SUSTAINABLE INNOVATION IN UNDERGROUND INFRASTRUCTURE CONSTRUCTION AND MAINTENANCE PRACTICES

OM23
26C

Moustafa Kassab
Civil Engineering Department, Faculty of Engineering, University of Prince Mugrin, Saudi Arabia
Systems Design Engineering, University of Waterloo, Canada

Abstract

Underground infrastructure utilities networks require continuous development, repair, and rehabilitation due to increased populations and their demands, aging networks deterioration. Networks of water, solid waste, electrical and communication cables are just an example of these essential utilities in our life. Today, decision-makers in public authorities, and engineers are facing a big challenge in finding and implanting not only the most economical construction and maintenance methods, but also, they must use the most less-disturbing and sustainable methods that have minimum impact on social and business public-life and the environment. New Innovativd technology of Trenchless construction and maintenance methods offer an opportunity as an optimum solution for installing new utilities networks and rehabilitating existing aged infrastructure networks using economical and green concepts. This paper explores this new construction technique, with its economic and environmental benefits in trenchless construction and maintenance compared with the traditional open-cut excavation. It demonstrates the merit of adopting trenchless construction technique for sustainable development of underground infrastructure, road construction and maintenance. next step.

1. INTRODUCTION

In today's modern society, the continuous availability of basic infrastructure services are essential part of daily life. No communities could be considered inhabitant without the availability of fresh water and wastewater networks, power and telecommunication. The necessity to provide these services and keep them in updated functioning condition is so crucial to the municipality in such away it make creating an emergency department and highly skilled emergency crew to repair urgent and damaged utility on the 24 hrs. basis are available. This task becomes big burden and heavy task when it comes to service and maintain old and damaged infrastructure utilities in the urban and critical locations of big cities and communities affected by. For Infrastructure new construction, and existing aged rehabilitation, and maintenance, local municipalities and Infrastructure Engineers, decision-makers and ccontractors in these dense- pedestrian and traffic are faced with challenging tasks of installing and maintaining underground infrastructure utilities in the crowded vicinities. This includes installation, inspection, repair, and replacement of underground service networks of various infrastructure utilities such as water and waste water pipelines, power, and telecommunication.

Traditionally, construction and maintenance of underground utilities involve open trenching methods are proven expensive, particularly in congested urban areas of crowded cities and critical locations (Figure 1).

Contractors have to close roads, divert traffic and create chaos and frustration for vehicles, commuters, and business in the operation vicinity, in addition, they must cautiously dig and operate carefully around other existing critical utilities to achieve the required depth and proper location, which in turn slows down the whole operation and delay the projects. Additional costs in open trenching construction are incurred by the process of restoring the existing original surfaces including pavements, sidewalks, and other disturbed facilities, as well as, landscaping. Open cut trenching operations often result in high user and social costs due to the disruption to vehicles and pedestrian traffic, as well as its adverse impact on nearby businesses [1,2,3,8], let alone the danger of possible collapse of trenches walls on the working personnel, and close by pedestrians. Furthermore, the increases in the population of crowded cities, and urgent need to rehabilitate, replace aging infrastructure utilities systems, as well as, repairing damaged utilities, together with the increased emphasis on user and social costs, have pushed municipalities and contractors to seek alternative methods for repairing and replacing underground utilities [4]. Accordingly, in many western countries, under-pressured municipalities found the solution for this problem by utilizing the Trenchless excavation technology in construction. This Trenchless construction methods are an emerging area of construction involving innovative methods, materials, and equipment used for the installation of new, and the rehabilitation, or replacement and maintenance of existing underground infrastructure with minimal or no need for open cut excavation [3].

Figure1: Traditional open-cut Trenches construction: Disturbance for Pedestrians, traffic, business and environment [8]

2. Trenchless Construction and Maintenance Tanique:

Trenchless construction (Figure 2) can be defined as "a family of methods, materials, and equipment capable of being used for the installation of new or replacement or rehabilitation of existing underground infrastructure with minimal disruption to surface traffic, business, and other activities" [1, 6,7]. Based on location, type of infrastructure utility, and soil type, different trenchless construction-techniques are available such as horizontal directional drilling, pipe jacking, micro tunneling, auger boring, and pipe bursting. Other trenchless rehabilitation techniques include lining of pipe, pipe scanning and evaluation, and robotic spot repair. Even-though, the extensive use of trenchless construction for the installation, repair, or replacement of underground infrastructure utility is a relatively recent development; yet, the idea and uses of trenchless techniques dates back to the 1860s, by Northern Pacific Railroad Company pioneer the use of pipe jacking techniques. By the 1930s, reinforced concrete pipes had been installed using this technique. Subsequently, other methods of trenchless construction began to emerge and utilized including horizontal directional drilling (1971), pipe bursting (1980). auger boring (1940), impact moling (1962), , microtunneling (1973), and [3, 6,7,10]. Thereafter many developed countries have successfully started to adopt trenchless construction technology in one form or another.

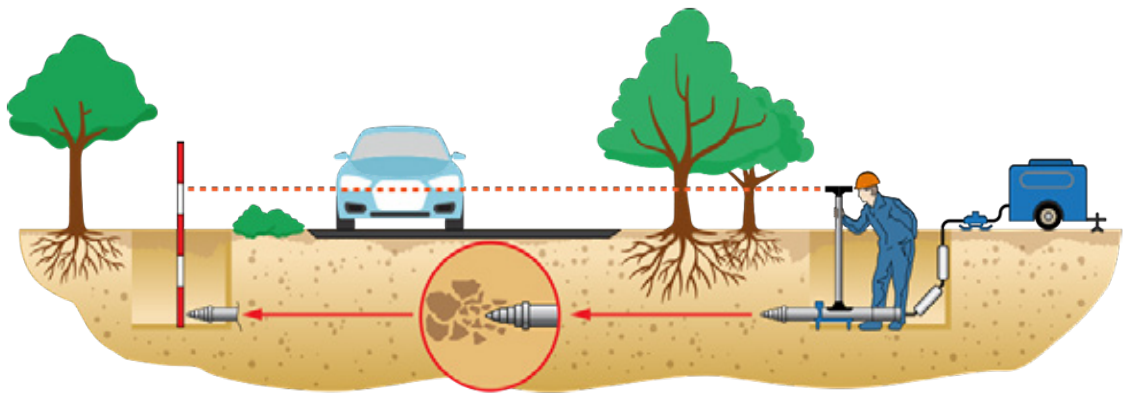

Figure 2: Sustainable Trenchless Technique: No disturbance for pedestrians, traffic, business, and environment [8]

3. Trenchless Construction methods

There are various methods of trenchless technologies that may be used (Figure 3) dependent upon utility type,

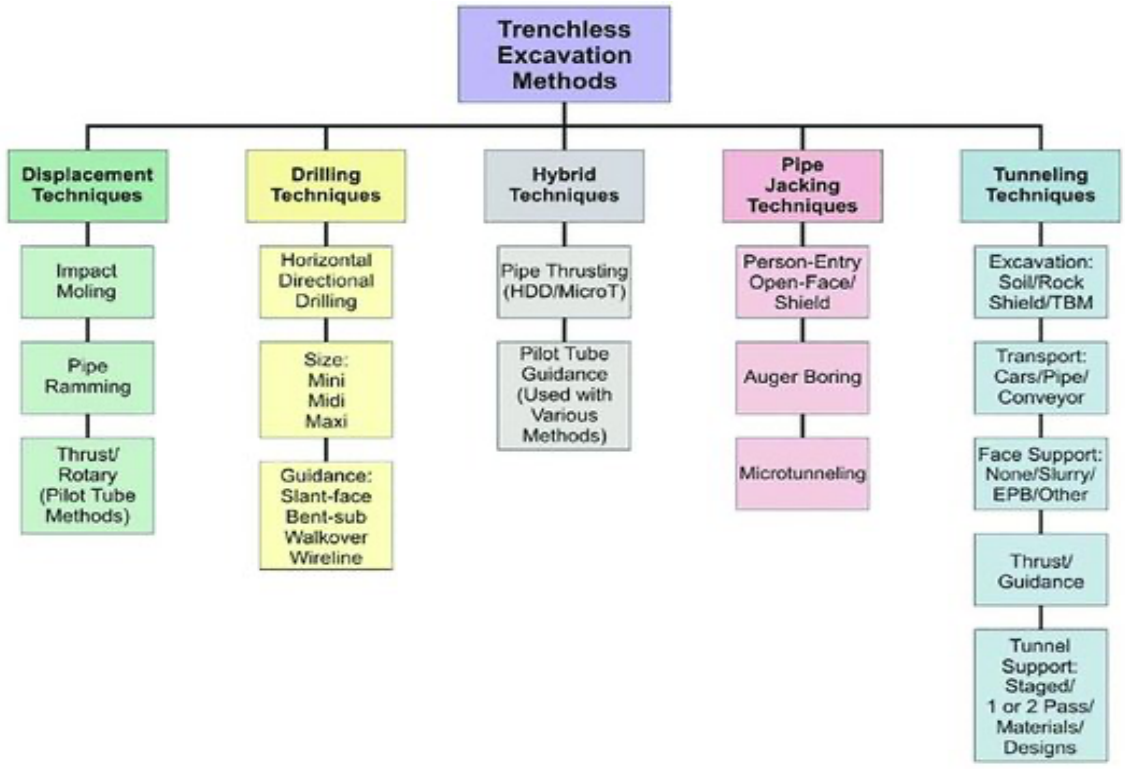

Figure 3: Trenchless Construction and Excavation Methods

location, soil condition of the ground, pipe size that needs to installed, the depth it needs to be installed to, and the overall cost of the method. Example popular methods have been outlined below (Michigan Department of Transportation 2006) [10, 11, 12].

Horizontal directional drilling: A steerable system for the installation of pipes, conduits, and cables in a shallow arc using a surface launched drilling rig. Traditionally HDD is applied to large scale crossings such as rivers in which a fluid filled pilot bore is drilled without rotating the drill string, and this is then enlarged by a wash over pipe and back reamer to the size required for the product pipe (Figure 4).

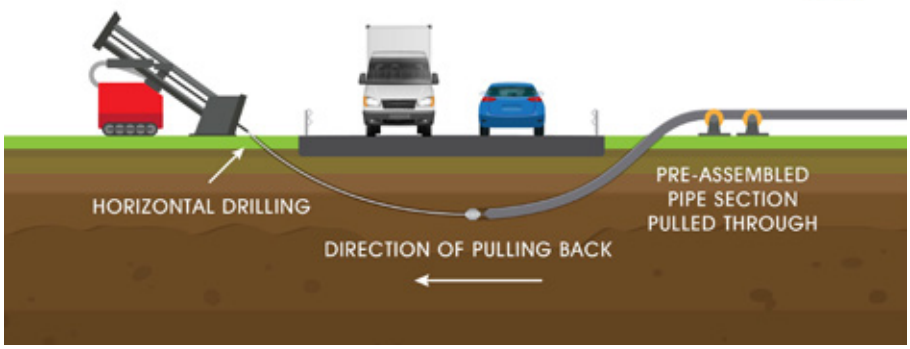

Figure 4: Horizontal Directional Drilling [10]

Pipe bursting: A technique for breaking existing pipe by brittle fracture, using force from within, applied mechanically. Pipe remains are forced into the surrounding soil. At the same time a new pipe, of the same or larger diameter, is drawn behind the bursting tool (Figure 5).

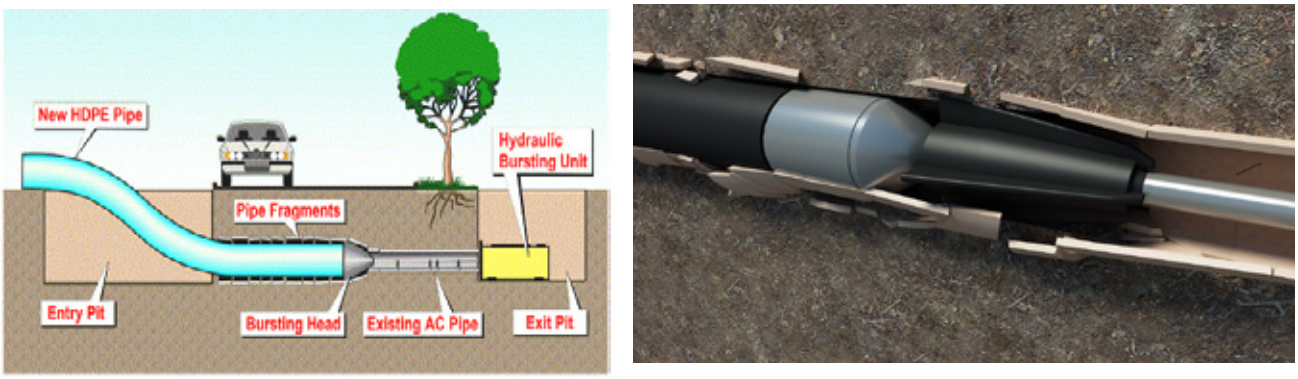

Figure 5: Pipe Bursting

Pipe ramming: A technique for installing steel casing from a drive shaft to a reception shaft utilizing the dynamic energy from a percussion hammer attached to the end of the pipe. A continuous casing support is provided and over-excavation or water is not required. This is a 2- stage process (Figure 6).

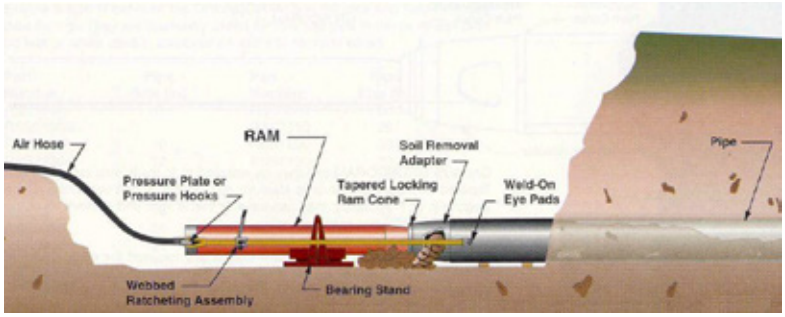

Figure 6: Pipe Ramming

Pipe jacking: A system of directly installing pipes behind a Shield Machine by hydraulic jacking from a Drive Shaft such that the pipes form a continuous string in the ground. Usually personnel are required inside the pipe to perform the excavation or spoil removal process. The excavation can be performed manually or mechanically (Figure 7).

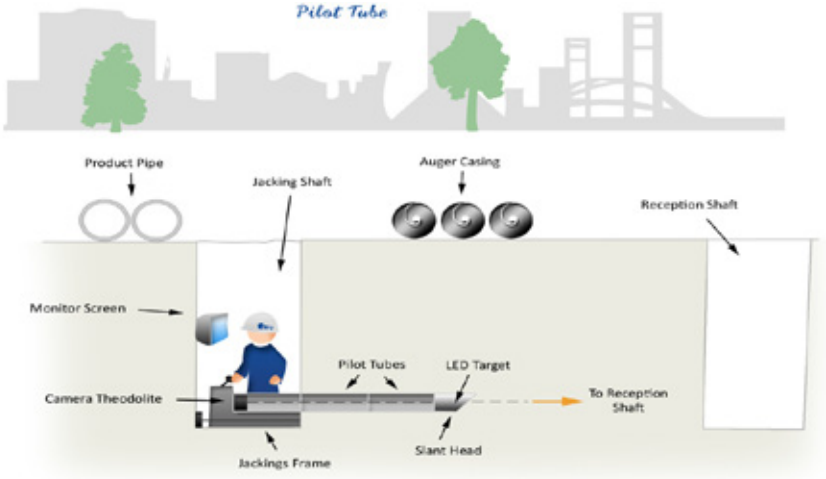

Figure 7: Pipe Jacking

Microtunneling: TT construction method for installing pipelines with the following features (Figure 8)

Remote Controlled – The Micro Tunnel Boring Machine (MTBM) is operated form a control panel, normally located on the surface. It simultaneously installs pipe as spoil being excavated and removed. The guidance system usually refers to a laser beam projected onto a target in the MTBM, capable of installing gravity sewers or other types of pipeline to the required tolerance for line and grade. It has Jacking Pipe – The process of constructing a pipeline by consecutively pushing the MTBM through the ground using a jacking system. The Face Support – Continuous pressure is provided to the face of the excavation to balance groundwater and earth pressure.

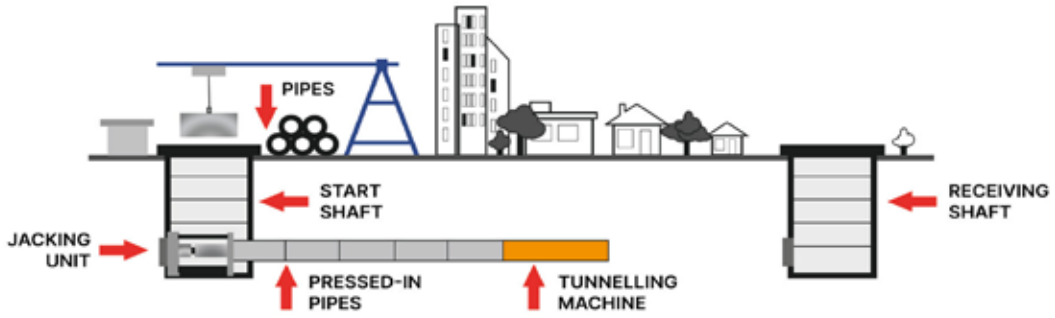

Figure 8: Microtunneling

4. Sample Successful case studies

Trenchless construction and maintenance technology for infrastructure projects (Construction, Maintenance, and Rehabilitation) in the crowded cities and critical sites are still rarely used in the Arab countries despite its successful usage and wide acceptance in western and developed countries who adopt this method of construction and maintenance, especially in the crowded cites, and critical sites. Every year, hundreds of trench less technology projects were successfully completed. Trenchless technology magazine and website list regularly stories and projects completed using this technology around the world particularly in North America and Europe. For example [17] Kezdi listed 50 projects which readers can access them through that reference.

Crossing under the River of Texas's Rio- Grande using HDD, USA

Webb County, Texas, nine-member directional drilling crews with PUMPCO Inc. have successfully crossed under the river of Rio Grande. The project involved boring and pulling back 2,200 ft of 36-in. pipe approximately 80 ft under the river's bed using Trenchless method of Horizontal Directional Drilling. It was the last leg of the 17-mile long Pipeline that has to cross the river. "Using the proper method and equipment of trenchless technology, the construction process was easy and quick" said by the project manager. On average, the crew drilled around 500 ft a day and took them around four and a half days to complete without disturbance to the river and the environment, and the project completed on time and budget [19].

Frankfurt Airport, Germany

With nearly 65 Million passengers using its services each year, Frankfurt Airport, in Germany, can't just shut down for maintenance. However, after 40 years of heavy usage, the airport's vast system of sanitation infrastructure was in danger of falling into a critical state. The system exacerbated normal

wear and tear, leading to cracks, pipe offsets, corrosion and multiple un-flushable deposits. The airport authority led a charge to repair or replace the wastewater network at Frankfurt Terminal 1 and contracted Germany's ANT GmbH to manage the project. ANT sought support from Trelleborg Pipe Seals, a provider of pipe renovation systems with coverage across Europe and the United States. With a vast spiderweb of pipes lying directly beneath the terminal's buildings, this would be no simple project for either firm. Using a combination of several trenchesless technology methods, the project team had managed to successfully repair almost two and a half miles of pipes without a single trench being dug. By working at night and using compact, portable equipment, the team was able to minimize disruption to the day-to-day running of Frankfurt Airport. Crucially, the solutions that are now in place are expected to last at least 50 years, helping Frankfurt's 1970s old sanitation system to last well into the second half of the 21st century [20].

Installing Sustainable Stormwater System at Krakow Airport, Poland

In this airport, the nearby stream into which the rainwater had previously been discharged could no longer handle the growing amounts. It was therefore decided to extend the storm water sewer system by new pressure lines which should lead the water over a distance of 3 km into the Rudawa River (Table 1). 5.85 km of drainage pipes will be installed with many stretches underneath roads and Aircrafts' taxi-ways using trenchless method of Microtunneling. The works at the airport started in November 2017 and completed ahead of schedule at the beginning of 2019. The installation of this new drainage network will lay the foundation for future expansions of the airport, among others a new runway and aircraft hangars. This will allow for the number of flight operations to increase and further strengthen Krakow airport's international importance [21].

These were just a sample successful stories of sustainable Trechless technology application. more ssucessful sories are available in the literature around the world, The advantages of Trenchless technology and methods in newly installed, maintenance, and rehabilitation of underground infrastructure services are clearly noticeable in the crowded locations, busy streets, and critical locations. It eliminates public disturbance and traffic congestion, reduces construction and maintenance cost, reduces project completion time, with overall benefits to the sustainable economy and environment in the crowded vicinities.

5. Ttrenchless Construction Methods vs. Open Cut trench Method

Research and piratical experiences show the innovative methods of trenchless technology methods advantages overcome open trench methods in many important aspects such as [10, 11, 12, 14, 15]:

• Less disturbing: By open cut method disturb local properties over agricultural land or disturbing local highways. But by use of Trenchless technology come out from these problems like landscape damages.

• Less time: open cut method is time consuming method. In this method time is required for the excavation and refilling of trenches. This process also means time is taken in site restoration, spoils storage and traffic control.

• Enhanced safety compared to steep excavations – by steep excavation Landslides can be occurs. Where the mud is likely to subside due to steep walls or water aggravation, protection needs to be taken with specialist equipment. By trenchless methods provided safety to the workers as there are no steep trenches involved in this work.

• Minimize chance of disturbing existing utilities . Trenchless technology methods 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.

• Problem to the public such as noise and air pollution – The indirect social costs of open cut projects consist of unhealthy, inconvenience to traffic, and noise pollution. But these problems can play a big part of local communities. These problems can be overcome with trenchless technology methods without the need for road closures, noise pollution.

• C02 Emission: Researches shows that trenchless technology are more friendly to the environment in many ways such as its identical operation using open cut exaction will safe 80% of carbon emission to the atmosphere [6,14]. In addition less dust and no trees or green landscape areas will be disturb or removed. As shown in Figure 9

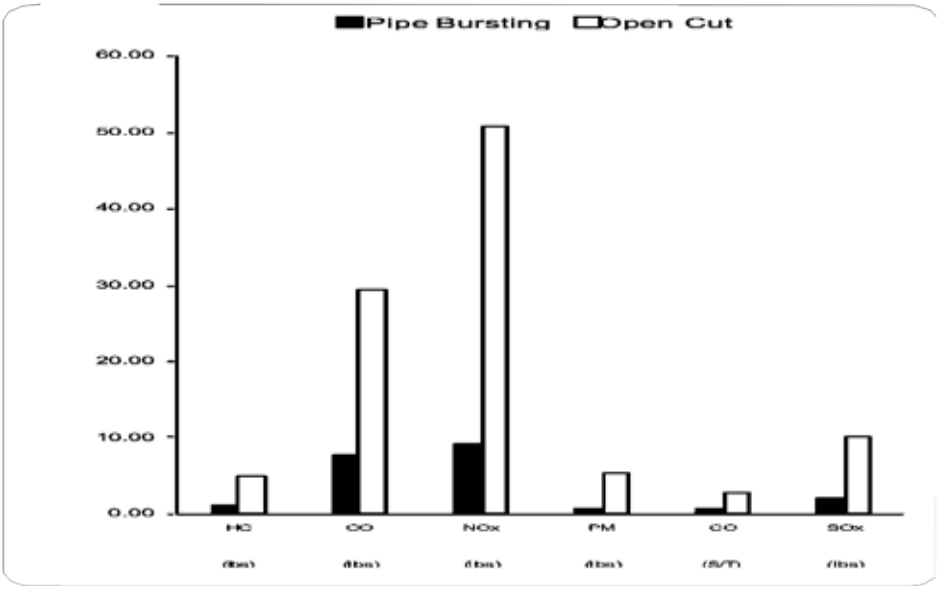

Figure 9: Comparison for reduction in gas emission between open cut and Trenchless method

• Choosing the right excavation method, trenchless technology methods could save up to ½ total cost of the similar operation [15]

• Encountering fewer unknowns in the ground – in open cut method, approximately 70% of the cost required for excavating and replacing the ground during the process. As per unknowns come in the excavation or digging cost of excavation increases. By use of Trenchless technology methods reduced this problem.

• Save time and cost related to survey and design – open cut method consists 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, ensuring that conditions are safe to work. But in trenchless technique saved time and cost related to survey.

Despite its many advantages, yet the decision to use the trench less technology should have careful pre-planning and thoughtful investigation for the type of project, location, soil type and cost. Michigan Department of Transportation [10] recommendation for engineers and decision-makers that should recognized there are conditions where trenchless applications are not appropriate, such as emergencies, where immediate trenching of the pavement is necessary, and advanced planning simply cannot be done. In other cases, conditions such as the nature of the soils and rocks below the surface, or the presence and/or uncertain location of existing utilities preclude the use of trenchless technology methods.

Table 1 : Appropriate Technique for Trenchless New Installation [10]

TECHNIQUE	Water	Sanitry & Storm Sewers	Gas	Electricilty	TeleCumuni-cations
Horizental Auger Boring	x		x	x	x
Pipe Ramming	x	x	x	x	x
Pipe Jacking		x			
Drirectional Drilling	x	x	x	x	x
Microtunnling		x			
Pipe Bursting	x	x	x		

6. Conclusions

In today modern society, having proper underground infrastructure utilities such as, service lines of water wastewater or gas pipes, electric or telecommunication cables, becomes an essential part of the our daily life, installing new utilities and maintaining the existing old, or damaged sections are becoming costly and disturbing for the society (traffic and pedestrian delays) and environment (safe trees, landscape, less gases emission, and less pollution to water and soils). This problem is especially magnified and tedious in crowded cities. Trenchless technology methods in construction and maintenance are an innovative new technology successfully utilized in many developed countries. Yet, it is not commonly adopted by the majority of the crowded cites in the Arab countries. Many innovative methods have been developed to suit type of utility, soil condition and locations. Many benefits could be gain by introducing these sustainable technology solutions in the region such as lowering construction cost, less traffic and pedestrian congestion and headache, and many others advantages that demonstrate the merits of adopting trenchless technologies for sustainable development of underground infrastructure systems.

References

[1] McKim, R., 1997. Bidding strategies for conventional and trenchless technologies considering social costs. Canadian Journal of Civil Engineering 24 (5), 819–827.

[2] Arends, G., Bielecki, R., Castle, J., Drabek, S., Haack, A., Nedbal, F., Nordmark, A., Sterling, R., 2004. Risk budget management in progressing underground works. Tunneling and Underground Space Technology .19 (1), 29–33.

[3] Zaneldin, E.K.. (2006).Trenchless construction: An emerging technology in United Arab Emirates. Tunneling and underground space technology. 22(2007) 96-105.

[4] Russell, D.E., Davies, A.T., 1997. New tools for water main asset management. No-Dig Engineering 4 (4), 2–6.

[5] Schreyer, J., 1998. GSTT investigation: guidelines for selecting construction methods for earth-laid lines. Tunnelling and Underground Space Technology 13 (2), 129–130.

[6] Ariaratnam, S.T., Lueke, J.S., Allouche, E.N., 1999. Utilization of trenchless construction methods by Canadian municipalities. Journal of Construction Engineering and Management 125 (2), 76–86.

[7] http://www.hms-it.co.uk/trenchless_technology.htm

[8] Bauhan, T., Fowler, D., Haas, C., 1997. Performance testing of trenchless wastewater line spot repairs. Journal of Infrastructure Systems 3 (1), 40–48.

[9] Committee on Construction Equipment Techniques, 1991. Trenchless excavation construction methods: classification and evaluation. Journal of Construction Engineering and Management 117 (3), 521–536.

[10] Michigan Department of Transportation Trenchless Guidelines. Michigan, USA. 3701(11/06). USA

[11] Mohammad Najafi, Brett Gunnink,(October 2005), " Preparation of Construction Specifications, Contract Documents, Field Testing, Educational Materials, and Course Offerings for Trenchless Construction", Missouri Department of Transportation Organizational Results Division, Pg.No.4-13.

[12] Onkar K. Chothe 1 , V.S. Kadam . Comparative Study of traditional method and innovative method for Trenchless Technology: A Review. International Research Journal of Engineering and Technology. V: 03 Issue: 05 | May-2016

[13] Sherif M. Hafez1, Remon F. Aziz1, Ahmed M. Attia2. Exploring Critical Factors Affecting upon Micro-tunnelling Equipment Productivity. International Journal of Education and Research. Vol. 3 No. 8 August 2015

[14] Ariaratnam, S.T. 1999. Sustainable development through innovative underground infrastructure construction practices. Arizona State University, Tempe, AZ USA. http://dl.lib.mrt.ac.lk/handle/123/9383

[15] http://www.istt.com/why-trenchless-no-dig.