of society. In the case of trenchless technologies, it can be the knowledge of the chemicals in a rehabilitation process, or optimal temperature control during a curing process, or long-term stress-strain relationships for rehabilitation methods. For new trenchless installation, an area for which this article is focused on; it is a deep understanding of geology, geotechnical engineering, material science, management of contaminated ground, spatial relationships, and program management; all of which are required for a successful project. Eliminating all risk is almost impossible, but limiting the cost of the risk event is possible by purposefully lowering the probability of the event from occurring.

Risk-based engineering therefore considers the risk involved, the probability of a risk event from occurring when using a specific engineering and construction method, and the potential cost of the should the risk event occur. For each potential risk, there is a cost. These costs are either monetary or time but may be both. There is also a probability that a risk event will happen. The probability ranges from it will not happen to it will happen or someplace in between such as it may
they are distinct. The difference is that each risk event has cost and probability, whereas a work packet has cost and schedule. For a risk event, the cost for the event that would be incurred is affected by the probability that that event will occur. For example, if the cost that would be incurred is estimated to be $5 million for the settlement of a busy intersection, and the probability it will probably happen is a 70 percent chance of occurring, the cost of that event that enters the project cost will be $3.5 million that is added to the ledger of total project cost. Whereas changing trenchless construction to another trenchless method or simply going deeper or considering ground modification reduces the probability to a 10 percent chance of occurring, the cost of that event added to the ledger would only be $500,000 plus the cost of mitigation. But the cost of the secondary risk may also need to be considered.

A secondary risk is a result of changes in design or construction that have a distinct set of their own risk. There is also the cost of implement risk mitigation mea-

Figure 2 - Trenchless methods cost, mitigation, cost of mitigation and cost of risk. Decisions made early with known schedule and cost can be impacted by risk, with various mitigation methods leading to unknown construction cost and schedule impacts followed by secondary risk impacts.

Figure 3 - Risk, risk mitigation and secondary risk. Decisions made early in process can affect overall project cost as each trenchless method has its own set of unique requirements and sets of risk class. Understanding all options early is critical.

The Cost of Risk in accounting for Project Cost

Not all risk can be eliminated. Risk, both original and secondary are like project management work packets,

happen. Assignment of risk and probability can be subjective and are best assessed by experienced engineers, managers, and construction experts in a brainstorm session.

And there can be a multitude of secondary risk from selected mitigation methods used to lower cost and probability of the original risk, each with their own additional cost and probability. Trenchless engineering is an iterative process. When you first begin the project, the project is full of risk and uncertainty. As more knowledge is gained through the design process, the risk profile changes. These changes can be in severity of a risk event when it occurs or the probability of the risk event occurring. Should a risk event occur there will be a definitive cost and schedule impact assigned to the event. The intent of risk-based engineering is to drive risk cost down as well as the probability of the risk event occurring.
a school. The movement of the jacking shaft has many secondary risk that are a direct result of the movement. The cost of these secondary risk may far out-weigh the cost of risk of an event at the school because the control on the probability of occurrence cannot be as effective. A solution to reduce the probability reducing solution to the risk event at the school would be to conduct work at the jacking shaft at the school when school is not in session such as over the summer vacation, introducing extra safety measures, and educating and involving not only the students at the school, but also social/political group being appeased. This does require a good stakeholder management program at a cost, but the cost has certainty whereas moving the shaft to the intersection may not.

Use of risk management techniques need to be utilized to qualify and quantify the risk and probable cost. The use of risk registers is a good start. A simple risk qualitative analysis in terms of probability of the risk event occurring and the impacts will establish risk rating or classification of risk.

Using the same risk probability in the risk quantitative analysis will result in a reasonable cost of risk should the risk event occur. By entering the estimated schedule in cost impact should the event occur and multiplying by the probability in terms of percentage, the cost of the risk can be determined. The cost and schedule estimates can be order of magnitude or detailed. For most projects, an order of magnitude is sufficient, especially early in the life of a project. It also simplifies comparison of alternative risk analysis when detailed costs are not available for alternatives.

Conclusions

Risk-based engineering for trenchless projects is, in all essence, an accounting system based on real risk to the project. The risk arises due to technical limitations of a specific trenchless method or material used, geological conditions not being accurately characterized, sensitive nearby structures and underground utilities that move and cause damage, impacts to traffic, etc. The risk may also arise due to stakeholder demands. In the end, there is cost to these risks, include administrative cost that can substantially increase the cost of the project for the owner if not properly managed.

This paper was edited for style and space for publication in NASTT's Trenchless Today. To view the complete version of Paper WM-T2-04, please visit nastt.org/technicalpapers.