CCC 2018

Proceedings of the Creative Construction Conference (2018)
Edited by: Miroslaw J. Skibniewski & Miklos Hajdu
DOI 10.3311/CCC2018-018

Creative Construction Conference 2018, CCC 2018, 30 June - 3 July 2018, Ljubljana, Slovenia

Advantages and Disadvantages of Trenchless Construction Approach as Compared to the Traditional Open Cut Installation of Underground Utility Systems

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Abstract

The construction industry in North America is faced with the ongoing task of incorporating new technologies and management methods into their operations. New technologies and methods generally receive acceptance very slowly due to a number of factors. The risk of applying a new or unproven technology or method is sometimes perceived as being too high. Trenchless methods allow inspection, access, repair, expansion, upgrade, and installation of most underground infrastructure systems with minimum surface disruption. The tools that trenchless technologies offer range from robots to microtunneling and from closed-circuit television to cured in-place lining. The ability to select from these approaches is hinged from knowing what is available in the market that will meet each owner's particular needs. Knowing what advantages and disadvantages that the trenchless technology offers will provide an advantage to reach the right decision when selecting the appropriate approach. This research provides information on the advantages and disadvantages trenchless provides in five (5) areas, environmental, safety, traffic, business and cost impacts.

Keywords: Safety, trenchless, underground utilities

1. Introduction

Every year municipalities, institutions, etc. see themselves with the need to upgrade, rehabilitate/repair or expand their infrastructure. The main portion of this infrastructure includes the utility systems that are composed or water, sanitary sewer, storm sewer and gas pipe lines. Millions of dollars are invested in these critical and necessary improvements or expansions to adequately provide these basic services to existing and new customers. The traditional approach to accomplish this endeavor continues to be primarily open excavation method.

In the last quarter century, new technological advances and approaches have been developed as alternate method to undertake the task of replacing, repairing, updating aging pipeline systems or installing new systems. (Trenchless Technology, Inc., 2017) This new approach implements equipment and methodology in the installation of piping system minimizing the need for open trench excavation. There are multiple systems utilized for the trenchless approach of construction such as slip lining existing pipelines, pipe bursting, micro-tunneling and horizontal directional drilling to name a few. As these systems have gained popularity and are increasingly being utilized as effective alternate, there is still a great majority of owners, engineers and contractors who continue with traditional open trench construction approach to execute their underground utility construction needs. (Trenchless Technology, Inc., 2017)

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1.1. Background

For several decades engineers, contractors and owners have employed the trenchless or no-dig method in the installation and rehabilitation of underground pipe system. With the latest technological advances, these methods are now posing some advantages to the traditional open cut methodology. The following are the trenchless technologies currently available:

- Horizontal Directional Drilling (HDD)
- Microtunneling
- Pipe Bursting
- Cured in Place Pipe Liners (CIPP)
- Sliplining

With these advances, other approaches have surfaced to supplement what was already established or as another alternative to these systems. Some of these advances and supplement technologies include:

1. CCTV line inspection to help with pre and post rehabilitation of pipelines to be rehabilitated.
2. Jetters: High pressure jetting systems with specialty nozzles to clean pipes in preparation of CIPP or Sliplining application. (A-1 Trenchless Services LLC, 2017)
3. Vactors: Vacuum excavators.

The primary technologies used in the approach of pipeline installation/rehabilitation identified above are employed depending on their applicability and nature of the project.

1.2. Purpose of This Study

With multiple methods now available for installing and repairing underground piping systems, the utility owners shall be better informed to implement the best approach at executing their utility repair or installation projects. This study is intended to provide key information in the advantages and disadvantages of each of these trenchless technologies as compared to the traditional open excavation approach.

The areas considered in this study to determine the advantages and disadvantages are as follows:

- Environmental impacts
- Safety
- Traffic impacts
- Disruption to businesses
- Cost evaluated in two parts: 1) direct cost for the actual design and construction of both alternatives and 2) indirect (social) cost impacts due to factors such as traffic, loss of business, and safety related issues.

1.3. Research Methodology

As utility owners take on a project to renovate or install a new underground system whether is a water distribution, sanitary sewer collection, gas distribution and electrical distribution system, many factors must be considered and the primary factor is cost along with impacts to their business. In order to identify the advantages and disadvantages of using trenchless technologies a case study approach was performed utilizing five (5) projects where different technologies were employed supplemented by research data obtained from two (2) papers published on related topics.

The following construction projects were analyzed in their use of trenchless technology:

1. Replacement of an Aging One Mile PCCP 36-inch Force Main to Minimize Environmental Impacts.
2. Improve Military Family Housing Infrastructure, PH 3, Misawa Air Base, Japan.
3. Upgrade Electrical Distribution System Phase 10, Misawa Air Base, Japan.
4. Reconstruct Taxiway Alpha 2 (Waste Water Drainage Line), Misawa Air Base, Japan.
5. Upgrade Hachinohe POL (Mabechi River), Misawa Air Base, Japan.

Projects no. 1, 3, 4 and 5 employed microtunelling for the installation of their underground utility. Project no. 2 used CIPP liner to rehabilitate existing sanitary sewer lines.

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Key information also obtained from EPA's Collection Systems O&M Fact Sheet Trenchless Sewer Rehabilitation; and USDA/Forrest Service Decision Analysis Guide for Corrugated Metal Culvert Rehabilitation and Replacement Using Trenchless Technology.

2. Literature Review

2.1. Open Excavation Approach

Installation of a sanitary sewer main line or water main line will have a different impact installed in a rural area as compared to an urban area using the conventional method of open excavation approach. A rural area will not be as impacted as an urban area when it comes to vehicular traffic, however, the environmental impact may be a different story if the rural area encompasses factors such as wetlands, creeks and such. Further impacts, as compared to these two different locations rural vs. urban, include indirect cost created from fuel consumption, which impacts the public, and business loses due to public accessibility to stores and restaurants. Another factor, which impacts both areas is safety related to workers and if the site is not properly protected for the general public.

Cave-ins pose the greatest risk and are much more likely than other excavation related accidents to result in worker fatalities. Other potential hazards include falls, falling loads, hazardous atmospheres, and incidents involving mobile equipment. One cubic yard of soil can weigh as much as a car. "An unprotected trench is an early greave." (OSHA, 2017). The workers in the under-ground construction industry, especially water, sewer, and utility lines companies, have traditionally had a higher accident and injury rate than other workers in the heavy construction industry. (Arboleda & Abraham, 2004). Also, open trench at an intersection in a busy city can create significant negative traffic impacts, and restrict/reduce access to business.

The direct cost for open trench installation can greatly vary depending on factors encountered. For example, installation an underground utility line in a wetland area will pose a high environmental mitigation price to execute the project. Depth of the utility line can have a great cost impact with factors related to type of equipment, especially for deep installation, and safety where costly implementation of safety systems are mandated to protect workers.

2.2. Trenchless Approach:

Trenchless technology involves the installation, replacement or renewal of underground utilities with minimum excavation and surface disruption. Trenchless technologies have been used successfully for all underground utilities from, water, sewer, gas, and industrial pipelines to electrical conduit and fiber optics. (The International Society For Trenchless Technology, 2017) Trenchless Technologies are particularly attractive construction options in urbanized area with heavy vehicular and pedestrian traffic and numerous existing underground utilities. They are also attractive for crossing roadways, transportation corridors, and rivers and waterways. Trenchless also can be used to install, rehab or replace utilities located in environmentally sensitive areas and locations where surface access may be restricted due to the existence of structures or vegetation. (The International Society For Trenchless Technology, 2017)

In cases where multiple factors come into play for the rehabilitation of an existing pipeline, open trench may not be a practical option. For instance, replacement of a One Mile PCCP 36-inch Force Main in Fairfax County, VA. The original construction of the 36-inch Dogue Creek Force Main was in 1977 using open cut type construction technique which traverses wetlands, streams, residential properties and the Fort Belvoir Military Base. Due to permitting requirements, regulations, the development of the properties in the nearby areas, and the Fort Belvoir Military Base requirements, open cut construction was not a viable option for this force main replacement. Specifically, 84% of the force main needed to traverse the Fort Belvoir Military Base, and it was determined that open trench construction would be too disruptive to their daily operations. Additionally, the force main crossed a state highway which would also not allow open trench installation. As a result, alternative methods such as trenchless technologies needed to be considered for the installation of the new force main. (Notheis & Schillo, 2015)

The US Federal Government also takes into consideration the trenchless approach in the renovation and upgrade of some of their underground utilities for example the USDA and Forrest Service in their maintenance plan for underground corrugated storm drainage system.

Trenchless technologies reduce the need for open trenches which requires expensive trench protection thereby greatly reducing the risk for injuries from trench cave-ins and falls. Another safety risk that is greatly reduced with trenchless is traffic accidents as the area where the actual work is conducted is minimized and provides a more manageable site for traffic control. In the project mentioned above for the Replacement of a One Mile PCCP 36-inch

Force Main in Fairfax County, the best trenchless method decided was microtunneling and this approach consisted of six shafts ranging in depths from 9.75 m (32 ft.) to 15.85 m (52 ft.). (Notheis & Schillo, 2015)

There are clearly several advantages that trenchless construction presents over the traditional open trench approach. However, there are cases where there may not be an alternative to open trench and a more in-depth evaluation should be conducted.

A brief description of the five trenchless technologies identified in this study is as follows.

2.2.1. Horizontal Directional Drilling (HDD)

HDD is a steerable system for the installation of pipes, conduits and cables in a shallow arc using a surface launched drilling rig. Traditionally the term applies to large scale crossings in which a fluid-filled pilot bore is drilled using a fluid-driven motor at the end of a bend-sub, and is then enlarged by a washover pipe and back reamer to the size required for the product pipe. The required deviation during pilot boring is provided by the positioning of a bent sub. Tracking of the drill string is achieved by the use of a downhole survey tool (NASTT, 2017), as shown in Figure 1 below.

a

Figure. 1. (a) HDD Rig setup.
(Intermountain Drilling Supply, 2017)

b

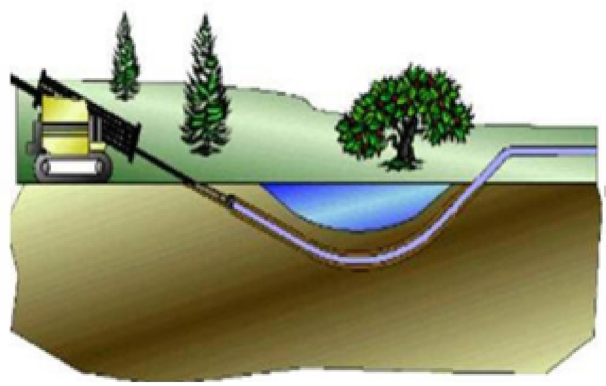

Figure 1. (b) HDD Process example.
(Underground Solutions, 2017)

2.2.2. Microtunneling

Microtunneling is a trenchless construction method for installing pipelines with the following attributes – remote control, guidance, pipe jacking, and continuous support, as shown in Figure 2.

Figure 2. Microtunneling launching pit with Equipment setup. (BRH-Garver Construction, L.P., 2017)

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2.2.3. Pipe Bursting

Pipe Bursting is a replacement method - a technique for breaking the existing pipe by brittle fracture, using force from within, applied mechanically, the remains being forced into the surrounding ground (as shown in Figures 3 (a), (b) and (c)). At the same time a new pipe, of the same or larger diameter, is drawn in behind the bursting tool. The pipe bursting device may be based on an Impact Moling tool to exert diverted forward thrust to the radial bursting effect required, or by a hydraulic device inserted into the pipe and expanded to exert direct radial force. Generally a PVC or HDPE pipe is used. This method is also known as Pipe Cracking and Pipe Splitting. (NASTT, 2017)

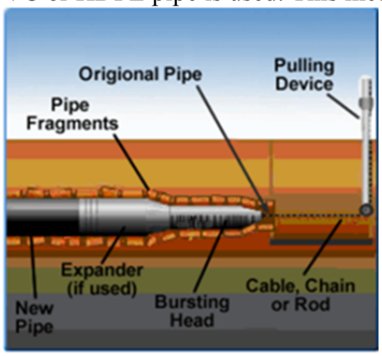

Figure 3 (a). Pipe bursting process. (TRIC Tools Inc., 2017)

Figure 3 (b). Pipe bursting operation. (A-1 Trenchless Services LLC, 2017)

Figure 3 (c). Pipe splitting operation. (A-1 Trenchless Services LLC, 2017)

2.2.4. Cured in Place Pipe Liners CIPP

CIPP is a lining system in which a thin flexible tube of polymer or glass fiber fabric is impregnated with thermoset resin and expanded by means of fluid pressure into position on the inner wall of a defective pipeline before curing the resin to harden the material. The uncured material may be installed by winch or inverted by water or air pressure, with or without the aid of a turning belt (Figure 4). (NASTT, 2017)

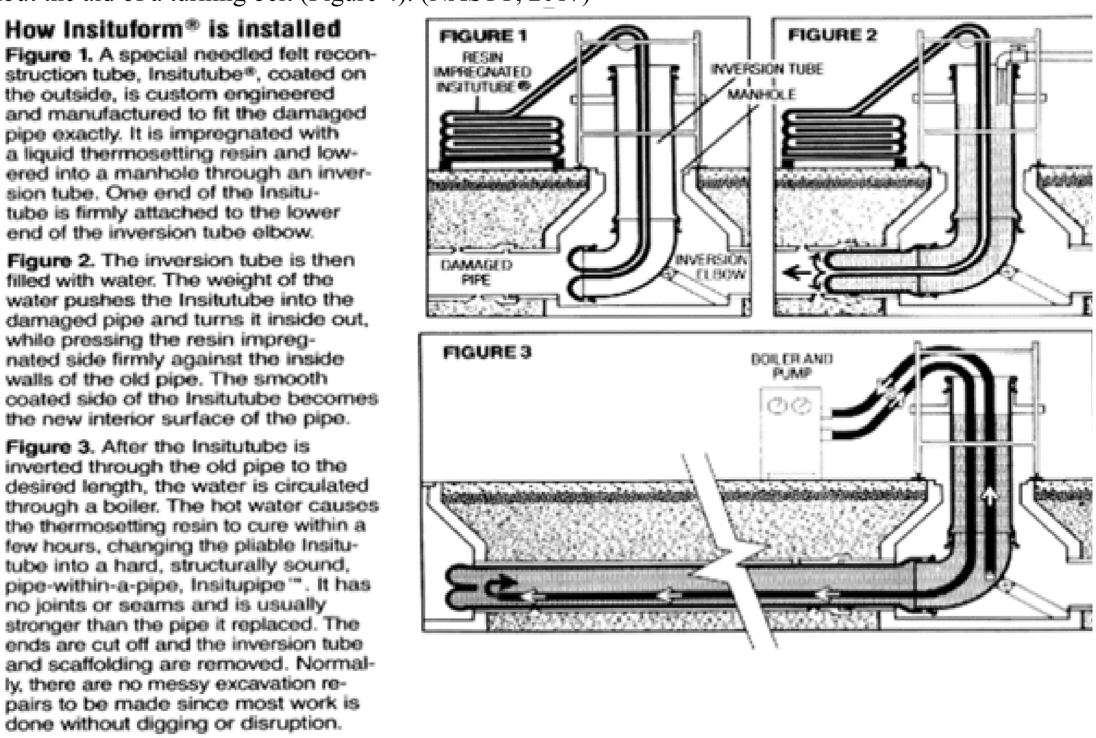

Figure 4. Typical Cure-In-Place Pipe (CIPP) Liner Installation, Source: Iseley and Najafi, 1995, (EPA, 1999)

2.2.5. Sliplining:

Sliplining (shown in Figure 5) is a general term used to describe methods of lining with continuous pipes and lining with discrete pipes. This method uses insertion of a new pipe by pulling or pushing it into the existing pipe and grouting the annular space. The pipe used may be continuous or a string of discrete pipes. (NASTT, 2017)

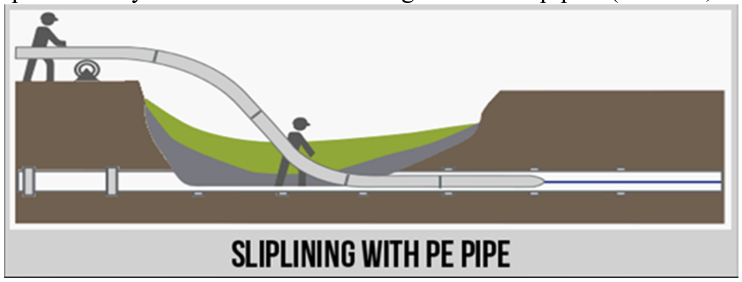

Figure 5. Typical sliplining process. (Trenchless Pipe Solutions, 2017)

3. Data Analysis

All trenchless technologies offer several advantages over the open excavation method of installation, replacement and repair of underground utilities. Some trenchless technologies, where some excavation is required as part of the system, i.e. directional drilling, microtunneling, sliplining, and pipe bursting, do not offer the full benefit of the advantages the no-excavation methods provide but greatly minimizes the implementation cost of environmental and safety control factors thereby also reducing the social cost impacts. The areas studied to establish the advantages and disadvantages of trenchless technology are discussed below and summarized in the subsequent table.

3.1. Environmental Impacts

The projects evaluated in this study presented a great advantage in the area of protection to environmental factors. It was observed that the primary area of concern for the Replacement of a One Mile PCCP 36-inch Force Main in Fairfax County, VA., was the environmental disruption that open cut would have involved taking that approach. The other benefit observed was greatly minimizing the magnitude of the Storm Water Pollution Prevention Plan and the effort that goes with the permit process, implementation and maintaining. For all project evaluated in this area, these advantages also applied for the portion where trenchless was implemented.

3.2. Safety Impacts

The area of safety was considered a substantial advantage using trenchless technology. The advantages were identified in the safety concerns that deep trenches pose such as cave-ins and fall protection. Although requirements are set by OSHA, USACE, etc., to abate potential safety problems by the installation of safety protection systems such as trench protection and fall arrest system, the absence of an excavation completely eliminates these factors. The other safety area where an advantage was observed is dealing with traffic safety and potential accidents from workers performing their duties alongside roads with active traffic as normally seen with trenching operations. The use of trenchless technology does not eliminate altogether the potential for accidents as each approach poses safety challenges in their particular implementation. The CIPP approach, that although does not require excavation, it does expose workers to traffic related safety issues and the placement of the equipment may be in the middle of the street where many times manholes are located. The others technologies such as microtunneling, HDD and pipe bursting require some excavation and many times placement of the launching equipment in the street bringing about the safety factors related to this approach.

3.3. Traffic Impacts

This area, overall, was considered an advantage based on the severity of the impact as compared to the open trench approach. As mentioned in the evaluation of safety impacts, all trenchless approach stand to impact traffic if positioning of the equipment is in the street. This is still considered an advantage because the impact to traffic is minimized due to the small foot print required. Where it becomes a great advantage is eliminating the need to cut across a heavily traffic street or highway. In the case of the projects in Misawa Air Base where two of these projects took place in an active airfield, obstructing taxiways and aprons was not allowed due to national security issues, microtunneling under taxiways became a big advantage.

3.4. Disruption to Businesses

As discussed in the literature review, open road construction in a heavy trafficked street within a business district can have a tremendous impact to businesses. Performing utility work in urban areas where there is a significant presence of businesses, trenchless technology is definitely an advantage from minimizing the disturbance and localizing construction operations to a small foot print. The businesses with the most impact are those located within the city's downtown area where open trench construction can sometimes extend beyond the schedule completion date and at times forcing small starting businesses to close their doors as a result of low sales.

3.5. Cost Impacts

Cost impacts are divided into two categories; first, direct costs, those associated with the design and construction of the project and second, indirect or social costs, those associated with the impacts attributed factors such as business losses, cost of fuel due to traffic delays and accident related costs. It is important to note that the social costs are extremely hard to quantify, thus this study does not attempt to estimate as it is not within the scope of this paper.

Figure 6 below shows a description of costs to consider in the typical approach of open trench as evaluated by G. Budhu and D.T. Iseley (1994).

Overall Cost	=	Direct Cost + Indirect Cost
Where:		
Direct Cost	=	Bidder Estimated Cost
Indirect Cost	=	Lane Closure Costs + Business Loss Costs + Fuel Consumption Loss Cost + Increased Pollution Costs + Increased Accident Costs
and		
Lane Closure Costs	=	Increased Travel Time x Average Wage x Average Daily Traffic x Construction Period for Closure
Business Loss Costs	=	(Income from Employee Reduction + Loss of Sales) x Construction Period
Fuel Consumption Costs	=	Based on Established Techniques as per Illustration
Pollution Costs	=	Based on Established Techniques
Accident Costs	=	(Number of Construction Accidents) x (Probability of the Occurrence of an Accident) x (Average Cost of Construction Accidents) + (Number of Traffic Accidents) x (Probability of the Occurrence of Accident) x (Average Cost of Traffic Accident).

Figure 6. Direct and Indirect Costs associated with Open Cut Method. (Budhu & Iseley, 1994)

3.5.1. Direct cost:

This data was obtained from the four (4) projects evaluated from the Misawa Resident Office in Misawa Air Base, Japan. The evaluation is primarily presented in general terms as a comparison of how the costs are distributed in the design and construction stages of the projects. The four (4) projects had between 15% - 30% increase in the design phase and this was expected since additional design effort was used to develop construction plans and specifications

 DOI 10.3311/CCC2018-018

specifically for the trenchless portion of the construction documents. A comparison was performed for installation cost using open cut and installation of CIPP of the sanitary sewer system repairs and replacement under the "Improve Military Family Housing Infrastructure, PH 3, Misawa Air Base, Japan. The comparison revealed a considerable difference in savings with the CIPP trenchless approach. The cost, as compared with the open cut approach, was calculated as shown in Figure 7. Figure 8 below shows the distribution of the sanitary sewer mains with the traditional open cut approach and with trenchless technology (CIPP).

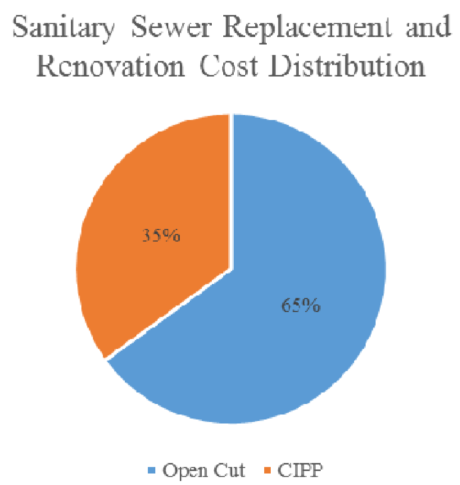

Figure 7. Cost distribution for open cut and CIPP method. (U. S. Army Corps of Engineers, Japan District, 2014)

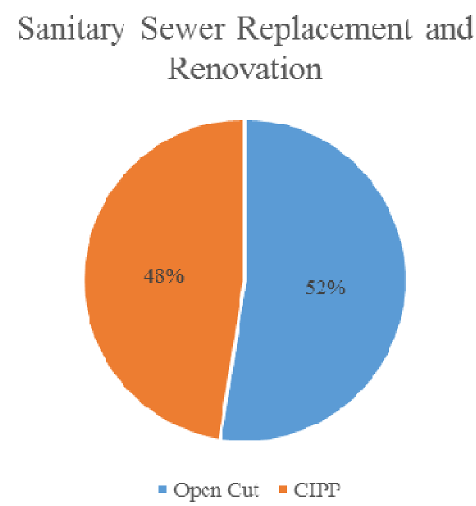

Figure 8. Distribution of sanitary sewer main installation by open cut and CIPP method. (U. S. Army Corps of Engineers, Japan District, 2014)

In this project, the CIPP approach proved to be a great advantage to the open cut method. Note that the CIPP approach was not implemented to the total amount of sanitary sewer lines in the project as some lines had factors to consider such as offsets beyond repairs and hydraulic improvements, i.e. change in slope, horizontal alignment and change in diameter.

3.5.2. Indirect/Social Costs:

These costs are extremely difficult to estimate but in comparison and taking into account the factors that are removed by using trenchless technology, qualifies this approach as an advantage in the installation/repairs of underground utilities. Note that the above factors evaluated in this study, all contribute to the social costs impacts and could be wrapped up into the social costs impact. However, the scope of this study is not to develop a formula or process to make a determination based on costs impacts but rather to provide the different approaches trenchless technology offers.

3.6. Advantages and Disadvantages by Technology

Table 1 summarizes the advantages and disadvantages that each trenchless technology in this study offers as they relate to the need of excavation to complete a project.

Table 1. Advantages and Disavantages of Trench Technology			
Technology	Construction Application	Advantages	Disavantages
HDD: Horizontal Directional Drilling	Sanitary Sewer, Storm Drain, Casings	Long runs with no trench excavation	Excavation required for Lauching and Receiving Pits. Elevated cost for small jobs.
Microtunneling	Sanitary Sewer, Storm Drain, Casings	Long runs with no trench excavation	Excavation required for Lauching and Receiving Pits. Elevated cost for small jobs.
Pipe Bursting	Sanitary Sewer(Mainly). Utilities with plastic, clay pipe.	Long runs with no trench excavation	Excavation required for service lateral reconnection. Elevated cost for small jobs.
CIPP: Cured in Place Pipe Liners	Sanitary Sewer, Storm Drain.	Long runs with no excavation	Only applicable for rehab of existing pipelines.
Sliplining	Sanitary Sewer, Storm Drain	Long runs with no excavation	Excavation required for service lateral reconnection. Elevated cost for small jobs.

4. Conclusion

Trenchless technology offers many advantages for the installation, repairs, and maintenance of underground utility systems and with the correct approach, owners stand to see a substantial savings at their bottom line when projects are completed. The method to determine the suitability of the approach to meet the utility repairs or installation will require a technical and in-depth study.

This paper provides general, non-technical information to provide utility owners with alternatives, that current technologies make available to meet their needs or open new avenues, to traditional open trench excavation for underground utilities. Often there is no single solution and a methodical selection process as proposed here should never replace sound engineering judgment. The recommendations indicated here are meant as a guide to start the decision process by focusing attention to the relevant variables of the piping system that impact the performance characteristics of the system. An expansion of this method can incorporate many more elements of both the system characteristics and the method capabilities, as well as economic and social factors. A formal selection process should offer rational suggestions to help the decision maker. (McKim, 1997)

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