

A TRENCHLESS ASSESSMENT GUIDE FOR CONSTRUCTION AND REPLACEMENT OF UNDERGROUND UTILITIES

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1.0 Background

When decision-makers try to select the optimal trenchless construction method for installing or replacing underground utilities, they are often overwhelmed by the large number of methods and attributes that one needs to consider as part of a comprehensive analysis. There are more than 20 trenchless methods for new installations and at least seven inline replacement methods used in underground construction, each of which presents a unique set of advantages and limitations. In 2004 the National Utility Contractors Association (NUCA) commissioned the Trenchless Technology Center, at Louisiana Tech University, to develop a stand-alone software program to assist municipal and utility engineers in evaluating the technical feasibility of various traditional open cut, trenchless construction, and inline replacement methods for their specific projects. The program, titled TAG (Trenchless Assessment Guide), is compatible with Microsoft operating platforms Windows XP and Windows 2000. TAG takes into account extensive performance data for 29 construction methods and sub-methods commonly used in utility type projects. The objective of this project was to develop and codify an algorithm to accomplish the following tasks. First, the program needed to perform a sound technical evaluation as a screening measure to eliminate incompatible construction methods. Next, TAG would need to evaluate the overall perceived risk associated with the competing alternatives. Finally, the program needed to raise awareness and provide guidance to the utilization of trenchless technology methods.

2.0 Model Overview

TAG employs a relational database that contains a wide range of information regarding each of the construction methods. The databases contain general information about each method, which includes a detailed method description, a color picture and the assigned degree of typical environmental impact. The databases also contain data concerning the method's technical capabilities, including the maximum and minimum pipe diameters, the maximum and minimum drive lengths, and the maximum and minimum allowable depths of cover. Other hard-coded data include pipe compatibility information for ten common pipe materials, soil compatibility information for ten types of geological materials, and limitations imposed by the height of the ground water table above the pipe's invert (if any).

The relational method databases contain information about 29 construction methods, 20 of which are trenchless technology methods, seven inline replacement methods and two open cut methods. The construction method database is updatable, customizable and expandable. The user can easily add new methods or pipe materials, and update the capabilities of existing methods as technology

develops and new innovations are introduced into the trenchless market. TAG is a living application, which is expected to remain a useful and relevant decision support tool for a prolonged period of time. Figure 1 shows a sample method data form from TAG (Auger Boring, Track Type 2). The technical content in TAG was collected based on a combination of an extensive literature review, industry surveys and face-to-face meetings with the specialty contractors.

The technical evaluation begins by defining the type of problem the user is facing. The vast majority of buried pipe problems can be reduced to either a structural problem or a capacity problem. TAG incorporates a built-in wizard, which employs a series of interactive questions presented to the user. Based on the user's answers, certain categories of construction methods might be eliminated. The next step in the technical evaluation is the input of the project's technical attributes and expected site conditions. Four categories of information are input during this stage. The first category includes performance parameters such as drive length, pipe diameter, depth of cover and elevation of the ground water table (see Figure 2). Also included in the input are the desired degrees of accuracy in terms of alignment and profile. The second set of input data deals with the pipe material(s) that are permissible in this project and the user is asked to select one or more pipe types from a list of commonly used pipe materials. The third category of user input deals with soil compatibility parameters. The user is asked to identify up to three dominant soil(s) conditions and their percentage in terms of the overall volume of the in-situ soil along the proposed alignment. The final category deals with information related specifically to the viability of in-line replacement options. This information consists of the degree of sagging and/or misalignment in the host pipe (if any), the desired level of diameter enlargement (if any), and the material type of the host pipe.

Following the technical evaluation stage, methods deemed technically viable for the project under consideration are then evaluated for their perceived level of risk. This is accomplished by considering four categories of direct and implied risk factors. Simply put, the risk score in TAG provides an indicator of the likelihood of undesirable complications arising during the project due to the risk factors considered. The first category is the installation parameters: drive length, pipe diameter, and depth of cover. In this category the project specific values are divided by the upper limit of each of the technically viable construction methods, resulting in a fraction, which is then assigned a risk score (i.e., length of installation equal to 90% of a method upper limit presents higher risk than the one equal to 40% of the upper limit). The second category of risk is assessment of the compatibility of a given construction method with respect to the anticipated geological conditions. Geological conditions were divided into ten categories, with soil types being further quantified in terms of the number of blows per foot (as per ASTM 1452). The geological conditions considered by TAG are: soft cohesive soils ($N < 5$), firm cohesive soils ($5 < N < 15$), stiff-hard cohesive soils ($N > 15$), loose cohesion less soils ($N < 10$), medium cohesion less soils ($10 < N < 30$), dense cohesion less soils ($N > 30$), gravel, cobble and/or boulders, sandstone and bedrock. The compatibility of each construction method with the ten soil classes is designated in the database as either: fully compatible (Y), possibly compatible (P), or incompatible (N). If geological conditions were found to be a combination of compatible (Y) and possibly compatible (P) with the construction method in question, then the method is considered to be permissible and the associated level of risk will range from very low to very high, depending on the percentage of length of the alignment of the possibly-compatible soils. The third category of risk is the SET (Specifications, Experience, and Track Record) index, which takes into consideration the availability of specifications, owner's experience with a given method and the method's track record. The risk

classification of the SET index is based on the sum of the score for the three parameters, which is calculated based on the user selected value and can range from a minimum value of 3 to a maximum value of 9. The final category of risk includes site accessibility and environmental impact. Each method has an assigned risk value in the database for environmental impact, based on the potential for ground settlement and heave (i.e., potential damage to paved surfaces, nearby utilities and foundations), erosion, removal of trees and flora, creation of temporary hazards (i.e., open trenches), and migration of drilling fluids to the surface. The six primary risk factors described above are then used to compute the Initial Risk Analysis Index Number (IRAIN). Prior to the calculation of the IRAIN value, a weight from 0 to 100 is assigned by the user to each of the six primary risk factors. The RAIN value represents the weighted average of the risk score of the method alternative under consideration, and reflects the user's preferences.

The final step sees the IRAIN value get adjusted for the level of site accessibility. The user is asked to choose the site description that best describes their project. Site accessibility determines the ease of a recovery operation if equipment or materials are lost under the surface. If recovery is not possible, or is highly complicated, the overall perceived risk associated with the project increases. The Risk Analysis Index Number is the final risk assessment score displayed by the program for each technically viable method. Figure 3 display the formant in which the final outcome of the analysis is presented. The risk scores are relative and depend on the user's attitude towards risk (i.e., degree of risk avoidance) as well as project parameters. The user is then able to make an educated decision regarding which method (or methods) is best for his/her particular project.

3.0 Model Validation

Validation is a vital aspect in the development of any decision support model. The validation of TAG was performed by comparing the model's recommendations to the methods selected by experienced utility engineers on more than a dozen actual utility construction projects for which adequate technical data is available. The validation included not only cases where appropriate construction methods were selected and used, but also a case history where incorrect methods were chosen, causing difficulties with the construction process and project execution. The case study outlined below presents the project background, the user input data, and a comparison of the model's recommendations with the actual method used on the project. The Southside Sewer Relief Program was a major sewer upgrade project undertaken by the City of Edmonton, Alberta, Canada in the early 1990's. This particular installation took place in October of 1992, in the West Millwood District, a residential area located in the southwestern part of the city. The existing eight-inch vitrified clay sewer pipe was lacking the capacity to properly serve the fast growing Millwood area, causing frequent back-flows and basement flooding. The CCTV inspection also showed that the current pipe suffered from multiple cracks/fractures, exhibiting a moderate to severe infiltration/inflow problem. A decision had to be made as to what type of construction method should be used. The owner could install a parallel line to increase capacity by either traditional open, cut excavation or trenchless methods. The owner could also choose to do an inline replacement of the line, and upsize it to help increase capacity. Both of these options can be considered by TAG, with the most suitable methods determined by the inherent risk associated with this project. Relevant project technical data is listed in Table 1.

The data from Table 1 was input into TAG, and five methods were identified to be technically viable by the model. Two construction methods for the installation of a parallel line are considered

viable, along with three inline replacement methods. These methods and their associated risk assessment scores are listed in Table 2. The risk score values were computed assuming equal importance of all risk factors.

TAG identifies open-cut excavation as the method with a lower perceived risk for installing a parallel line. The practical limit of pilot tubing is approximately 100 m, a value close to the needed drive length. On the other hand, open-cut excavation would be difficult considering the elevation of the ground water, and would require significant surface restoration. Also, the depth of the line will make open-cut excavation technically challenging. If the user chose to increase the relative weight of the environmental impact and depth ratio, making them the primary factors, the risk score for open-cut excavation would increase to 3.2. The model comes to assist and guide the user, rather than serving as a “black box.”

The pneumatic and hydraulic pipe bursting methods were given the same relative risk score for performing an in-line replacement. It can be seen from Table 2 that overall, in-line replacement is deemed to be less risky than the construction of a parallel line in this case. Pneumatic pipe bursting was used in the actual construction, successfully.

4.0 Conclusions

In summary, TAG is a fully computerized algorithm for the evaluation of competing construction methods capable of installing, repairing, or replacing buried pipes and utilities. This approach emphasizes simplicity and practicality, while limiting the input data to these readily available to municipal and utility engineers, by utilizing an extensive built-in database. The built-in wizard as well as relational database can assist users who have limited experience with trenchless construction methods. To date a dozen case histories, representing a wide range of scenarios, were modeled using TAG. In all cases the model was found to the method employed in the construction (or recovery) of the projects modeled. This suggests that TAG is a useful aid in assisting utility engineers in selecting the optimal construction method for a particular installation.

Tables and Figures

Table 1

Length	85 m
Depth	7 m
GWT Depth	4.3 m
Host Pipe Diameter	200 mm
Host Pipe Material	Vitrified Clay
New Pipe Diameter	300 mm
New Pipe Material	PVC and HDPE
Alignment Accuracy	5 – Very High
Profile Accuracy	4 – High
Soil Type #1	Firm Clay (50%)
Soil Type #2	Medium Sand (30%)
Soil Type #3	Gravel (20%)
Excessive Sagging	No
Pipe Upsize > 2.5 Sizes	No
Allowable Extent of Excavation	Continuous Excavations
Site Accessibility	Medium Accessibility (Residential)

Table 2

New Installation Methods	Relative Risk Value
Open-Cut Excavation	2.24
Pilot Tubing	2.78
Inline Replacement Methods	Relative Risk Value
Pipe Bursting Pneumatic	1.85
Pipe Bursting Hydraulic	1.85
Pipe Bursting Static	2.24

Method Database

Method Selection

Method Category: Trenchless Methods

Methods:


- Auger Boring Cradle Type
- Auger Boring Track Type 1
- Auger Boring Track Type 2**
- HDD Maxi 1
- HDD Maxi 2
- HDD Maxi 3
- HDD Midi
- HDD Mini 1
- HDD Mini 2
- HDD Micro
- Microtunneling Auger
- Microtunneling Slurry
- Non-Steerable Impact Mole
- Steerable Impact Mole
- Pipe Ramming 1
- Pipe Ramming 2
- Slurry Horizontal Rotary Boring
- Rod Pushing
- Pilot Tubing
- Water Jetting
- Pipe Jacking Hand Mining
- Pipe Jacking Open Face TBM
- Pipe Jacking Road Header Method
- Pipe Jacking New Austrian Method
- Pipe Jacking Closed Face TBM

Method Information

Max Drive Length	500.00	ft.	Soft Clay	<input checked="" type="checkbox"/>
Min Drive Length	20.00	ft.	Firm Clay	<input checked="" type="checkbox"/>
Max Pipe Diameter	72.00	in.	Stiff Hard Clay	<input checked="" type="checkbox"/>
Min Pipe Diameter	37.00	in.	Loose Sand	<input type="checkbox"/>
Max Depth of Cover	100.00	ft.	Medium Sand	<input checked="" type="checkbox"/>
Min Depth of Cover	6.00	ft.	Dense Sand	<input checked="" type="checkbox"/>
Environmental Impact*	2.00		Sandstone	<input checked="" type="checkbox"/>
Extent of Excavation*	3.00		Cobble/Boulder	<input type="checkbox"/>
GWt Classification*	C2		Bedrock	<input type="checkbox"/>
Alignment Accuracy*	4		Gravel	<input checked="" type="checkbox"/>
Depth Accuracy*	4			

*Defined in Appendix D.1.

Method Picture



Method Description (Refer to NUCA's Trenchless Construction and Rehabilitation Methods, Fourth Edition 2004)

Auger Boring is the process of simultaneously boring and jacking a steel casing through the earth between two points. A cutter-head is attached to the lead auger section. As the cutter-head is rotated, the earth is excavated and the spoils inside the casing are removed by means of rotating auger flights, which are installed the total length of the casing. As the soils are conveyed through the auger flights, they are ejected into the bore/jacking pit. Auger is installed inside the casing prior to installation of the casing. As the casing is installed it supports the surrounding soils as the auger-head excavates the earth. Auger boring can be classified into two methods: (1) Track type and (2) Cradle type. The Track type auger boring method uses hydraulic thrust to jack the casing into place. Track method consists of a track system, boring machine, casing, auger-head, auger, and thrust block or reaction wall. The boring operation is cyclic, casing segments with auger flights inside are attached together either by welding or compressed fittings after the prescribed casing section is bored into place. The Track method

Figure 1. Technical Data for Auger Boring (Track, Type 2) Method

Project Parameters

Recommendation

- New Construction (TT)
- New Construction (OC)
- Inline Replacement
- Rehabilitation*
 - Structural Rehabilitation*
 - Non-Structural Rehabilitation*

*Not Included in Current Version

Construction Parameters | New Pipe Material | Soil Parameters | Pipe Installation Details

Drive Length: 575 ft.

Pipe Diameter: 24 in.

Depth of Cover: 20 ft.

Alignment Accuracy*: 4 - High

Profile Accuracy*: 4 - High

Ground Water Table Depth*: 15 ft.

*Defined in the User's Manual

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Figure 2. Project input data form

TAG Risk Analysis Results

Method	Risk	Risk Score Δ
▶ Pipe Jacking Closed Face TBM	Moderate Risk	3.12
HDD Maxi 2	High Risk	3.67
Microtunneling Slurry	High Risk	3.67

Please contact NUCA's Trenchless Technology Committee for more information.

Figure 3. Final ranking of technically viable methods