iJRASET
International Journal For Research in Applied Science and Engineering Technology

# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

**Volume:** 6 **Issue:** XI **Month of publication:** November 2018

**DOI:**

www.ijraset.com

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887*
*Volume 6 Issue XI, Nov 2018- Available at www.ijraset.com*

# Effectiveness of Trenchless Technology in Waste Water Disposal System: A Review

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***Abstract:*** ***In India, waste water disposal systems are usually managed by local bodies. In a few specific cases these are managed by State Government Department/ Statutory Boards set up by State Government. The development of the sector is assisted at three levels(Government of India, State Government Level and Local Body Level).Now in Indore trenchless technology is adopted .Government has issued legislation, based on the inherent advantages, government has facilitated and encouraged the corporations & councils to adopt the technology in their cities. The success story of Indore shows how they introduced the technology. For crossing of railway tracks, canals and even river beds etc. Trenchless technology is the right choice. Trenchless technology is helpful to the policy contributes to the bank's mission of poverty reduction and sustainable development by ensuring that the development process fully respect the dignity, human right, economies and cultures of Indigenous people. The bank provides project financing only where free, prior and informed the affected Indigenous peoples. The government of Madhya Pradesh is also focussing more on infrastructure development. and is welcoming the technologies in all fields those easy to service for residents about environmental and traffic easiness. India provides trenchless technology as part of public health engineering projects to serve the millions with drinkable water and sewer for sanitation and water storm drain in urban area like rural area. The time has come when the conventional method of open trench digging will be selectively banned or not prefer in cities where dense population and traffic problem due to passing of more vehicles. To begin with work should be under taken the crossing, under roads, national highways, railways, canals, rivers etc. and all renovation of sewerage systems in metropolitan cities. Municipal authorities all over India lay guide lines to adopt the trenchless technology as in Indore. Municipal Corporation Indore has adopted this trenchless technology. National highway authority, Ministry of surface transport, ministry of environment communication, water resources, petroleum etc. can issue departmental letters to their engineers to adopt trenchless technology. Partially trenchless (some open excavation required) technology and fully trenchless technology have benefits as a methodology for renewing or rehabilitating comparatively in open trench technology, when discuss about comparisons of cost and factors that impact on a project. In Indore city laying of sewer line by trench less technology method. Municipal Corporation Indore desirous that certain works should be executed by the contractor (M/S EMS-HIMAL HYDRO JV C/O M/S coastal projects LTD.). In this project scope of work is "Providing, laying, jointing, testing & commissioning and allied works of secondary sewerage system to connect the secondary sewerage out fall discharging the sewage in khan & Sarasvati rivers of city to the primary sewage network, under sinhasths 2016 works probable cost of this project is Rs. 41.45 crores. Length of sewer line is 24.69km, RCC pipe ranging from 200 mm to 1400mm are used. This work is conducting for connecting secondary sewers, those falling directly in the rivers to the primary sewers which are already laid under JNNURM. After laying of sewer line by trench less technology and the treatment of sewage at sewage treatment plant the treated sewage can be used for farming purpose. This dissertation focuses on trenchless technology cost savings gained social and environmental factors associated with underground municipal pipe construction.***
***metropolitan cities.***

***Keywords: Trenchless technology, open cut, cost comparison, social, environment, direct, indirect, sewer, pipe jacking, construction.***

## I. INTRODUCTION

### *A. General*

The concept of digging of open trenches, that is a common practice for laying of almost all utility services beneath the ground. Cutting of highways and busy roads in the municipalities area causes the traveler and residents suffer a lot due to delays, accident. We observed that those suffering are not given due importance. About this our opinion that the time will soon come when the conventional method of open trench digging will be selectively banned in India and Municipal authorities all over India should lay guide lines to adopt the technology. They found that enough know-how and technology is available to make a beginning in the field. Governments need to issue regulations those are helpful in development of trenchless technology.Since the beginning of human

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*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887*
*Volume 6 Issue XI, Nov 2018- Available at www.ijraset.com*

civilization as seen in Mohenjo-Dero and Harappa and elsewhere in the world digging of open trenches as drains for water supply, sanitation, channels for irrigation etc. Open trench was a common practice, which is for laying of underground service as communication cables, petroleum, gas pipe lines, water supply, sewerage pipe lines underground the surface. Digging of open trenches is a simple method, which has not any problem due to labour intensive method. Cities are growing more population have road congestion with more vehicular traffic cause of jams, increasing emission and a pollution problem including accident etc. Adding to these if streets are dug for laying pipes and cables either new or part of renewals/ repairs; it will aggravate the situation further. If it happens to be a rainy season or involves dewatering, they will have the poor commuters suffer for many days till the work is completed. In India, we still do not much value for the social costs involved in such delays. (Gunjal et.al, 1996).

*B. Type of method*

There are two type of method- those are consider for laying the pipe line to various utility:

1) *Open Trench Method:* The open trench method is also known as conventional open cut method. Open trench method is a traditional method of trenching for laying the utility lines below the surface. That is widely used, which involves excavation of a trench, usually with a backhoe. The pipeline trench is excavated to the line and grade and can be vertical sided, V-shaped, or stepped (Jung et al, 2007). The workers produce another open trench method of installation, renewal and repair. It includes the development of all kinds of underground mapping techniques, tunnelling devices and special materials and equipment. The accepted types of installation or construction conditions are shown in Fig. 1. Ground floor

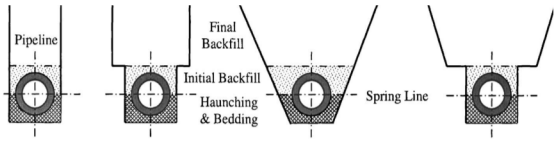


Fig.1 Classification of construction conditions in Conventional Open-Cut Method of Pipe Construction(Jung, 2007)

There are many disadvantages and difficulties in adopting this method, mainly in major cities of urban area. These are described below:

Inconvenience to vehicular, pedestrian traffic(Jung, et. al. 2007)

*a)* Disruptive open-cut methods are often not acceptable when working in the underground infrastructure systems. Increase in traffic congestion can cause major inconvenience to the public, and decreased road lane widths can make road accidents more likely to occur.

*b)* *Worker Safety:* Safety in the trench is a matter of grave concern when performing the open-cut method. OSHA estimates that nearly 63 workers are killed due to trenching accidents each year. In fact, the accident rate for trenching work is about 112% higher than that for construction in general. (Jung, et al.2007).

*c)* *Interruption of Local Businesses:* Local businesses around congested construction sites are likely to lose customers due to traffic disruption or loss of access from the open-cut method. This may also result in loss of sales tax revenue for the local government.

*d)* *Impact on Residents:* Major inconveniences such as traffic congestion and passing delays are often imposed on neighbour-hood and residents when the open-cut method is used near their homes. The original users of the road have to undergo hardships in the form of additional mileage as well as time. Many a times, while cutting deep trenches in congested areas problems appear in the adjacent buildings

*e)* *Impact for Roadways:* The open-cut method often requires removal of pavements followed by subsequent restoration, which significantly reduces pavement life. Surface subsidence of the pavement from the cutting and patching process in the open-cut method can reduce pavement life by about 40%. As the open trench is going to create obstructions at roads in busy areas, diversions have to be provided before the start of any digging work, the traffic has to be diverted causing traffic jams

*f)* *Impact for Existing Utilities:* Existing utilities near the construction site are often damaged by subsequent soil settlement or trench and compaction techniques during trench excavation.

*g)* *Soil Disposal:* Contaminated soil is often encountered during pipeline construction. The open-cut methods require removing large volumes of soil. The disposal of this material, which requires specialized equipment and labour, can be costly.

*h)* *Air Pollution:* Fine soil particles may become airborne in the form of dust due to wind blowing over the soil stockpiles created during the process with the open-cut method.

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i) *Water Pollution:* Rain or water encountered during construction using open-cut methods can cause soil erosion and contaminated solids runoff into streams, rivers, and sewers.
j) *Noise Pollution:* The open-cut method requires the use of heavy equipment that produces high levels of noise, which can cause a great deal of disturbance, especially to established communities and residents.
k) *Land Defacement:* The open-cut method frequently causes damage to grass, trees and other landscaping features and can have negative effects on conservation initiatives of modern society. (Jung, 2007)
2) *Trenchless Technology:* This is an alternate method to conventional open trench technology. Trenchless technology is the science of underground pipes, cables, conduits and ducts laying for new installation, rehabilitation and renovations, using techniques which has minimal need for excavation or eliminate it. It can minimize environmental damage, social costs and protect trenchless users and the designing stage and non-trenchless projects planning element. Development of technology for sewer pipeline installation today brings alternative method that can be used in installing the underground pipeline which is able to decrease the cost and time of the project.

### C. Aims and Objectives

The rivers which are flowing through the cities, are generally polluted due to drains waste water. So for trapping all such drains falling in these rivers and divert converting them to sewerage plant. The waste water pipes lives are usually laid for the purpose.
Two method namely- (1) Open cut and (2) Trenchless technology are used commonly.
The objectives of the dissertation are as below

1) To review the literature on application of methods based on trenchless technology.
2) To compare the trenchless technology and traditional open trench method for laying of pipes on roads with different pavement types.
3) To compare the trenchless technology and traditional open trench method for laying of pipes with different traffic condition.
4) To compare the trenchless technology and traditional open trench method for laying of pipes in commercial area and residential area.

### D. Scope and Methodology

In the present work the study is carried out to compared the open trench technology with. Trenchless technology. The analysis is limited to the work, which involves diverting the waste water drains to sewer treatment plant, so as to protect the river which flows through the heart
of cities. Two cities of Madhya Pradesh namely Indore and Gwalior are considered in this study.
Comparison of two method is made for different side conditions namely.

1) Rigid and flexible pavement,
2) Commercial and residential area, and
3) Heavy traffic versus less congested road

Cost is parameter for the comparison. The cost involves cost for laying of pipe and equivalent cost towards social and environmental factors.

## II. TRENCHLESS TECHNOLOGY

### A. General

Trenchless technology consists of the methods, materials, and equipment used for replacing, rehabilitation or installing pipes with little or no excavation of the ground above. It also makes it possible to install the utilities under, highways /railways; rivers/ canals and other obstacles with no need to divert the flow and minimum damage to the environment. (Kramer et all,1994). It is a rapidly growing sector of the engineering industry. The type of construction technology below surface of the ground in which no need of continuous trench excavation for laying pipes, conduits and other utilities. Trenchless technology is arguably the fastest-expanding technology applied in the construction today (Jung,2007) The concept of trenchless construction method was started from 1900's (Duddala, 2016). The pipe jacking was originated between $6^{th}$ decade of the 19th century. In the 1950s and 1960s, new capabilities were added to pipe jacking by European and Japanese companies. The micro tunneling concept which is one of the methods of trenchless technology, originated in Japan in the late 1960s as the result of the public's demand to control water pollution and to improve the environmental surroundings. Horizontal Directional Drilling (HDD) technology evolved from boring techniques employed in the 1960s for the underground installation of cables and conduits in urban areas and originated in the petroleum

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industry during the 1970s. Pipe bursting was first developed in the United Kingdom during the late 1970's for the replacement of small diameter cast iron gas mains.(Najafi, 2005) As time passed new method got added with new studies and innovation. The trenchless method during underground construction is mainly to avoid problems and nuisance arising from surface and subsurface disturbances. Demand for installation of new underground utility systems in congested areas with existing utility lines laid at shallow depth has increased the necessity for innovative and economical systems to go below and alongside in-place facilities. Environmental concerns, business interruptions, traffic obstructers, social [high user costs due to the disruption to traffic and adverse impact on nearby business(indirect)] costs, new and more stringent safety regulations, difficult underground conditions (containing natural or artificial obstructions, high water table, etc.) and new developments in equipment have increased demand for trenchless technology. (Najafi,2005). During the past few years, trenchless technologies have been gaining popularity in the area of existing buried utilities. The methods of trenchless technologies applying for pipe line laying in various utilities, such as -(i) Gas pipe line. (ii) Oil pipe line. (iii)Water pipe line. (iv) Sewer pipe line. (v) Power cables(vi)Telecommunication cables, etc. and structures such as (vii) railway, (viii) high-way (ix)canals-rivers and (x) building, etc. due to economic, social and environmental factors. (Kakadiya,2017)

*B. Advantages of Trenchless Technology*

Need of Trenchless Technology always increasing and required due to more beneficial in all aspects of residents and vehicular/pedestrian traffic. Main studies have shown the following advantages of trenchless technology proves to be better approach for difficult site conditions. Compared to conventional methods employed for providing underground utilities, the trenchless technology is convenient and possess large number of advantages. Some of the advantages offered by trenchless technology are as described in following section.

1) *Less Disturbing:* No more disturbance occurred in the field , so by use of Trenchless technology come out from these problems like landscape and paved surface damage. (Chote and Kadam et al, 2016).
2) *No More Time Consumption:* Techniques in method of trenchless is less time consuming method. In this method less time is required for the excavation and refilling of trenches comparatively tendential open cut method. This process less time is taken in site restoration, spoils storage and traffic control. Faster construction due to the use of modern machineries and skilled man power can be used in environmentally sensitive location, crossing of buildings, roads, highways and railway lines.
3) *Enhanced Safety Compared To Steep Open Trench Excavations: Landslides* can be occur due to steep excavation, Where the mud is likely to diminish due to steep walls or water aggravation, specialist and equipment essential to taken with needs of protection. By trenchless technology provided safety to the workers as there are no steep trenches involved in this work. Used in difficult geological situations.
4) *Save Time And Cost Related To Survey And Design:* In trenchless technique saved time and cost related to survey because no need as well in open cut method consist of preliminary survey, detailed survey etc. In detailed survey consist of the depth of the cut, the ground conditions where the trenches will run and also how much dewatering will need to take place for that conditions are safe to work.
5) *Encountering To Fewer Unknown Problems In The Ground:* In open cut method, more part of the cost required for excavation and replacement of the ground during the process. As per unknowns as public hesitancy come in the excavation or digging cost of excavation increases. This problem can be reduced.by use of Trenchless technology.
6) *No More Disruption To Existing Utilities:* At the time of trenchless technology, most important problem of disruption to above surface activities decrease. as well as at the time of digging has to avoid existing utilities. Trenchless technology comes with the ability to install new pipelines and rehabilitate existing pipelines with limited disturbance to traffic and business activities, reduce damage to existing paved surfaces.
7) *Decrease The Problems To The Public Such As Noise And Air Pollution:* The indirect social costs as traffic congestions can be reduced, causes for consist of unhealthy, inconvenience to traffic, and noise pollution. these problems can play a big role in hesitation of local communities. These problems can be overwhelmed with no-dig method ( trenchless technology) and no need for road divertions and noise disturbance. An Environmentally sound technology, handle all residual waste in a more environmentally acceptable way means Less polluting. Wide range of uses. (Mohan Priya et al, 2015)

*C. Limitations Of Trenchless Technology*

1) If the underground strata consist of both soil and hard material like rock or boulders different type of machine will be required which may inconvenient and uneconomical

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*2)* Ground obstacle like existing services, old pipe lines etc. may create a problem.

*3)* Precise control of gradient and alignment are sometime difficult to achieve, and large tolerance should be acceptable with certain machine and in certain ground conditions.

*4)* Equipment for trenchless technology is presently not manufactured in India while planning the work. The machine operator should have extensive experience in this work. [sd0710/6]

*5)* Trenchless technique provides assistance to the utility developers and managers to execute works remotely. without The physical entry of the (operator) is restricted at the exact work location, then a substantial portion of work is done through mechanical means. For an example in a micro tunnelling and pipe jacking project the earth face of tunnel is excavated by the cutter and a slight error in the alignment or project / tunnel deflection lead by grade of the cutting shield.

*D. Methods of Trenchless Technology*

Depending upon the purpose whether the method is to be used for New Installation or Rehabilitation / Renovation, the methods applying can be categorized into two part (i)Methods for New installation , and (ii)Methods for Rehabilitation and Renovation The details of various methods are described in following sections.

*1)* *Trenchless Methods For New Installation:* The method is commonly known as the Trenchless Construction Method(TCM). It involves different techniques that are related to the commencement of a new work or new project in underground. It may be a new pipeline, conduit or any other new utility installation below the surface at the site. (Chote and Kadam, 2016) Following techniques are commonly used for new installations(a) Micro tunneling (Myers et al,1999). One rapidly growing type of trenchless technology is micro tunneling. The micro tunneling concept which is one of the method of trenchless technology, originated in Japan. The existing conditions of high population density and traffic congestion throughout, Japan initiated a need to develop a method to perform the construction work with minimal disturbances to the surface. (Myers et al.,1999). Komatsu Tokyo, introduced the first micro tunnelling machine in 1975. Iseki Inc., Tokyo, soon followed with the introduction of its first machine in 1976. This technologically advanced equipment opened the doors to the new market of micro tunnelling methods in conduit construction. Micro tunnelling was first introduced into the United States in 1984, when 188 m of 1.83 m diameter sewer pipe line laid. Micro tunneling can be defined as a remotely controlled and guided pipe jacking technique that provides continuous support to the excavation face and does not require personnel entry into the tunnel, Micro tunneling is a systems where the spoil is removed from the cutting head within the new pipeline which is advanced by pipe jacking. Micro tunneling is used extensively in sewerage work where surface disruption has to be minimized. The micro tunneling process is applicable to conduit construction in areas of contaminated water. The principle of the micro tunneling process is the ability of the micro tunneling boring machine (MTBM) to control excavation face stability by applying mechanical or fluid pressure to counterbalance the earth and hydrostatic pressures imposed To perform this ‘‘tunnelling ’’ process, the micro tunnelling technique uses a variety of technologically advanced equipment and systems. The basic micro tunnelling system may be divided into four basic integrated subsystems. These include MTBM, slurry circulation/ spoil removal system, pipe jacking system, and information and control systems, as shown in Fig.2.1. MTBM. The MTBM consists of a pressure balanced cutting chamber and a slurry spoil removal system. The cutting chamber consists of a cutting-head that is fitted to the front of the MTBMs This cutting-head contacts the soil/rock and controls the bore diameter. Modern-day MTBMs are designed to be fitted with cutting-head extension units so that each MTBM can be used to install a wide range of pipe diameters. The machines are electrically or hydraulically powered to provide the optimum efficiency in creating the high torque needed in the cutting process. Also, most MTBMs are equipped with a variable frequency drive (VFD) on the drive motor to allow for precise speed control of the cutting process to provide the machine with the ability to adjust RPM and thrust, in order to accommodate varying soil conditions. Rock crushers behind the cutting head assist in crushing cobbles. High-pressure jetting nozzles, installed in the MTBM, are used to assist with excavation. The cutter head or closed face attachment is connected to an inner drum, which is rotated by hydraulic motors. As the drum turns, the teeth (on the cutter head) excavate the face and the spoil falls into the drum. Scoops in the drum dump the spoil onto a conveyor that transfers it for removal. Hydraulically operated torque wings prevent rolling of the machine. Laser guidance systems are an integral part of the MTBM These guidance systems typically consist of a laser mounted in the jacking pit/shaft, which communicates a reference line to a target mounted inside the MTBM’s steering head. This system is essential to the accuracy of the tunnelling process. These guidance systems accurately measure the x- and y-coordinates of the MTBM, MTBM roll, MTBM incline, and yaw, and calculate the anticipated position of the MTBM. The MTBM guidance system feeds the control console with data, which is displayed for the machine operator. Micro tunnelling consists of using a remote controlled tunnelling shield to excavate a bore in which temporary steel

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tubes are jacked in and removed at the next manhole position, the product pipe line is installed in it. The presence of a control container with a hoist for pipes lowering in the drive shaft. Pipe installed from drive shaft to reception shaft. Noise levels and traffic disruption are minimized. It is normally used for longer distances and larger diameters(drives over 25 meter and 1.2 meter diameter)

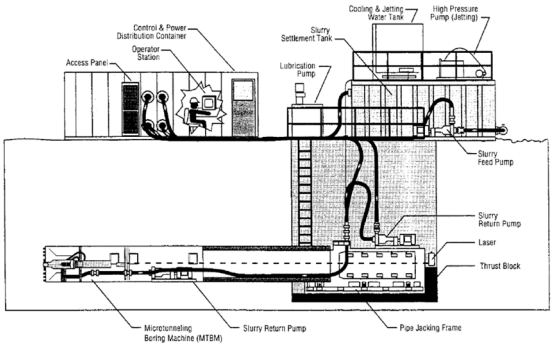


Figure 1. Cumulative Micro tunneling Installations for various pipe materials(15/58)

*a) Micro tunneling Process*

The basic micro tunneling work sequence can be described as follows:

*i)* Excavate and shore the jacking shaft.
*ii)* Set up the control container and any other necessary surface equipment near the jacking shaft.
*iii)* Place jacking equipment into the jacking shaft.
*iv)* Place the hydraulic rams in the track and adjust to the proposed design line and grade of the conduit.
*v)* Place the micro tunneling boring machine MTBM on the jacking tracks (this includes simultaneous installation of the laser guidance system).
*vi)* Connect the jacking push-plate of the hydraulic rams to the MTBM.
*vii)* Advance the (MTBM) through the prepared sidewall opening in the jacking shaft support structure using the hydraulic rams. Begin tunnel excavation and spoil removal.
*viii)* Continue the excavation and spoil removal until the MTBM is installed.
*ix)* Retract the hydraulic jacks
*x)* Place the first conduit segment on the jacking tracks. (This is usually accomplished using a small crane or hoist to lower the pipe segment into the shaft.)
*xi)* Mate (connect) the push plate to the conduit and the conduit to the MTBM.
*xii)* 12 Initiate the forward advancement of the combined system, and thus continue the excavation and spoil removal.
*xiii)* Repeat the jacking cycles, pipe by pipe, until the conduit is installed.
*xiv)* Just prior to step 13, a reception shaft needs to be excavated at the end of the conduit run. This shaft is necessary for the removal of the
*xv)* MTBM upon completion.
*xvi)* Remove the jacking equipment from the drive shaft
*xvii)* Grout the annulus of the installed pipe/conduit.
*xviii)* Construct manholes, junction chambers, and structures at shaft locations.
*xix)* Remove and backfill the shafts.

*b) Pipe Jacking (PJ [37]:* Pipe jacking is a technique or trenchless technology method for installing a pipeline through a bore, created by a shield machine. Pipeline is hydraulically jacked process, it implies a tunneling operation with the use of thrust boring and pushing pipes with hydraulic jacking force. below the ground surface from a drive shaft or trench to a reception shaft or trench. Pipe is jacked horizontally from drive shaft to reception shaft. Workers required in pipe to perform excavation and/or remove soil. Excavation performed either manually or mechanically. This concept of a jacking system is adopted by many trenchless technologies, including auger boring and micro tunneling. The excavation method developed from the basic process of digging by workers, the face with pick-axe and shovel to the use of tunnel boring machines (TBM).The method requires personnel working inside the tunnel, it is limited to personnel entry size tunnels. (Min Shang)[17]

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Application of pipe jacking for large diameter gravity sewers, force mains, diversion chambers, the minimum recommended diameter for pipe installed by pipe jacking is 42 inches. The casing diameter is typically in the range of 24in to 48in. Crossings are practically limited to about300 ft. Due to the nature of the excavation, trenching must be done above the water table or with some form of de-watering to keep the area dry. The capability of a high degree of accuracy due to use of laser to control line and grade in pipe jacking method. Installations to an accuracy within an inch are common, with reasonable anticipated tolerances of between + 3 inches for alignment and + 2 inches for grade.[37]

Pipe jacking (PJ) is a trenchless construction technology applied to install underground pipelines, ducts and culverts, and it can provide a flexible, structural, waterproof, finished pipeline as the tunnel is excavated complexity. PJ demonstrates unique advantages such as smaller disruption to the traffic and other ground activities, fewer utility diversion, lower noise and dust pollution, inherent strength of pipeline, smooth internal finish with fewer joints, and higher construction efficiency. In recent years, due to its mature technical procedure and limited incurred environmental impacts, PJ has increasingly become a popular technique for installation of municipal infrastructure, such as sewerage and drainage pipelines, electricity and telecommunications cables, oil and chemical pipe lines, and culverts.( Cheng, et al. 2015).

Description of Pipejacking method

In this method jacks located in the drive shaft for jacking force propel the pipe, this force is transmitted through pipe-to-pipe interaction to the excavating face. When excavation is accomplished, spoil is transported through the jacking pipe to the drive shaft by manual or mechanical means.. The excavated earth is transported through the inside of product pipe to the drive trench, it is removed from this trench and disposed of. Excavation process completed by hand mining or mechanical excavation with the help of a auger boring machine. Based on an assessment of the subsurface for instability, selected excavation method. If any possibility creates of face collapse due to excavation at site, techniques of soil stabilization, dewatering or grouting which is appropriate, should be considered. The developments and experience with improved skills of operator, and pipe material's better quality is make enabled pipe jacking to be accepted as a popular trenchless method. Figure 2 illustrates the pipe jacking operation machine with components. The cyclic procedure uses by helping the thrust power of hydraulic jacks to force the pipe forward through the ground just after as the pipe jacking face is excavated. After installation of each pipe segment, the rams of the jack are retracted then another pipe segment can be placed in position for the jacking cycle to tracked again.

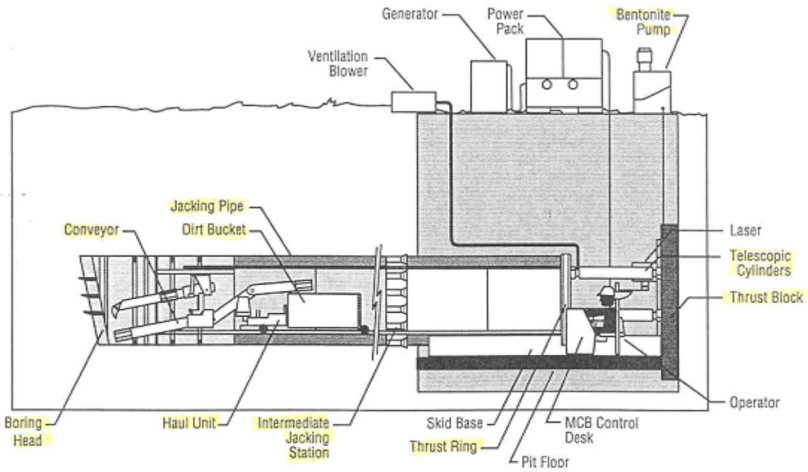


Figure 2. Illustrates the components of a pipe-jacking machine about typical operation. (Iseley and Gokhale, 1997)

However, the initial geotechnical report is outlined to additional needs. Minimum 60m by 60m construction area adjacent to the fill for a launch shaft, to storage of pipes, and all necessary equipment with accessories for the pipe jacking; cushioning material in between resilient joint of the pipe to be jacked (plywood recommended as per report) to prevent deflection and edge loading of pipe at each joint between these jacked pipes; and that pipe excavation should not exceed 60cm ahead of the pipe being jacked, with no more than 3cm of overcut. In an incident of unintended over-excavation or void, External grouting of the pipe was also recommended with a suitable cementitious grout. Reinforced concrete pipe generally has low thermal resistivity for good heat transfer properties and the reinforcing bars have minimal heat producing effect. RCP is only suitable for pipe-jacking applications . (Bascon,2016) Concrete pipe being jacked into place behind cutterhead assembly shown in figure2.3.

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Figure 2.3. Concrete pipe being jacked into place behind cutterhead assembly fixed with . For spoil bucket removal to out of pipe for track leading

c) *Pipe Ramming*: Pipe ramming is most valuable for installing larger pipes over shorter distances and for installations at shallower depths. Some other trenchless methods can lead to solid rock while it is suitable for all ground conditions and is often safe where unacceptable surface settlement. Pipe ramming is typically used for horizontal installations, but can also be applied to vertical projects, such as driving pile and the installation of micro pilings. The use of the dynamic force and energy transmitted by a percussion hammer attached to the end of a pipe involved in pipe ramming method. Generally comprises ramming by a steel pipe through the soil by using an air compressor is the basic procedure of pipe ramming, it permits the installation of large steel casings in the soil with a wide range of soil conditions. It provides continuous casing support during the drive with no over excavation, and it does not require the jetting action of water or the use of drilling fluids. The use of small amounts of drilling fluids for pipe lubrication as the percussive thrust force of the hammer diminishes over distance is necessary for longer drives, for pipes up to 20cm in diameter applied that method . Typical diameters of pipe installed by pipe ramming range from 6 to 60 inches, though pipe ramming has been used to install pipe as large as 147" in diameter. Drive lengths can be up to 200 feet in length, though longer crossings have been completed Two major categories of pipe ramming are closed-face and open-faced pipe ramming. The leading edge of the first segment of pipe or casing is usually reinforced by welding a steel band from 15cm to 60cm in width around the exterior of the lead end of the pipe to facilitate the pipe ramming method. This banding provides two distinct advantages: (1) it reinforces the leading edge of the pipe, and (2) it decreases the amount of friction around the casing as the pipe is advanced.

An open-ended pipe ramming procedure has normally eight steps:

i) A shaft or pit is called launch pit, constructed to launching purpose.
ii) A steel leading-edge band for reinforcement is welded on the leading edge of the first segment of casing.
iii) Casing is placed in the drive shaft or pit, and is adjusted to achieve the desired line and grade. Where line and grade are not critical, the pipe can be supported by construction equipment such as backhoes, cranes, side-boom tractors, wood or block supports, or directly on the pit floor. In cases where the achievement of line and grade are critical, the pipe is supported by adjustable bearing stands, launch cradles, platforms, I beams, or pipe jacking/ auger boring machine tracks (The final item has the added advantage of being able to support augers during the cleanout process, possibly decreasing time spent on the job).
iv) The pneumatic hammer or pipe ram device is attached to the casing, and is connected to an air compressor or other pneumatic or hydraulic power source. This may be accomplished by the use of special adapters for 13 particular sizes of pipe, known as "collets". For larger pipes, specially designed "ramming cones" are used to enhance the energy force transfer between the pneumatic hammer and the pipe.
v) Complete installation held continue from initial to last through drive. If multiple pipe segments are being used, after each segment the pneumatic hammer is removed from the launch area so that additional pipe segments can be welded into place.
vi) As per requirement, cleaned out the casing.
vii) The launch pit is removed from equipment.
viii) Restoration of area completed as required.

Pipe ramming and Thrust boring are similar processes where a steel casing, is driven through the ground from the drive pit to the reception(exit pit). Excavated spoils is removed with the help of compressed air and water after completion of the bore. Pipe ramming is suitable for most types of soil but not suitable in solid rock formations for process. Pipe ramming is said to be a cost saving method, alternatively to conventional open trench method, augering or pipe jacking methods.

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d) *Auger Boring [9]:* The auger horizontal earth boring is a technique for forming a horizontal bore under a crossing, using a cutting head and auger flights. Auger boring has simultaneously jacking casing through the earth while removing the spoil inside the casing by means of a rotating flight auger. The auger tube having dual functions, firstly it is couplings at each end and transmit torque to the cutting head from the bore pit by the power source situated in it and secondly, it transferred excavated earth (spoil) back to the machine to serves. Auger boring applied for Pipe pushed removes spoil. This method does not apply pressure from drive shaft to reception shaft, while rotating flight auger simultaneously removes spoil. This method does not apply pressure to cutting face. The sewer line laid with Trenchless technical process. The pipe installation method is called Horizontal Auger Boring (HAB), Relatively short crossings (pipes and conduits). (Zaneldin, 2006).Auger boring is used in the range of 100-1000mm diameter.(Kramer, et al.1994). The pipe size that can be installed by this method ranges from 4 inches (100mm) to over 60 inches (1500 mm). The use of latest techniques up to 180 meter in length of boring is possible by using auger boring. The most common range of auger bore size is 200 mm to 900 mm and the average bore length ranges between 53 meter and 68 meter.

i) *Advantages:* The major advantage is that the casing is installed at the same time as the bore hole excavation takes place. In the various types of soil , this method can be used. Disadvantages- Through site investigations are required. This method increases the investment in equipment requires different sized cutting heads and auger sizes as per casing diameter, which is in bore, pit construction, and the initial setup is also required. This method cannot be used advantageously in case of soils containing large boulders,

e) *Horizontal Directional Drilling:* Horizontal drilling systems are now a days widely used for installing pressure pipes under major obstacles such a motorway intersection, large rivers and airport runways. [22]Horizontal Directional Drilling (HDD) technology originated in the petroleum industry during the 1970s and has evolved with additional technology that was developed in water well installation and in the utility industry. Much of modern HDD technology evolved from boring techniques employed in the 1960s for the underground installation of cables and conduits in urban areas. Trenching or open-cut methods were commonly used at that time to install a variety of utilities. Over time, the method has matured from relatively simple utility borings to installation of large diameter pipes (50 inch diameter and larger) for as far as 4000 to 5000 feet. These methods allow the installation of both small and large diameter ducts, pipes, and conduits without the risk of environmental damage often associated with trenching operations. A small diameter directional hole is first drilled to provide pilot hole and a back reamer and product are then pulled back through pilot hole. No excavation required. The small rotating and steerable hollow drilling head is launched from the surface at predetermined an angle 8 to15 degree and is used to drill of around 80 to 140 mm mud slurry pathway. During the drilling operation a 140mm diameter is drilled wash over pipe is drilled over the pilot string and follows some 100mm behind the head. First, a pilot bore is created in which alternate drilling continues on the pilot string and the wash over pipe until the exit point is reached, then removed. In the second stage the bore is enlarged by a rotating barrel reamer(back reamer) attached to the end of the drill string and pulled back by the wash over pipe, drilling mud being used to spinning away the cuttings and to support the reamed hole. Subsequent camion continues until the required diameter is achieved. The product pipe is installed along a bentonite mud slurry pathway attached to the reaming head, this is normally carried out at the same time as the finally back reaming operation conducted. It is pulled through the bore drives of more than 1.5km and of up to 1200mm diameter have been carried out. [9] Application of HDD for force mains, gravity sewers, utility conduits, geographical investigation, pipelines. L of excavated pits located at intervals along the trajectory of the line to be replaced. The geometry of the project, location of manholes, ease of access for excavation purposes, and pull force limitations of the pipe bursting machine are determine the specific interval. The HDD industry divided into three major categories.

| Type | Typical equipment footprint [m] | Diameter [mm] | Depth [m] | Drive length [m] | Typical application |
|---|---|---|---|---|---|
| Maxi HDD | 3.0 x 18.0 | 600-1200 | _<61 | <_1800 | Rivers and highway crossings |
| Midi HDD | 0.9 x 4.8 | 300-600 | _<23 | _<270 | Rivers and roadway crossings |
| Mini HDD | 0.9 x 3.6 | 50-300 | _<4.5 | _<80 | Telecommunication, power cables and gas lines |

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*f) Utility Tunneling Ut*ility tunneling is a method of soil excavation similar to pipe jacking. The difference is in the lining used. In Pipe Jacking, the pipe is the lining where in utility tunneling special steel or concrete liner plates, wood box tunnels, steel rib and wood lagging systems are used to provide temporary ground support. The process involves removing soil from the front cutting face and installing a liner to form a continuous support structure. The tunnel is normally constructed between two access shafts. The procedure has four major steps:

*Soil Excavation.*

*i)* Soil removal.
*ii)* Segmental liner installation.
*iii)* Line and grade control.

| Type | Guided Boring (GB) | Auger Boring (AB) | Pipe Ramming (PR) | Horizontal Directional Drilling (HDD) | Pipe jacking (PJ) |
|---|---|---|---|---|---|
| Diameters(mm) | 100 to 600 | 100 TO 1500 | 100 to 2000 | 100 to 1500 | 1000 and up |
| Lengh of drive(m) | up to 120 | up to 180 | up to 120 | up to 1500 | up to 180 |
| Type of pipe | RCP, CLAY, STEEL, | steel | steel casing | hdpe, steel, pvc, ductile iron | RCP, Steel, fiberglass |
| accuracy | Within 20mm | varies | depends on initial setup | varies | Within 20mm |

*g) Trenchless methods for Rehabilitation and Renovation:* The method is Trenchless Renewal Methods (TRM) The trenchless renewal methods that facilitate already existing utilities. It may be rehabilitation or renovation. This work is applied on old, existing utility or pipeline systems that may have some problem with their performance.[Chothe and Kadam,2016] Trenchless rehabilitation methods are generally more cost-effective than traditional exhume (dig) and replace methods.

Following techniques are commonly used for renovation and rehabilitation as below-

Pipe bursting is a unique method of underground rehabilitation in that it involves the replacement of the existing, or host, pipe with a new pipe or product line with minimal surface disruption along the pipe right of way. In general, a typical pipe bursting project consists of a series of excavated pits located at intervals along the trajectory of the line to be replaced. The geometry of the project, location of manholes, ease of access for excavation purposes, and pull force limitations are determine the specific interval. Currently in the North America three systems of pipe bursting are used by industry.

These are the static, pneumatic, and hydraulic expansion systems. The main difference between methods is the manner in which force is generated and transferred to the host pipe during the bursting operation. Existing pipe is burst or split with use of conical shaped bursting head, while simultaneously new pipe of equal or greater diameter is pulled behind bursting head. Application of pipe bursting for replacement of force mains and gravity sewers Initially, this process was used only in the replacement of cast iron gas distribution lines; later, it used to replacement of sewer and water pipelines up to 400mm diameter by 1985, while pipe bursting applications used by majority in North America it was later employed in the replacement of water and sewer lines. By 1985, the pipe bursting process had been further developed to a capacity to install up to 400 mm outside diameter (O.D.) medium-density polyethylene (MDPE) sewer pipe. Today, the majority of pipe bursting applications in North America for the replacement of deteriorated sewer lines with typical replacement diameters ranging from 50 to 400 mm and lengths ranging from 100 to 200m, (Lueke et al. 1999). Pipe bursting uses in recent 75 to 1060 mm diameter of pipe and 100-900 m length .

*i) Pipe eating(Patel, et al. 2015) [9]:* Pipe eating technique used for replacement of pipeline, this is an online micro tunnelled replacement technique. The existing defective pipes in buried infrastructure is demolishing or crushed and removed accomplish with the new pipeline installation. Lateral connections must be disconnected in advance and may be replaced by rider sewers or reconnected by angled drilling. Japan is country of origin..

*ii) Lining of Pipe[ 9]:* Pipe slip lining method used to replacing the damaged old sewer pipeline with inserting new smaller pipes. But the new pipe is reduced in diameter, replacement method (insertion of new pipe inside old line) and relining method (extends useful life of pipe) Relining of water, sewer and natural gas lines. Close fit lining or modified slip lining used the properties of PVC or PE is reduced the shape and size than inner diameter of defective pipe before inserted in the pipe. ipr Modified slip lining often called close fit lining utilize the properties of PE or PVC to allow temporary reduction in diameter or change in shape prior to insertion in the defective pipe. Generally uses in 100-1500 mm diameter, length up to 1000m. The

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method includes Roll down, Swage lining and deformed lining. The inserted pipe is subsequently expanded to form a tight fit against the wall of the original pipe, thus avoiding the need for annular grouting as in conventional slip lining. For Roll down and Swage lining, temporary reduction in diameter is achieved either by mechanical rolling (Roll down) or drawing through a reduction die (Swage lining). For Deformed linings, the pipe is deformed and folded immediately after extrusion and is coiled on a drum. After insertion in the defective pipe, the lining is expanded using steam and a re-rounding device to form a close fit. These systems are suitable where the existing line is of good shape. As compared to conventional slip lining, in this method there is little or no loss of hydraulic capacity.

iii) *Robotic Spot Repair*: Involves use of remotely controlled systems for structural repair or leak control of pipes. It uses inflatable "shoes" as temporary forming while Epoxy is injected in damaged sections and allowed to cure. Repair of sewer and water lines, where structure enhancement is required.(Ariaratnam,1999 )(23) In Robotic Spot Repair length, diameter of pipe and cost varies are not restricted, varies by method.

iv) *Pipe Scanning & Evaluation:* Non-destructive methods for inspecting pipes to determine their condition. Methods include sonar, impulse radar, seismic transmission, radio electromagnetic and closed circuit television. Usually first step in evaluating of existing infrastructure systems in lining, in this method there is little or no loss of hydraulic capacity.

## III. LITERATURE REVIEW

### A. General

Lot of studies have been performed on various aspects of trenchless technology. The studies general deals with highlighting importance of trenchless technology, use of trenchless technology for different purposes advantages of trenchless technology on conventional open trench technology, etc. Few of the relevant papers are reviewed and the procedures and findings of these studies are describe in following sections.

Kramer, et.al [1994] carried out a study on guided boring systems of trenchless technology. They analyzed the use of this trenchless technology for underground utility in past and present. They found that trenchless methods have become a perfect method for conduit installations in city regions where there is a need to reduce the problems of open trenching restoration costs and the disturbance caused to the community and environment. In view of growing demand for minimum disruption in installation and rehabilitation methods, they found that the guided boring systems is better alternative applied to such applications particularly for the installation of distribution duct banks and underground transmission lines, particularly in urban environments.

Gunjal, [1996] recommended suggestions to modify the concept of digging of open trenches, that is a common practice for laying of almost all utility services beneath the ground. Cutting of highways and busy roads in the municipalities area causes the traveler and residents suffer a lot due to delays, accident. Author observed that those suffering are not given due importance. Author was of the opinion that the time will soon come when the conventional method of open trench digging will be selectively banned in India and Municipal authorities all over India should lay guide lines to adopt the technology. They found that enough know-how and technology is available to make a beginning in the field. Governments need to issue regulations those are helpful in development of trenchless technology.

Aria Ratnam, et al. [1999] conducted a survey on application of trenchless construction methods in Canada, tendency in the application of trenchless construction technologies in the municipal field. Intimate about they carried out survey on 87 municipalities. Based on the analysis of survey authors were of the opinion that trenchless technology is gaining increasing acceptance between engineers of municipal across Canada. They predicted that after 5 years the percentage increase of municipal projects utilizing trenchless construction methods will be about by 180% (Trenchless installation) and 270% (rehabilitation).*

Myers et.al.[1994] worked on micro tunneling trenchless method of conduit construction. Authors highlighted the details of micro tunneling method. They found that Micro tunneling may be used to replace the underground weaken conduits as well as to provide conduits for increased. They described key principle offer basic systems of the micro tunneling boring machine. the economic, production, and safety issues with micro tunneling. Authors identified several factors those are effecting selection of micro tunneling like geotechnical considerations and consideration about natural obstructions of micro tunneling boring machine.

Lueken, et. al [1999] developed a model about pipe bursting project model in Symphony which is a simulation platform for building special purpose simulation for construction applications. This model is helpful for pipe bursting method of trenchless technology that enable construction, rehabilitation, or replacement of urban infrastructure with least interruption to surface movement. The recommendation arrived at from this model may be useful in assisting owners, engineers, contractors, and equipment manufacturers in designing and planning pipe bursting projects.

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Tighe, et al [1999] carried out study on cost savings resulted from removal of traffic interruptions necessary in open cuts to help in underground construction process. In this case study, they determine traffic disruptions associated with utility construction durations and traffic control plans for two lane roads. Plans have been utilized to develop equations for calculating traffic interruptions. Authors found that the user delay costs is important and need to be analyzed is difficult. They considered three basic variables associated with traffic capacity analysis are the rate of flow, speed and density compute indirect cost caused due to traffic disruption and traffic delay. Authors recommended that both direct and indirect cost should be considered before making a decision.

Gokhale, et. al [2012] presented studies on underground utility infrastructure in U. S. that were constructed early of 20th century and due to eroding, needs demand for construction, rehabilitation, renovation of these utilities. They observed that systematic evaluation of the criteria is necessary for decision model like analytical model or a group decision model. They presented a framework for a Decision Support System (DSS) to assist design engineers and system managers to selecting the greatest suitable technology for a project by thoroughly estimating with respect to the knowledge based favorite of the user and the project precise situations Their proposed decision model had important criteria and sub criteria like knowledge about the firm, technical knowledge, current project knowledge, experience etc.

Lueken et.al.[2001] worked on the identification of a trenchless pipe replacement method mainly pipe bursting that offers an alternate for reorienting below the ground setup of utility with minimum interruption to surface traffic. It is documented as the only method of trenchless pipe reintegration in which a underground laid pipe can be exchanged with a completely new pipe that functions self-sufficiently of the existing line and permits the diameter of the new line to be augmented over 300% of the original. They carried out a study on three bursting systems those were using presently in North American industry, in study presents summary about sequencing, risks, and a assessment of project components of these three systems comparatively open cut methods. Study matter accomplishes with three case studies recitation the submission of pipe bursting in projects that prolonged the recent operating covering of the technology to explain project detailed specially engineered resolutions to certain rehabilitation necessities. Discussed with facts and practice, a better thoughtful technology and its application, which possibly will be attained to encourage trenchless pipe replacement as a workable substitute to open cut construction methods.

Allouche, et.al. (2001) presented an article dealing on horizontal site characterization technologies, it involved a fast developing alternate to old vertical site investigation methods for subsurface surveys of large diameter trenchless construction projects. A advanced review of horizontal site description tools, both recently presented and underneath development, is accessible. Moreover, a rational procedure for the selection and deployment of horizontal site investigation techniques in trenchless construction projects is also obtainable. The procedure empowers the user to explain and calculate the risks involved in a particular project, as well as to assess the degree to which these risks can be moderated via many site depiction techniques. The planned model is established using a working example. In the paper arranges with a discussion of future movements in this stimulating new field. The main assumptions pinched from this work are (1) suitable subsurface data is helpful for underground construction; (2) site investigation programs of direct construction projects can be improved by horizontal characterization techniques; and (3) the convenience of continuous and nearby-continuous subsurface information qualifies to the use of new methods for the study and representation of sub surface data.

Shayhadinov et. al [2002] observed that conventional open trench methods for repair of water pipe line resulted into expensive damage to underground communication line. Therefore, they carried out study on use of trenchless technology for repair of water pipe lines. Their study includes application of Torous vehicles which rolls over the internal surface of pipe and has internal arrangements for repairs. They concluded that the application conducted experiment on the method, based on application of torus vehicles. It used for repairing tube line of communications, which was a very important matter because of the great amounts of works spent on repairing these lines.

Chin et. al [2004] worked on the identification the disadvantages of open cut method technology for repairing and replacing of damaged pipes in infrastructure below the ground, many trenchless technologies have been established and used for maintenance of utility. There after trenchless technologies thus far away technologically advanced have some problems such as high cost and troublesomeness of process. Carried out the study, on rehabilitation process for pipes in infrastructure below the ground has been established via vacuum assisted resin transfer molding (VARTM) with glass fiber fabric preform to overcame the drawbacks of present no-dig method. For the dependable of the established method, a simple method to apply pressure and vacuum to the reinforcement was invented with a stretchy decoration technology. From the search, it has been found that the advanced process necessitates short time period of operation time and lesser cost with smaller and simpler operating apparatus than those of the conservative no-dig method technologies.

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Ariaratnam et.al.[2006] worked on identification of three trenchless construction methods adopted in China are horizontal directional drilling (H. D. D.), pipe bursting, and pipe ramming. Open cut methods for new installation, rehabilitation and renovation were applied in laying of infrastructure below the ground up to that time. Due to urbanization construction works for underground utility by open cut method create road closures, traffic delays, unnecessary detours, loss of access to homes and business, unsightliness, noise, and general disruption. Population with urbanized settings have not so easiness in applying the open trench method for maintenance and renovation of an old utility system below the ground. China has observed to developing skills to assist in providing justifiable resolutions to addressing this condition. They recommended horizontal directional drilling method that suitable for laying of conduits and pipelines with minimum need for open-cut surface excavation. Pipe bursting is suitable method for trenchless pipe replacement where an existing sewer or utility pipeline is replaced with a totally new structural pipe of equal or greater inside diameter.

A cost effective alternate by placing steel casings below roads, railway tracks, landscapes and other surface structures, provided by pipe ramming method in trenchless technology. They describes every trenchless construction method in above three and deliberates numerous applications for satisfying utility networks below the ground with the help of detail briefing of fruitful projects in China.

Zeneldin [2006] worked on the survey by sending a questionnaire to all municipalities and contractors, in the questionnaire delivers an indication of current and imagined forthcoming trends in the application of trenchless construction technologies including types of technologies engagement and percentage of projects that engagement trenchless technologies. However growth of trenchless methods has grown motivation in the construction industry in United Arab Emirates owing to increasing amounts of investment in underground infrastructures laid below the ground that are new, detemir or under capacity. After survey, results show that trenchless technology is fast increasing popularity in servicers, also municipalities engineers and amongst municipalities across United Arab Emirates. The survey discovered existing, and by extrapolation expected future development, in applying trenchless construction methods and the regular expenditures of municipalities in UAE for new construction and for rehabilitation.

Jung and Sinha[2007] recommended suggestions to modify of utility systems of municipalities laid below the surface of ground which is in position of mandate for more resourceful installation, renovation, inspection, repair, reintegration, and replacement of utilities in sub surface of ground due to weakening, corrosions of municipal infrastructure systems and a rising demand for usefulness services have enlarged the requirement for. They depict with open-cut construction methods, direct costs are critically increased by the necessity to restore ground surfaces such as walkways, roadway ,landscaping, and brick/interlocking paving. Moreover, pleasing social and environmental factors into account, due to traditional open-cut methods have adversative effects on the public, business, and travelers due to unwanted pollution and traffic interruptions. Addressed the difficulties of open cut method beyond reported application of no dig methods (trenchless technologies) that are used to overhaul, renovation, rehabilitation or new installation in laid infrastructure systems (utilities) below ground level with minimum surface disturbances offer a viable substitute to prevailing open-cut methods. Presented the result to describe a procedure for quantitatively evaluating and equating direct, social, and environmental costs related with pipeline construction for public utility below ground surface by municipal and other service provider. Due to expectation of production, employees' care, and structural problems occurs in trenchless technology and considering combined costs i.e. direct capital cost, so suggested to all concern of project and policy maker to combining social and environmental cost aided with direct capital cost then found greatest economical substitute. and is a more effective method for utility infrastructure systems below surface, in sub surface

Sameh et.al.[2007] developed a model namely productivity index (PI) model, to signify this particular outcome in filtering productivity assessment. The systematic grading procedure and uncertain reasons are used to grow the proposed PI model. It relies on the authentic presentation of twelve sub factors underneath 3 groups - management, environmental, and physical conditions. Productivity of Trenchless Techniques is precious by a number of subjective aspects that requirement to be evaluated. Horizontal directional drilling and micro tunneling projects resulted PI value equal to o.7251 and 0.7323 correspondingly produce by PI model. Multi characteristic result support system software is developed to regulate the PI for a exact TT technique using Uncomplicated. The PI model is tested, which shows reasonable results. They presented this article dealing for Trenchless technology (TT ) which have a large family of methods applied for new installation of pipe laying, rehabilitating and renovation of utility systems beneath ground surface with slight surface distraction and demolition resulting from excavation in open trench method. This study is appropriate to both industry practitioners and researchers. The study offers to practitioners with a model that rationalizes their productivity calculation by calculating subjective factors effect, which will mark their plan and cost estimation for trenchless projects. Impetus it delivers to researchers with the progressive methodology for trenchless technology.

Ma et.al [2007] presented the results of research, education, training, marketing and technical status of trenchless technology those are developed in China between last 19$^{th}$ and 20$^{th}$ century. Development of trenchless technology was held between year 1996-

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2007 because in between time conventional open cut methods were widely used to installation and replacement of infrastructure for utilities in sub surface. Addressed the difficulties of traditional method among growth of population and urbanization , discussed the potential market, trends and factors that will influence trenchless technology in the next decade in China. China has motivated by the melodramatically improved demand of pipeline installation and rehabilitation below the ground all over the China., It has made significant progress in research and development in trenchless technology in that time. The more popular methods of trenchless construction technology that have adopted were horizontal directional drilling, pipe jacking, micro tunneling, pipe bursting and pipe ramming. After establishment of China Society for Trenchless Technology (CSTT) in 1998, trenchless technology has developed and made many accomplishments in education, research, and new products development and has accomplished various exciting projects in terms of complication, diameter and distance in the field of trenchless technology for utility construction. There were more than 200 contractors involved, using more than 2700 horizontal directional drilling machines in trenchless construction among the 'biggest HDD rig in the world" in mainland China. Obviously the market of China is worldwide fastest upward market and has vast possibilities of development in the field of trenchless technology.

Apeldoorn[2009] carried out a study with deliberates on the evaluations of cost and the reasons that impact on a project, the environment and society that should be considered when choosing the suitable pipeline installation or rehabilitation methodology. The residential areas have utility infrastructure, those keep growing demand on sustaining and improving infrastructure in cost effective and socially satisfactory ways, there is an cumulative trend in the development and usage of trenchless technologies to make available the best results. In Australasia the progress of trenchless technology has gradually growth in the telecommunication sector for laying of cables, and gas pipe line laying in oil and gas authority with other utilities in most industries and important sector to take benefit of the trenchless technology in the meantime1993. The trenchless technology used and applied probably for rehabilitation or renovation of utilities for water services in Australasia. is amazing, with sewer and sewer pressure mains that demand full for new installation due to their design life which was approaching or exceeding. Australian Society for Trenchless Technology (ASTT) have shown in study that trenchless technology is beneficial, unit costs decreased as per proved records due to more work has been undertaken and more industry players have become involved in Australia and New Zealand. As perspective fully or partially(depend on excavation) trenchless technology have many proposals as a technique in maintenance that ease the disruption, interruption of surfaces, emission of gases and the impacts over inhabitants and the community environment. Mitigate in a growing number of cases limit the options for open cut method.

Dziadaket.al.[2009] presented an article dealing with developed a model to found the three-dimensional (3D) location of under laying utilities created on radio frequency identification of dimension (RFID) technology and discoveries from laboratory and field experiments. Addressed the difficulties to associated with the laid underground infrastructure of utilities ruptured due to excavation for new construction to laying the other utility or rehabilitation same in the area.. Service provider and users, may be whole groups can suffer in this position for use to extensive utility, reserve services and losing essential utilities such as water, gas, and electricity. To increase the skill to physically determine at site the position of underground utilities is serious to reduce risk and importance during excavation. To relief for utility companies from these reasons and especially for relief to users , developed that model. Submissive, low frequency RFID devices were used during the research. Two approaches of this model, "Method A" and "Method B," laterally with main experimental results are conversed in the paper. In order to authenticate the applicability of each method, "actual" field experiments were achieved. The discoveries from this research verified that applying RFID technology to detect underground utilities has a excessive possibilities for helping to find the accurate 3D data of buried infrastructure.

Bugbee et.al. [2011] presented an article dealing with developed an analytical hierarchy Process decision modeling tool which was used to develop a methodology for assessing pipeline installation technologies for a precise application via subjective criteria in the areas of environment, safety, and health (ES&H); project cost and schedule; and technical operability. Site-precise premium factors were technologically advanced for Oak Ridge National Laboratory (ORNL) applications using a pair-wise assessment technique. However mostlytrenchless technologies for laying to pipe line developed over the last 20 years for a variety of pipeline installation applications, used expansively in the sanitary sewer and natural gas pipeline businesses, while used under contaminated environments area in limited. So mostly applied trenchless technologies to installation was considered for all-purpose applicability for changing long turns of laid pipe lines in arena and/or installing new pipelines in possibly contaminated areas. The methodology was used to assess pipeline laying through trenchless techniques for three definite ORNL pipeline applications. Granting developed methodology for evaluation made by ORNL through the detailed evaluation results obtained from example are applications specific for the ORNL. It should be suitable and beneficial for viability level engineering to substitutions investigates, that may be achieved at other DOE sites in the upcoming.

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Sai Kumar Daddalaet.al. (2016) recommended suggestions to modify some of the methods were available in the early 1900's and carried out a study with the addition of new techniques are coming into much more widespread use because of their inherent{intrinsic} advantages.

They suggest that trenchless technology consists of a variety of methods, materials, and equipment for inspection, stabilization, rehabilitation, and replacement of existing culverts and installation of new culverts with a minimum of excavation from the ground surface. They concluded that trenchless methods as pipe ramming used to install the conduit below garden at the center of the museum and other methods are using due to minimize damage to the highway, cause little or no disruption to traffic, have less impact on the environment, and occasionally avoid or minimize the handling and disposal of contaminated soil

Kakadiya et. Al. [2017] conducted a study on an open excavation is most common method used to install underground pipeline involving surface disruption and brings negative effect to communities and environment comparatively trenchless technology offers viable with innovative method with cost-effectiveness. Trenchless technologies are used to repair, upgrade, replace, or install underground infrastructure systems with least{minimal} surface disruption and offer a viable{feasible} alternative to existing{present} open-cut methods They observed that as communities and regulators place build up demand on maintaining and make better infrastructure in cost effective and socially acceptable ways, there is an improve trend in the development and usage of trenchless technologies to provide the alternate solutions with advancement of technology for pipeline laying.. Authors compared the cost effectiveness and viability of trenchless technology over traditional open-excavation method. Authors analysed to evaluated the existing water supply system and new method of trenchless technology for the water supply system for forecasted population of Mota Varachha area of Surat city, Compared the total estimated cost of the project then found the total estimated cost over traditional method of water pipeline is equal to 93% of installed pipeline by trenchless technique.at flexible road in same length and diameter, however by open cut method the direct cost is margining low as compared trenchless technology but in open cut method many problems as time delay, due to duration(Time duration for Open cut laying of pipeline in selected area is 1 month compared to 5 days for trenchless technology ), traffic diversion, disturbances as jams, are faced by inherent, contractors, travellers, municipal corporation and government. At present, the trenchless technology brings different method that can be used in installing the underground pipeline which is able to decrease the cost of project for large area of work trenchless technology is beneficial both in project cost and time as compared to open cut method.

Methews et. Al [2018] This expedite{further} the optimum solution by evaluating all of the trenchless paper presented an article dealing with a mathematical approach to technology methods capable of installing, replacing, or rehabilitating each pipe segment (a solution set) and minimizing the number of methods and their total costs. They conducted experiment on the many tools, models, and algorithms to aid in the selection of appropriate{suitable} trenchless methods for pipeline installation or rehabilitation. However, one key concern is which method or technique provides optimum solution to the rehabilitation of multiple pipe segments rather{relatively} than just a single pipe segment. There for, the searching criterion for an optimum{optimal} decision support system is divided into two parts. First, the selection of the optimum{optimal} method capable of solving the problem properly. Second, a simultaneous analysis of other parameters such as cost, time, and quality to improve the overall benefits{advantages} of the project. It is observed that most of the cases involve multiple segments in a single{lonely} project. Therefore, an optimization of the solution must be made for those multiple pipe segments. Although use of different methods for each{every} segment is a preferable{desirable} solution, it may not be feasible in a wider consideration of project cost, quality, and time. Hence, one way to determine the optimal{optimum} solution for multiple line segments is to minimize the number of methods and their anticipated{expected} total costs which include direct costs and social costs and carbon cost.

Lia et. Al [2018] The rock and soil cutting efficiency and reliability of cutting tools are critical factors to tunneling. However, due to its complexity, in-depth researches on some problems existing in rock fragmentation has not been conducted. This paper introduces the mechanism of cutting rock and soil by cutting tools. On the basis of this mechanism, it establishes finite element models using ABAQUS software to simulate the cutting processes when a cutter and disc cutter are cutting rock and soil masses. The results show that when the cutting force of a cutter is stronger than the shear strength of soil mass, breakage occurs at the interface between the cutting edge and the soil mass, leading to a successful cutting. When a disc cutter is pressed into a rock mass, with penetration depth increasing, the maximum Mises stress of the rock increases almost linearly, and plastic strain accumulates constantly, resulting in the stress growing as well. The plastic deformation zone in the rock mass is larger than the area compressed by the disc cutter. Along the working direction of the disc cutter, the rock mass is subject to continuous compression, producing plastic deformation until a fragment is broken off from its parent body. In this paper, a finite element model is established to simulate the process of cutting rock and soil by cutting tools, and a method for analyzing the interactions between cutting tools and the rock and soil is provided.

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## IV. COST COMPARISONS

**(**Application Of Trenchless Technology In Tier 2 Cities In India - Major City-Indore )

### *A. About the Project Area*

For the case study Indore town has been preferred as it is a growing town having very fast life with dense traffic as Gwalior. The Infrastructure works are also running very large scale under different financial scheme.

### *B. Indore*

Indore is the most populous and the largest city in the Indian state of Madhya Pradesh. It serves as the headquarters of both Indore District and Indore Division. It is also considered as an education hub of the state and first city to have campuses of both the Indian Institute of Technology and the Indian Institute of Management Indore. Indore had a census-estimated 2011 population of 1,994,397 (municipal corporation) and 2,170,295 (urban agglomeration), and 4,160,000 (Metropolitan Area), in 2017. The Indore Metropolitan Area's population is the state's largest in 2011. The city is distributed over a land area of just 530 square kilometers (200 sq m), making Indore the most densely populated major city in the central province. It comes under Tier 2 cities in India. Indore traces its roots to its 16th century founding as a trading hub between the Deccan and Delhi. Indore has been selected as one of the 100 Indian cities to be developed as a smart city under the Smart Cities Mission. Indore has been elected as the cleanest city of India two years in a row as per the Swachh Survekshan 2017 and the Swachh Survekshan 2018, respectively.

### *C. Status of Sewerage and Sewage within Indore City and Pollution in Khan River*

The entire Indore city is covered by three rivers Khan, Chandrabhaga, and Sarsawati. All the three rivers and outlet of Ponds are covering the rural area of Indore in the initial stage hence it receives agricultural run-off in a large proportion, the disposal of waste, burning of fussily fuels, discharge of domestic wastes, hospitals and industrial effluents from small and large scale industries which are located at the bank of the rivers. Hence all the rivers and outlet of ponds are converted in to nallahs that is why the water of these rivers and outlet of ponds is unsafe for domestic, industrial and irrigation purposes. Indore does not know how much sewage it generates - wide disparity, therefore, rules its estimations. As a result, its capacity for treating sewage is also off the mark: its two sewage treatment plants (STPs) at Kabir Khedi can only treat the amount (78 MLD) that the city claims to officially generate. The city does not have a proper sewage collection and disposal system.

In 1936, its Holkar kings constructed a 30-km covered sewerage line over 10 per cent of the city's area; the system served a population of about 150,000. In 1990, the PHED prepared a sewerage master plan for Indore till the year 2028, which included the laying of 300 km of sewer lines in phases. The plan was technically approved by the CPHEEO, but could not be implemented due to lack of funds. Subsequently, the Indore Development Authority (IDA) - with financial assistance from the British government's Department for International Development - built a sewerage system in 183 slums: 47 km of sewer lines were installed. The IDA also constructed a 17-km sewage line on the banks of the Khan river and connected it to the city's STP. Of the city's road network of 1,710 km, only 600 km has drains; 90 per cent of the drains are open. This network collects 55 per cent of the sewage that is generated in the city; another 43 per cent is disposed off in septic tanks and ultimately discharged into nullahs. Of the city's 1.8 million-strong population in 2005-06, about 0.7 million used septic tanks. Besides, about 1,000 pit latrines were still in use, and about 5 per cent of the population resorted to open defecation.

There were about 1,464 seats of public toilets in the city attached to septic tanks, all of which were poorly maintained. Most of the wastewater is drained into Indore's three major streams, which flow towards the north and meet at the city's municipal borders. These three are the Khan and Saraswati Rivers, and the Piliyakhal Nullah.

The IDA has laid interceptor sewers along these streams and the Plasiya Nullah to collect wastewater from the slums situated on their banks. The interceptor sewers along the other nullahs discharge into the sewers along the Khan, which conveys the sewage to the STPs at Kabir Khedi. The eastern parts of the city are partially sewer. Wastewater from these parts flows through a brick arch sewer that finally discharges into the river Khan near Kabir Khedi. This brick arch sewer is now broken at various places - as a result, sewage bypasses it and flows into the Bhamori Nullah. Sewers laid under a British Overseas Development Administration-assisted project have collapsed as well; most are reported to be broken or choked at various locations. As a result, the sewage had been flowing directly into the Khan. As a temporary arrangement, a weir has now been built across the river to divert the sewage into the STPs. Since the STPs cannot handle all the sewage generated by Indore, about 73 MLD of untreated sewage goes directly into the Khan river. However, considering the poor condition of sewage drains, the actual amount of sewage reaching the STPs could be much less.

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*D. Proposed Measures To Abate Pollution In Khan River*

In the basis of various field conditions observed – analyses and based on the records / reports available with the Indore Municipal Corporation, the followings strategies may be adopted to abate the pollution in River Khan. However, the additional suggestions other than those described in the sewerage system report of M/s MWH India Pvt. Ltd. requires additional investigation of current characteristics of water quality and quantity in Khan river, its hydrology and topography, to arrive at the best techno-commercial alternatives. The preliminary suggestions are as under.

*1)* The Indore Municipal Corporation requires to take the secondary sewer project on Priority Basis to collect all the sewage that is being generated in the city. The tenders for several stretches are already floated.

*2)* The augmentation of existing sewage treatment plant of 78 MLD at Kabir khedi up to the desired capacity (About 245 MLD as described under MWH India Pvt. Ltd. Report) to implemented on priority basis. This would provide the adequate capacity to treat all the sewage which is being generated and will be collected and transported to the sewage treatment plant, on completion of secondary sewerage network.

*3)* The separate Common Effluent Treatment Plant (CETP) of about at least 5 MLD capacity, would be required to installed to treat the industrial wastewater that is being observed flowing directly into River Khan through Narbal Nallah. The precise wastewater generation from these industries needs to be ascertained before finalizing the capacity of CETP.

As per current scenario the work of construction of 245 MLD sewage treatment plant at Kabir Khedi is completed and it is under operation. The CEPT at industrial area is also completed and it is in operation.

The laying of the different diameters of sewer is in progress the proposed sewers are as under. Project components:

*a)* *Primary Sewer Network:* The entire area of 134 sq km comprising of all the 69 wards of the city, within municipal limits, shall be covered by sewer network with 165.304 km primary sewer lines of 300 mm dia. and above dia. - RCC pipes

*b)* *Secondary Sever Network:* Suitably designed 260 km long secondary sewers of diameter less than 300 RCC pipe shall be laid under the project.

*c)* *Sewage Treatment Plant:* Sewage treatment plant shall be provided to treat 245 MLD sewage of Indore city during phase -I against total 335MLD generated sewage, since 90MLD capacity STP has been already constructed under Khan River Pollution Abatement Scheme.

*d)* *Project Cost:* The estimated project cost for the improvement of water quality in Khan River would be as provided below. The augmentation of existing sewerage system is taken from the MWH India Pvt. Ltd. Report and current tendered amount. The project listed below are targeted to be commissioned within a span of two years and hence, total amount of about Rs. 415.80 Crores would be required in next two years to commission the projects and to improve the water quality in Khan River.

Pipe diameters and its classification for Primary Sewerage System

| Pipe | Phase I | | | | Total | Phase II | | Total | Grand |
|---|---|---|---|---|---|---|---|---|---|
| Diameter | IDA Sewers augmentation | Central | Western | Eastern | Phase I | Western | Eastern | Phase II | Total |
| MM | m | m | m | m | m | M | m | m | m |
| 300 | | 6,041 | 13,524 | 16,877 | 36,442 | 4,010 | 1,757 | 5,767 | 42,209 |
| 400 | | 824 | 5,527 | 14,569 | 20,920 | 2,369 | 6,470 | 8,839 | 29,759 |
| 450 | | | | 3,410 | 3,410 | | 2,350 | 2,350 | 5,760 |
| 500 | | 712 | 8,251 | 5,504 | 14,467 | 2,188 | 1,300 | 3,488 | 17,955 |
| 600 | 1,149 | 2,553 | 10,088 | 1,543 | 15,333 | 5,918 | 823 | 6,741 | 22,074 |
| 700 | 3,133 | 678 | 1,654 | 2,985 | 8,450 | 1,292 | 2,732 | 4,024 | 12,474 |
| 800 | | 230 | 2,095 | 1,057 | 3,382 | 2,095 | 200 | 2,295 | 5,677 |
| 900 | | | 1,349 | 1,386 | 2,735 | 1,349 | 200 | 1,549 | 4,284 |
| 1000 | | | 565 | 1,659 | 2,224 | 565 | 1,659 | 2,224 | 4,447 |
| 1200 | | 21,717 | 584 | 730 | 23,031 | 584 | 730 | 1,314 | 24,345 |
| 1400 | | | 1,666 | 1,190 | 2,856 | 708 | 1,190 | 1,898 | 4,754 |
| 1600 | | | 5,916 | 6,070 | 11,986 | 2,912 | 5,260 | 8,172 | 20,158 |
| 1800 | | 16,854 | 3,215 | | 20,069 | 2,490 | | 2,490 | 22,559 |
| | 4,282 | 49,609 | 54,434 | 56,979 | 165,304 | 26,480 | 24,671 | 51,151 | 216,455 |

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| No. | Components | Amount in Rs. Crores |
|---|---|---|
| 1 | For trapping all Sewerage outfalls in Khan River | 120.00 |
| 2 | For completion of 122.5 MLD STP at Kabirkhedi (Execution started) | 85.00 |
| 3 | For Completion of another module of STP of capacity 122.5 MLD | 125.00 |
| 4 | For industrial wastewater collection and Treatment system<br>Wastewater collection system- 55 Kmts. 5 MLD capacity CEPT | 30.00<br>10.00 |
| 5 | For Immediate measures<br>a)Aeration system to increase DO<br>b) Bioremediation by applying bacterial culture (for two years till completion of basic sewerage infrastructure | <br>10.00<br>5.00 |
| | Total | 385.00 |
| | Add 8% Contingency charges | 30.80 |
| | Grand Total Rs. | 415.80 |

The details of the Gravity Mains are as under

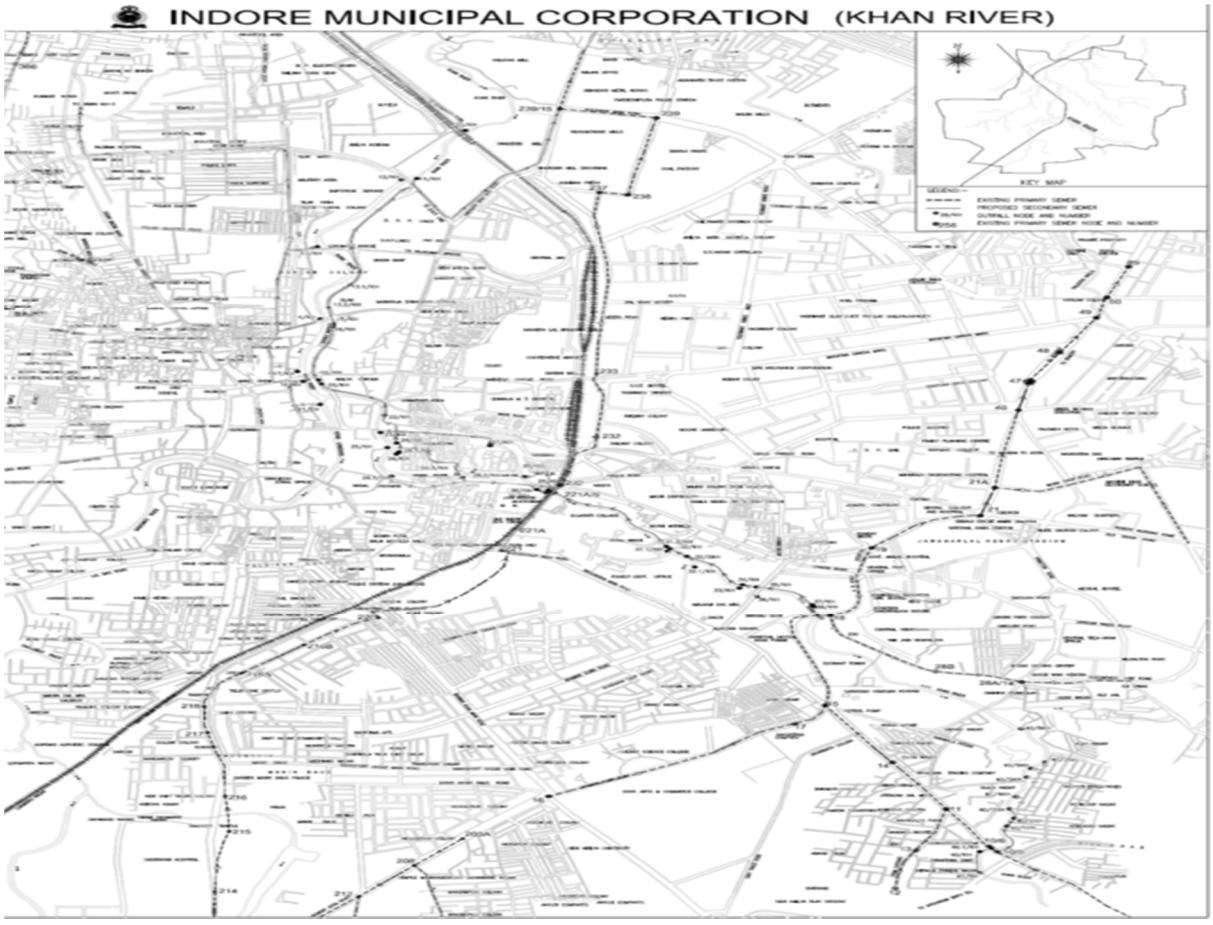
*a)* The Gravity Main of 1800 mm diameter located along the Khan River covering West Zone area (Line-'A')

*b)* The Gravity Main of 1800 mm diameter located along the Khan River covering Central Zone area (Line- 'B'). This line becomes 1800 mm diameter from the Junction of Line-B1 (1600 mm dia. ) and Line E (1200 mm diameter).

*c)* The Gravity Main of 1600 mm diameter covering East Zone area (Line-'C')

*d)* Final Trunk Main of 2200 mm diameter leading to 245 MLD STP carrying the combined flow of East, West and Central Zone (Line –'D')

The work of all above pipelines as above is in the final stage of completion including near the Railway Crossing and other junctions.

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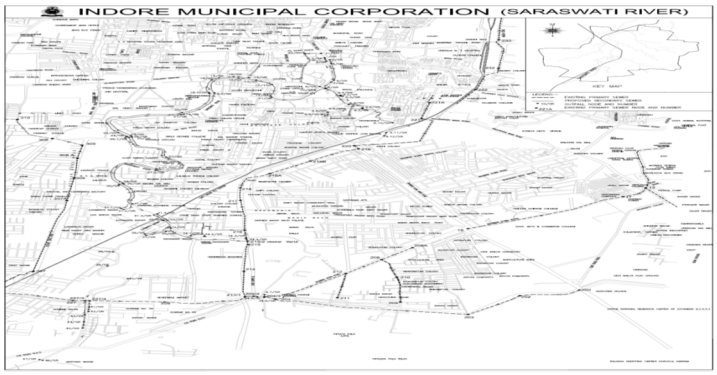
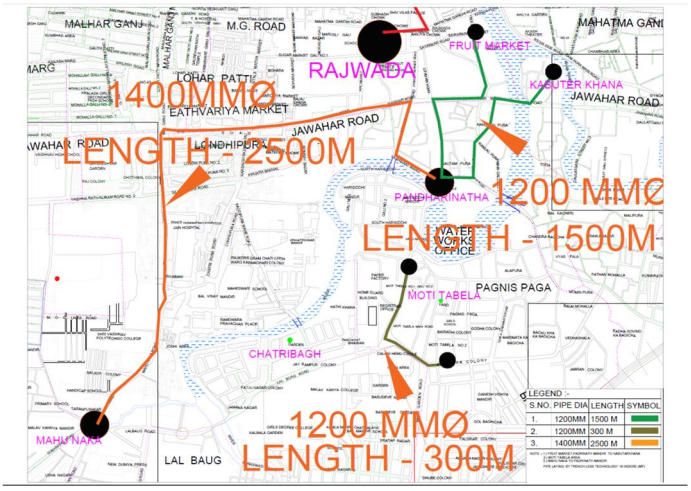
Indore city conducted study at varios places in which mainly as –

*a)* Fruit market to Padrinath mandir area
*b)* Mahoo naka to Kabutarkhana through Padrinath mandir
*c)* Moti tabela area

| SL | Dia | Ward 18 & 19 | Ward 21 & 25 | Ward 60 | Ward 59 | |
|---|---|---|---|---|---|---|
| 1 | 200 | 56794 | 16337 | 44322 | 28849 | |
| 2 | 250 | 2720 | 1162 | 2086 | 225 | |
| 3 | 300 | 679 | 687.1 | 2524 | 478.9 | |
| 4 | 350 | 403 | 1706 | 1486 | 14.9 | |
| 5 | 400 | 619 | | 1677.4 | 1946 | |
| 6 | 450 | 2279.4 | | 460.8 | | |
| 7 | 500 | | | 400.5 | | |
| 8 | 600 | | | | | |
| 9 | 650 | | | | | |
| 10 | 700 | | | 607.7 | | |
| 11 | 800 | | | 504.9 | | 284 |
| 12 | 900 | | | 3068 | | 499 |
| 13 | 1000 | | | | | 526 |
| 14 | 1100 | | | | | 682 |
| 15 | 1200 | | | | | 758 |
| 16 | 1400 | | | | | 1830 |
| 17 | 1600 | | | | | 1459 |
| In | Totall | 63494 | 19892 | 57137 | 31514 | 6038 |

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*E. Direct & In-Direct Costs*

The Direct and In-Direct costs are those most often associated as the "Project Costs" or "Construction Costs", which are usually relatively straight forward to estimate using standard estimating methods, and are greatly represented proportionally by the construction cost fees tendered by contractors. The cost of any particular rehabilitation or renewal method, open-cut or a trenchless method varies significantly depend on the site conditions. The variability of costs and uncertainty of what cost items are included or not included in project estimates, makes comparing the cost between open-cut and trenchless methods difficult, and there is little recent published data available. A recent (2008) published case study comparing the potential cost of open excavation versus pipe bursting to replace the sewer network in the City of Troy, Michigan in the United States concluded that the trenchless method of renewal if implemented would be 25% less expensive than open excavation (R. Mohammed et al2008). The study had a number of caveats and areas for further research; sewer laterals, and lateral connections had not been considered as part of the comparison study, or the possible Effects of ground condition variability. Other, less recent published comparisons may also be considered:

Public Works Technical Bulletin published by the U.S Army Corps of Engineers on the Application of Trenchless Technology at Army Installation in 1999, compared the cost of Open Excavation and Trenchless Technology rehabilitation methods utilizing 1991 USEPA (United States Environmental Protection Agency) values.

*1)* The costs fall broadly into the costs paid by the utility, as direct and indirect construction costs, and those paid for by society at large, termed social costs, that are as a result of the project being undertaken.

*2)* The costs of trenchless and traditional open excavation methodologies by considering both cost centers; direct and indirect costs and the social costs affected by many factors' such as the location of the pipeline, its depth, size and also the local availability of the various trenchless technology methodologies.

The cost of a pipeline construction or renewal project can be divided into several components, as described in Figure 2.

| cost category | cost paid | Examples | |
|---|---|---|---|
| Direct | Owner | CONTRACTOR COSTS | D1 |
| | | ENGINEERING | D2 |
| | | BIDDING COSTS | D3 |
| | | CONTRACT MANAGEMENT | D4 |
| | | COMPENSATION CLAIMS CUSTOMERS | 11 |
| Indirect | | COMPENSATION FOR CONTINGENT DAMAGE TO PROPERTY | 12 |
| Social Quantifiable | Society | Traffic Delay | S1 |
| Social Non Quantifiable | | Busines s Disruption | S2 |
| | | ACCIDENT COSTS | S3 |
| | | POLLUTION | S4 |
| | | ENVIRONMENTAL IMPACT | S5 |
| | | QUALITY (OF LIFE) | S6 |

In addition to direct cost and social costs, carbon offset or carbon cost is a quantifiable parameter that can be included in the analysis precisely, carbon offset not only has impact on the environment but It also calculates the cost per ton of carbon emission. Because the environment and sustainability is a key concern for many of the stakeholders associated to construction and rehabilitation of buried pipelines, the interest in carbon offset is neither negligible nor insignificant. Therefore, optimal solution to multi-segment renewal decisions should include cost (direct, social, and carbon) reduction.6. Cost calculation The total cost presented in Table 5 is a combination of three categories of cost, namely direct, social, and carbon cost. First, the individual cost corresponding to each method found in TAG-R software is calculated for these three categories. Then the total cost is determined by summing up each individual cost (Matthews, 2010). Further details of cost categories are illustrated in the following sections.

*a)* *Direct Cost:* There are three types of costs involved in a construction project: direct cost, indirect cost, and social cost. The direct cost is associated with the purchase of material, transportation, and labor payment whereas the indirect cost is mainly the cost for running administration, management, and overheads. The direct costs for each method were compiled from the sanctioned rate for the project in municipal corporation indore.

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b) *Social Cost:* The social cost is generated from the negative effects of construction such as noise and air pollution. Moreover, social cost is borne by the community, not the contractual parties involved in the construction processes (Allouche and Gilchrist, 2004). A great deal of loss is involved in social cost as it consumes resources, diminishes productivity, decreases value, delays in time, damages property, and deteriorates eco-systems. Social costs for each segment are calculated using the SCC (Social Cost Calculator) and presented in Table 5. Here, the durations for each construction method had to be estimated to be able to determine the full social impact of each method considered to be technically viable.

c) *Carbon Cost:* The quantity of carbon depends on the length and diameter of the pipe, depth of backfill, number of daily traffic, time of operation, and fuel efficiencies (liter/day). Carbon emission is calculated for each segment separately using the NASTT Carbon Calculator and is summarized in Table 5. Generally, the carbon calculator provides the amount of carbon dioxide emission in tones. Then the per ton cost of carbon is assumed as 40 dollars (for the US market) and multiplied with the amount of carbon emission to get the carbon cost[12] An estimate of the social and environmental cost as indirect cost at the minimum, medium and maximum intensity of traffic effected areas calculated at the based on the below table which based on NZ dollars and metric units

| social cost | minimum ($/m) | maximum ($/m) | minimum ($/day) | maximum ($/day) |
|---|---|---|---|---|
| vehicle operating cost | 9 | 271 | 26 | 1,973 |
| travel delay cost | 13 | 940 | 41 | 6,435 |
| dust & dirt | 13 | 66 | 55 | 136 |
| parking meter s revenue | 26 | 39 | 83 | 217 |
| decreased road surface value | 66 | 144 | 227 | 318 |
| noise pollution costs | -26 | 2.10 | | 7 |

Above study by Steve Apeldoorn (2009) concluded from maximum and minimum unit rates for social cost from case studies (J. Pucker et al 2006)

J. Pucker et al (2006) case studies focused on traffic related social cost but more consideration needs to be given to green house gas emissions resulting not only from the traffic disruption / diversion but from the construction activities themselves. They found that trenchless construction methods resulted in 78% to 100% lower green house gas emissions than open cut pipe line installation methods , the main difference is the large differential in the energy used to remove and replace the material above the utility , the difference in material to be removed between trenchless and open cut to allow installation of the pipe is 53 times or 5300%. Another important social cost factor that should also be considered in comparison is the visual impact on the environment . Trenchless technology projects have a far smaller impact on the project zone , reduce the disruption , stress and effect on the life style of the inhabiting community particularly during large and long duration projects. Social cost will not always be significant, particularly in low density residential areas but in situations where the impact of social cost to the community and environment are potentially substantial , the inclusion of social cost in calculation of the project cost should be considered when comparing open cut and trenchless construction methodology.

## V. CONCLUSION & RECOMMENDATIONS

### A. *Conclusion*

A comprehensive study of literatures was provided in the previous chapters with the intention of giving a specific approach when selecting the appropriate trenchless technology method for installation, repair and rehabilitation purposes of underground urban infrastructures. From the study of literatures it is clear that Pipe jacking, HDD, Micro tunnelling and Pipe Bursting are the most commonly used method of trenchless technology that give more productivity. Obviously Geo engineering Considerations are also important in the implementation of trenchless technology for the safety of underground and contiguous structures. The trenchless technology method is more expensive to perform than the conventional open-cut method if only direct costs are considered. However, trenchless technology has great advantages if social and environmental costs such as traffic delay, noise, and income loss

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of area businesses are considered. The social and environmental advantages of trenchless technology are becoming more significant as the societal concerns of the public increase. Trenchless technology is much more efficient than the conventional open-cut method if one also considers productivity, workers' safety, and structural issues. In this thesis, only a few aspects of construction projects are discussed. As other social and environmental factors are considered, it will be more obvious that trenchless technology is a much more cost-effective method than the conventional open-cut method.

Recommendation- In study we observed that the laying of sewer line .in same pavement at places where traffic intensity is medium or maximum, trenchless technology is seems to be cheaper as compare to open trench method. In low intensity traffic areas trenchless technology is seems to be costlier as compare to open trench method. The time will soon come when the conventional method of open trench digging will be selectively banned in India. To begin with, work should be undertaken for crossings under roads, national highways, railways, canals etc as well as installation, rehabilitation and renovations of sewerage systems in major cities as well metropolitan cities will be construct by trenchless technology

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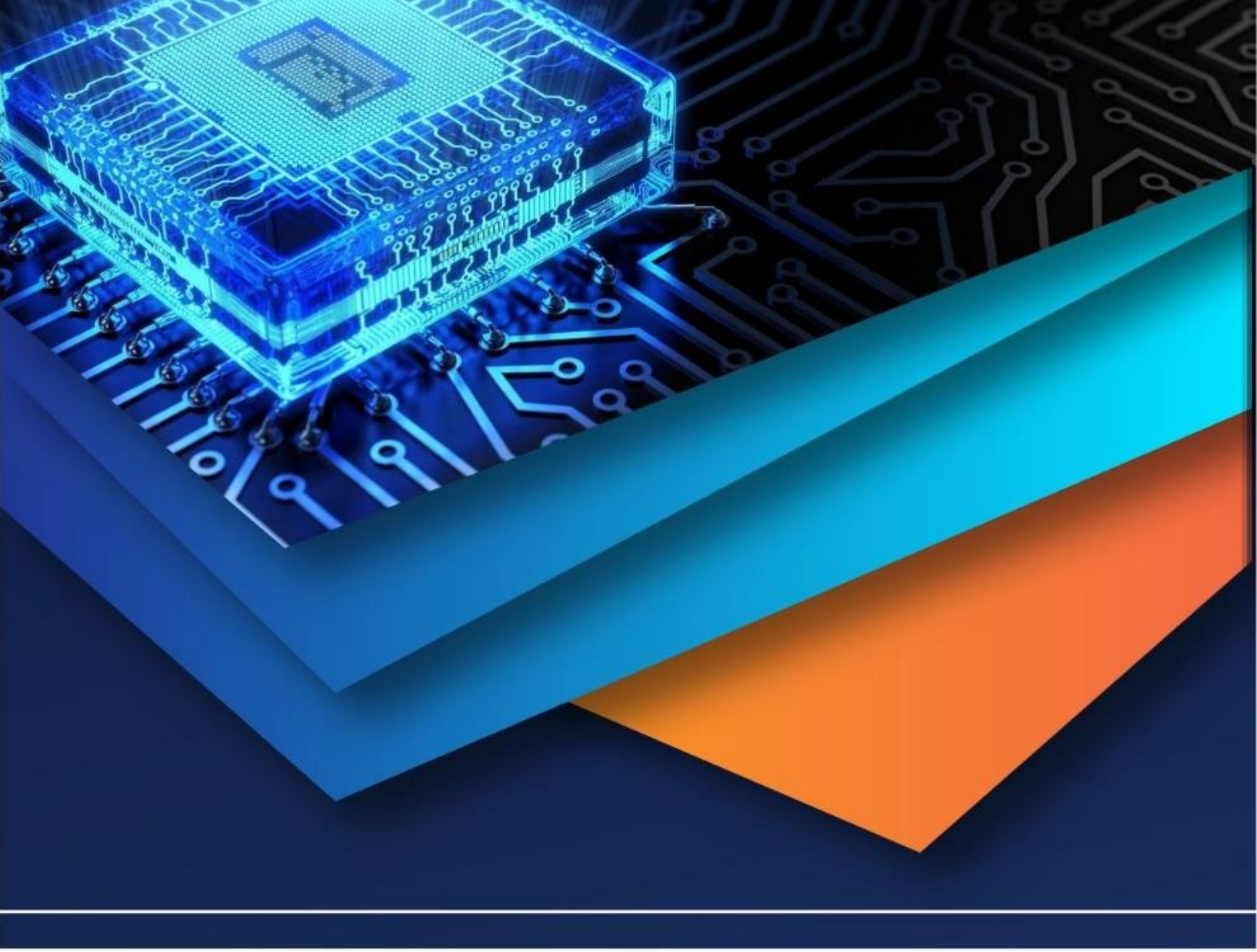

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