# ENHANCED COST SOLUTIONS FOR BURIED FIBER INSTALLATION


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## INTRODUCTION

One of the major concerns facing the deployment of FTTX is the perceived labor cost of installation. Some of the most effective methods of dealing with cost issues will be based on innovation and cooperation among plant owners, contractors, and equipment manufacturers. There are two main installation areas related to fiber installation, the "homes passed" loops and "house drops" or service to the home from the network loops. Equipment manufacturers and installation contractors are strongly focused on bringing more cost effective solutions into play to make the FTTH network more affordable for owners and consumers. Some of the most cost effective installation methods include "bore and stitch" and directional drilling for passing homes with network loops and small plow attachments on compact utility equipment for service to the houses. "Stitch" boring with pneumatic boring tools is a favorite of contractors because of the low operating cost per foot of installation, very reasonable equipment investment and low level of expertise necessary for equipment operation. There are some drawbacks to "stitch" boring however, lack of guidance or steering is the major drawback related to this method. Directional drilling remains a popular application because of the minimal damage to the surface areas of lawns and landscapes and the ability to drill underneath roads, streets, driveways, and other surface obstacles. In addition, the cost of surface restoration related to open cut excavation is eliminated when using directional drilling.

Some of the more exciting, innovative, and cost effective activities are occurring in the area of installing the fiber service to the house. The industry is seeing a great deal of activity in the area of small compact utility equipment with attachments of either vibratory plows or new special disc plows that are especially useful in house drop situations. The vibratory plows can go six to twelve inches deep and are extremely cost effective in placing 70 to 100 foot services to houses. Double disc plow attachments are designed to minimize the impact to lawn sprinkler systems and usually bury the cable about six to eight inches deep. Another unique and innovative piece of equipment that is finding good use in service drops and hand held boxes is the Vacuum Excavators. This type of equipment is advantageous to use in congested areas around other buried utilities because of the reduced likelihood to cut or damage other lines or cables. Since it is estimated that 50% to 70% of the cost to provide service to a house is installation labor cost any equipment types that make in-roads into cost efficiencies are extremely valuable to plant owners, customers, and equipment manufacturers.

This paper will explain and discuss the types of equipment and methods that are most frequently used in network loops and house drops and the cost effectiveness of these types.

The objective of this information is to identify and discuss new cost effective trends and updated methods of underground installation for fiber optics. In addition, information will also be provided for the traditional methods and equipment used in installing fiber optics underground because these methods and equipment are still used in a majority of situations in the field. Some of the new trends are driven by the need of the construction owners for the most cost effective construction scenario possible. After all, replacing an entire nation wide copper communications infra structure is a time consuming and costly effort that requires optimum cost efficiencies in construction and eventually with operations and maintenance. This paper includes a brief explanation of the construction labor per house passed. This should be helpful in converting construction costs, which are bid and awarded on the basis of cost per foot and the type of soil conditions involved, into costs per house passed in neighborhood loops for fiber optics.

## NEW TRENDS

A recent trend in the industry is the increasing placement of more fiber optics underground (versus aerial) with the ratio beginning to exceed more buried than aerial. This is driven by several factors. From a business model standpoint the fiber optics construction owner is interested in generating lower risk and higher profit business especially during the initial startup phases of laying FTTH networks. This leads them to focus on new developments (greenfields) and wealthier existing neighborhoods where the take rate should be higher and easier to sign up. In these residential areas most local ordinances or building covenants require utilities to be buried for aesthetic purposes. In addition, more and more facilities owners are seeking the protection from storms and weather damage that underground installation offers over the long run. If aerial poles already exist, then fiber optics can be installed on these poles for lower cost than burying cables. However, there are several instances, as mentioned earlier, when it is more advantageous to place fiber underground.

As more neighborhood loops are being installed in congested areas and heavily landscaped areas there is a growing need for and use of compact utility construction equipment along with Horizontal Directional Drills (HDD). Smaller size Horizontal Directional Drills are easier to fit in narrow confines of most yards and front right of ways and yet still have adequate power to perform the jobs. In addition, compact equipment such as mini skid steers and excavator tool carriers equipped with augers and coring attachments are being used to pothole in street pavement and asphalt and expose existing buried utility lines that are in or near the path of the purposed bore. Vacuum systems are then used to complete the pothole and clean up the area. This method of potholing is faster and more efficient than digging the entire pothole with vacuum systems alone or by using jackhammers or separate coring machines.

## TODAY'S TYPICAL JOB SITE

The typical job site today for burying fiber optics in FTTH applications has taken on a distinct and somewhat different character from that of a short time ago and tends to vary from region to region. Since a large portion of the initial market addressed by the FTTH owners tends to be wealthier, affluent, and highly landscaped neighborhoods, surface damage and traffic disruptions are undesirable and efforts are focused on keeping these distractions to a minimum.
The best way to achieve these goals is through the use of HDD drilling rigs, pneumatic piercing tools, and small compact, maneuverable equipment that fits and operates well within the narrow confines of these neighborhoods. Generally, the job plan is to drill down one side of the street, usually under or near the sidewalk. Next, hand digs or buried vaults are placed nearby to service two or more homes. Then street crossings are bored under the street at about 4 different places connecting the vaults on the other side of the street. These crossings tie in houses on both sides of the street with the neighborhood loop that serves the neighborhood. Because of the congestion of existing buried utilities in these neighborhood areas, a great deal of time and effort is aimed at identifying and locating existing buried utilities to avoid hitting lines or cables and disrupting services. In some cases, more than half the construction time and activity is associated with these identifying and exposing activities of locating and potholing. Vacuum systems mounted on trailers and skids have proven to be quite effective tools to perform this job. Vacuum systems perform soft excavation activities quite well and are good at cleaning out exit areas as an alternative to digging an exit pit, and also serve to clean up job site spoils such as drilling fluids and loose mud. Today a typical job site may contain 3 drills with 3 man crews each, 2 vacuum systems with 1 to 2 men per system, a small mini skid steer, and an excavator tool carrier. These compact utility equipment machines when equipped with augers or coring attachments are useful at coring and potholing through the street to expose existing buried utilities such as water mains, gas mains, or power lines. The inherent versatility of compact equipment machines, such as mini skid steers and excavator tool carriers, with their ability to utilize multiple attachments can also be advantageous and increase productivity on the jobsite.

By simply changing the attachments on the compact equipment, many of the common tasks associated with the jobsite can be performed by one unit. Generally, crews of this nature try to achieve 300’ of drilling and two street crossings of about 100’ each per day.

However not all jobsites and construction objectives are identical. In some situations, the tradeoff favors reducing cost expenditures rather than an emphasis on schedule. If the price being paid for the construction labor is marginal then outside plant contractors will choose other higher paying jobs for using their equipment. On a lower paying jobsite, the HDD rig and crew may be a sub contractor drilling only for a week or two at a time or maybe only a few blocks at a time. The sub contractor and contractor will always be seeking to obtain the highest price available for the use of his crew and equipment to maximize his return on investment (ROI). Some manual labor may be utilized to supplement and keep the construction efforts going while waiting for the availability of HDD rigs on the jobsite. Also, other types of equipment such as trenchers, plows, and rock saws will be utilized for installing fiber underground where conditions allow for this equipment.

## METHODS AND EQUIPMENT

Included among the underground construction techniques to be examined in some detail are Horizontal Directional Drilling (HDD) and other trenchless methods, vibratory plows, and open cut trenching. HDD and trench less methods incur little if any surface damage and vibratory plows have minimal impact on the landscape. Both of these underground construction techniques require minimal surface restoration and enhance job site productivity. In some situations, surface obstacles such as driveways, sidewalks, streets, and parking lots dictate the use of HDD rigs. And currently, the preferred method of installing fiber optics in new developments or greenfields is underground burial. This choice is driven by maintaining and improving the aesthetics of the residential areas and homes. Generally speaking, open cut trenching is a low *initial* cost method of burying fiber optics. Open cut trenching can be utilized in open areas with undeveloped land and few buried obstacles. In summary, the advantages of buried versus overhead fiber optics include protection from stormy weather, aesthetic appeal, improved productivity, and lower long term costs for maintenance and upkeep.

## SITE PLANNING

Installing fiber optics underground requires a great deal of site planning and preparation, particularly from an obstacle avoidance and safety perspective. On an overhead installation, generally, the poles are already in place and the main issue is rearranging the position of the existing aerial lines if needed. Typically, over 45 % of the telecommunication lines are buried with almost all new lines installed underground. When fiber optics and other utility lines are to be installed underground this raises additional issues of path planning, soil types, buried obstacles, required depths and size of buried lines.

The first step in site planning and preparation is to obtain the customer engineering plans for the installation. These plans may be simple and straightforward or they may be elaborate and detailed drawings. From these plans, a construction plan and route may be created. These plans should show the utility right-of-way, which will be the general path of installation of the utility or fiber line. Also, these plans will disclose street and road crossings, river crossings, if any, and hopefully, the location of other buried utilities in the area. After the general layout of the path of the utility or fiber line is determined, a walkover or drive over on the actual job site should take place. This visual inspection process should identify any surface obstacles such as trees, buildings, driveways, meters, transformers, poles and signs that must be dealt with.

In addition, the job site inspection allows the rising and falling of the terrain to be evaluated, and surveyed if necessary.

## HORIZONTAL DIRECTIONAL DRILLING (HDD)

If Horizontal Directional Drilling (HDD) and other trenchless methods are to be used as the method of installation, taking into account the terrain features and soil types are key to a successful and efficient boring operation. When boring in sloping ground, either uphill or downhill, the bore must be kept parallel with the surface of the ground to avoid protruding from the ground at the wrong place. This requires the bore to be guided at the necessary upward or downward angle to maintain the required depth below the ground surface.

Special electronic instruments are placed inside the drill housing to determine the position (12 o'clock, 3 o'clock, etc) of the bit and transmit this information to the surface. An electronic receiver on the surface receives the information and also determines the distance (depth) of the drill bit from the receiver on the surface of the ground. These electronic tools, along with a slant-nose drill bit angled like a shovel allow the drill rig operator to steer or guide the bit through the ground to complete the desired underground installation pathway. To steer, the operator places the bit at the correct orientation for the desired direction (12 o'clock to go up, 6 o'clock to go down, 3 o'clock to go right, and 9 o'clock to go left). He then pushes without rotating for a few feet. This motion forces the bit to be deflected in the direction of orientation and the bit changes to the desired direction. Once the bit and the drill pipe are orientated in the desired direction, the operator then begins to rotate the drill string which causes the bit to continue on in the desired direction.

After the pilot bore is completed, usually connecting an entrance pit with an exit pit, then the bit is replaced with a larger back ream tool, the drill string is pulled back and the pilot bore is enlarged to the desired diameter. Sometimes the product to be installed, the utility or fiber line or conduit(s), is pulled in and installed right behind the back reamer on the first pullback.

The advantages of the HDD method are a minimal surface disturbance with little need to restore turf or streets, except at the entrance and exit pits. Also, HDD allows installations underneath streets, sidewalks, rivers, landscapes, and in some situations even beneath buildings which can't be done with trenching or plowing or other surface open cut methods. However, HDD does require more training than other methods and involves the use of mud mixing capabilities to enhance the boring process through the ground. Also, mud disposal methods using vacuum systems are necessary to maintain a clean job site and in some cases required by local ordinances. Because of the greater capabilities and less clean up and surface restoration required with HDD rigs, the cost per foot is usually higher for this type of underground installation. However, cost savings can be achieved with less surface damage and traffic disruptions.

When using HDD rigs, extra care should be taken in locating other buried utility lines in the vicinity of the new construction activity. *One-call locates should always be called and all buried utilities in the proposed construction area should be marked by paint on the ground.* Location and type of buried utility will be designated by the paint on the ground but depth will not be shown. When the proposed new underground construction crosses or comes within 24" to 36" (the distances vary from state to state) of existing buried utility lines, *then these existing lines need to be exposed by hand digging or potholing with vacuum systems.* It is important to monitor the progress of the pilot bore and the back ream as they cross or come near to the existing buried utility to prevent any accidental hits on the existing line. Generally, *more hits occur during the back ream process than on the pilot bore.* This is because the back reamer is a larger diameter than the pilot bit and also tends to rise up higher through the ground during the pullback operation.

Typical productivity rates for HDD bores, depending on terrain, surface and underground congestion, and soils usually average about 400' to 600' per machine per day. A very general rule of thumb would be about 100' per hour for pilot bore and back reaming with a HDD rig. The

HDD rigs usually have a crew of 2 to 3 per rig. Typical costs for HDD drilling for fiber work ranges from $7 to $10 per foot in normal soil conditions. Usually the HDD rig would drill a 4" hole, back ream to 6" and pull back a 2" or 4" conduit for fiber lines. Most of the time the installed depth would be 18" to 24" or 30" deep, but can go deeper if necessary.

## PIERCING TOOLS

In addition to HDD rigs, another method of trenchless underground installation includes pneumatic driven piercing tools. Sometimes referred to as "missiles," these are fairly small, light weight, tools powered by an air compressor. Piercing tools resemble the front end section of a HDD drill string without the rig power unit. They are launched from a pit dug at the desired depth of installation and have no guidance capabilities and are only for short range operations. Generally, they are used to cross underneath driveways, sidewalks, and roads. They are placed in the entrance pit, leveled, and launched toward the exit pit as the desired target to hit. Some advantages of pneumatic piercing tools are low operating cost per foot of installation, reasonable equipment investment, and minimal expertise required for operation of the equipment. Entrance and exit pits, usually about 24 inches deep, are placed about 25 to 40 feet apart. In an eight hour day a crew of five can be expected to achieve anywhere from 250 to 450 feet of production, depending on soil and surface conditions.

## BORE AND STITCH

A method utilizing both methods of trenchless installation that is being used today is called "bore and stitch." In this technique, a HDD rig bores from one end of the block to the other end. The bore intercepts two or more pits placed along the block in the path of the bore. These pits contain house boxes that will connect to two or more houses. From these pits, a piercing tool is launched under the street to hit (stitch to) similar house pits serving houses on the other side of the street. This application allows boring down only one side of the street to service the entire block. In addition to "bore and stitch" there is also "stitch boring" where pneumatic piercing tools are used to provide neighbor loops for passing houses and for installing service lateral lines to houses. This is a process where pits are dug about 30 feet apart and piercing tools are used to stitch the bore from pit to pit.

## VERIFY EXISTING LINES LOCATION AND DEPTH

Because of the possible negative consequences of accidentally hitting an existing buried utility line and to determine depth, contractors frequently will verify and confirm the locating marks placed by one call employees using their own locating equipment. Most contractors will use electronic line locators to detect the location and depth of buried lines. These locator systems consist of a transmitter to impart a signal on the line to be located and a hand held receiver to detect the location and depth of the existing line. Lately, with improvements in technology, more contractors and utilities are able to use Ground Penetrating Radar (GPR) units to determine the location and depth of buried utility lines. GPR units are also capable of locating non-metallic pipes such as HDPE or PVC used for water and sewer. Success in using these GPR models is usually heavily dependent on soil types. Generally, GPR works better in dry sandy soils than in wet clay soils.

## SELF-CONTAINED VIBRATORY PLOWS

Another frequently used method to install utility and fiber lines underground involves self-contained vibratory plows. These construction equipment units pull behind them a plow blade resembling the rudder of a ship. The bottom tip of the blade is hollow allowing a utility or fiber line to be fed through the bottom of the blade into the ground as the plow moves ahead. These plow blades slice through the ground to a depth of about 24” and accommodate product diameters 1” to 3”. They utilize a powered shaker box that actually causes the plow blade to vibrate which increases productivity. There is minimal surface damage, similar to cutting through the ground with a thick knife.

An additional feature of some self-contained vibratory plow units is the ability to mount a small rotary drilling unit on one end of the plow. This small drilling unit has the capability to drill under driveways and sidewalks. It can not be guided and requires some skill to complete the bore under the driveway or sidewalk.

Productivity rates for vibratory plows can vary greatly depending on the type of soils and terrain and the depth of plowing. However in favorable soils, plowing a 2” diameter conduit at 18” to 24” deep, a productivity rate of 800’ to 1,000’ per day, per unit can be averaged with larger plows. Cost rates for plows usually run from $2 to $4 per foot. However, plows can not work in all soils. Rocky, cobble, and thick heavy clays are not suited well for plow work.

## TRENCHERS

Trenching, as a method of installing utility or fiber lines, has been around since the ‘50’s. In most situations it has replaced hand digging and is useful, especially in new developments and non-congested areas where surface and landscape restoration are not as critical or expensive as in overbuilds. Trenchers can install 2” to 4” diameter conduits at depths of 24” to 30” cover or even larger and deeper depending on the size of the machine. Trenchers can trench in favorable soils at approximately the same rate as plows per unit per day. After the product is installed, the trencher backfills the trench with a backfill blade. There is more soil disruption and site disturbance associated with open trenching than with plowing and HDD drilling so it is less preferable than trenchless methods in established neighborhoods with existing lawns and landscapes. The cost for installing fiber with trenchers averages from $4 to $6 per foot.

Rock or concrete saws can be attached to the trencher unit and are helpful in cutting small 3” to 4” wide slots in road and street right-of-ways. As an alternative to tearing up the street, a rock saw can produce a small slot 18” to 24” deep in which to install the utility or fiber line. Fill dirt is then put in the slot and the top 2” to 3” of concrete replaced but this is more attractive than digging up the street and hindering traffic flow in the area. Production rates for concrete saws doing street work can approach about ¼ to 1/3 the rates of plows or trencher in soils. Rock saw work can cost from $7 to $9 per foot.

## CONSTRUCTION JOB COSTS

Earlier, costs per foot were estimated for various methods of installing utility and fiber lines underground. While costs may range from $7 to $10 per foot just for drilling, the combined cost of drilling, potholing, and other construction activities may approach $12 per foot. Total costs for drilling/trenching, finishing, restoring, setting boxes, and the tie-in of all connections may run as high as $15 to $30 per foot. Perhaps another more relevant way of viewing the cost of passing homes would be to take the construction labor cost per home passed and not the cost per foot. After all, it is the home passed and connected that will eventually generate the revenue for fiber providers. For example, assume a city block varies from 660’ to 900’ long and contains 16 houses per block. Running the neighborhood tie line under the sidewalk on one side of the street and connecting it to houses on the other side of the street with four 100’ long crossings under the street would total 660’ plus 400’ of boring. Assume one buried vault would link to two houses. This would amount to four buried vaults on each side of the street for 16 houses per block. If buried vaults cost $75 apiece then eight vaults would cost $600 per 1,060’ (660’ plus four street crossings of 100’ each) of boring for this block of 16 houses. If the total cost per foot for burial of fiber is $10 and the cost of hand-digs or vaults adds another $0.57 per foot then the total cost of construction labor is $10.57 for this situation. Thus, the total construction labor cost to pass 16 homes on this city block would be $11,204 or approximately $700 per home passed. If the rate of construction per foot were higher, then 1,060 feet of underground installation at $15 or$30 per foot would amount to $15,900 to $31,800. If this construction passes 16 homes, eight on each side of the street, then the cost per home passed would range from $994 to $1,988. These estimates depend on the density of housing in the construction area as well as other factors such as soil and clean up requirements. In addition to these construction labor costs are the cost of the buried vaults, the buried conduits and fiber optics, along with the other materials costs involved in passing the home activities.