PIPELINE CONSTRUCTION PROJECT: A STUDY ON THE EFFECTIVENESS OF TRENCHLESS TECHNOLOGY FROM PROJECT MANAGEMENT PERSPECTIVE

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ABSTRACT

Development of technology in pipeline construction industry nowadays brings alternative method that can be used in installing the underground pipeline which able to reduce the cost usage for a project. Open-cut is a common method used in installing underground pipeline but with surface disruption and brings negative impact to communities, trenchless technology may offer viable alternative with innovative method and cost-effectiveness. Therefore, the research aims to compare the cost effectiveness between trenchless technology and open cut method. The research also provides the criteria to be considered in implementing the trenchless technology. Close-ended survey questionnaire has been used as research methodology while scope of study focusing on east coast construction contractors. There are four respondents that involved in the research. The study proved that trenchless technology is the most cost effective compare to the open-cut method. Comparison has been done based on preconstruction and construction (direct and indirect) cost. The research also identified the criteria to be considered in trenchless technology by highlight on the pipe jacking and horizontal directional drilling. Limitation for the research is the small amount of contractors who specialize in trenchless technology. Future research is needed to consider the other cost factors which may contribute to the project cost.

ABSTRAK

Pembangunan arus teknologi dalam industri binaan pada masa kini telah membawa kaedah alternatif yang boleh digunakan dalam pemasangan perpaipan bawah tanah serta mampu mengurangkan penggunaan kos untuk sesuatu projek. Kaedah "open-cut" adalah kaedah yang biasa digunakan dalam pemasangan perpaipan bawah tanah tetapi dengan adanya gangguan persekitaran serta memberi impak yang negatif kepada masyarakat setempat, kaedah "trenchless technology" mampu menawarkan kaedah alternatif yang diyakini dengan kaedah inovasi dan menjimatkan kos. Oleh itu, kajian ini bertujuan untuk membandingkan dari segi penjimatan kos antara kaedah "trenchless technology" dan "open-cut". Kajian ini turut memberikan kriteria yang perlu diambil kira dalam penggunaan "trenchless technology". Borang kaji selidik tertutup telah digunakan sebagai kaedah penyelidikan sementara skop merangkumi kontraktor pembinaan di kawasan pantai timur. Di dalam kajian ini, terdapat empat responden yang terlibat. Kajian ini telah membuktikan bahawa kaedah "trenchless technology" adalah lebih menjimatkan kos berbanding dengan kaedah "open-cut". Perbandingan telah dibuat berdasarkan kos sebelum pembinaan dan kos semasa pembinaan (kos langsung dan tidak langsung). Kajian ini juga mengenal pasti kriteria-kriteria yang perlu diambil kira dalam penggunaan kaedah "trenchless technology" dengan mengetengahkan kaedah "pipe jacking" dan "horizontal directional drilling". Bilangan kontraktor yang khusus untuk kaedah "trenchless technology" yang sangat terhad menjadi faktor penghalang untuk kajian ini. Kajian lanjut diperlukan bagi mengambil kira faktor kos lain yang mampu menyumbang kepada kos sesuatu untuk projek.

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ECER	East Coast Economic Region
HDD	Horizontal directional drilling
HDPE	High-density polyethylene
JKR	Jabatan Kerja Raya
LRT	Light rail transit
NATM	New Australian Tunneling Method
OSHA	Occupational Safety and Health Administration
PKK	Pusat Khidmat Kontraktor
SMART	Stormwater Management and road Tunnel
SPSS	Social package for science social
TBM	Tunnel boring machine

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Throughout this chapter, it discussed on background of study, problem statement, research objectives, research questions, scope of study, limitation of study and expected result of the research.

Technology is common thing that being used by mankind nowadays. Dorf (2001) referred technology to be machines, processes, methods, materials, tools, and devices applied to industrial and commercial objectives. Others define technology as the organization of knowledge for the achievement of practical purposes (Dorf, 2001). Nowadays, the contemporary world is influenced by technology which major technological changes can set population shifts in motion, determine development pattern, and create or solve pollution problems (Dorf, 2001). Technology has been developed and being use in industries widely such as automotive, manufacturing, renewable energy, construction even in transportation systems.

In managing technology, organization must capable in exploiting the existing knowledge and technologies for short-term profits and also explore new knowledge and technologies to ensure long-term innovation (Eriksson, 2012). Najafi (2005) mentioned that, consideration should be taken in applying new technology whether on efficiency, environmental friendly or cost-effective of method use. As example in construction project, applying prefabricated technology can shortened construction time, lower overall construction cost and improved in quality and durability rather than conventional on-site construction method (Chen et al., 2009). However, the successful of applying the technology not only rely on the method but also the management team. Hence, project managers in today's construction industry must adapt the changes in industry environment to maintain competencies in practicing project manager by relying on skill, knowledge and experiences (Edum-Fotwe and Mccaffe, 2000).

Malaysia has been one of the successful countries in mega tunnelling construction project by introducing the SMART (Stormwater Management and Road Tunnel) project. This project was introduced in metropolitan city, Kuala Lumpur. With 9.7 km long constructed by large slurry tunnel boring machine (TBM), the project serves dual function as storm water management and road tunnel for vehicle; one of it kinds for the first time in the world (Rieker, 2006). Moreover, the SMART project serves to solve the frequent flash flood in the Kuala Lumpur city centre and provide alternative road for traffic at Sungai Besi, Kuala Lumpur southern gateway thus avoid traffic congestion (Kumar, 2005).

Technology is indispensible in any large construction project which being one of the most critical factors to succeed and sustain in today's business environment and construction (Long et al., 2006). Findings from Yang et al. (2006) showed that technology is critical to assist in the execution of project work functions and may contribute significantly to project performance in terms of stakeholder success. Hence, it would help managers in decision making for new technology investment whether to apply technology to certain work functions (Yang et al., 2006). But, shortage of information regarding technology benefits along with uncertain competitive advantage from new technology has resulted in industry reluctance to implement new technology (Yang et al., 2006).

1.2 BACKGROUND OF STUDY

Installation of underground utility or pipeline can be done in numerous ways. The conventional method often being used is open-cut method. Nevertheless, there are other methods of construction that can be used such as tunnelling using drill and blast, and tunnel boring machine. In general, most all of the utilities installation today is buried underground. Exploration of underground space drastically increases since 19th century as development of the urban areas (Canto-Perello and Curiel-Esparza, 2012a). However, placement of utilities has not been generally accomplished in any sustainable technique resulting in a veritable maze in high density urban areas (Canto-Perello, and Curiel-Esparza, 2012a). Various type of utilities are being install underground including electricity, telecommunication network, sewage and water supply (Zaneldin, 2006). Therefore, Canto-Perello and Curiel-Esparza (2012a) stated that the method use for utilities installation must align with proper infrastructure planning by considering alternative methods to achieve sustainability and compatibility.

Installation of new pipeline can be done whether using open-cut method or trenchless technology. Open-cut is common method used in Malaysia for utilities installation (Khairunnisa, 2011). However, this method should be use at minimum for subsurface urban area project (Canto-Perello and Curiel-Esparza, 2012b). Therefore, trenchless technology may provide an option for that issue. With minimum adverse effect on public life and disturbance to infrastructure, trenchless technology may generate interest to use in construction industry (Gupta et al., 2001). Establishment of North American Society for Trenchless Technology (NASTT) organization in United States on 1990 accelerate the developments of trenchless technology including manufactured powerful horizontal directional drilling and, new locating and tracking tools by digital control (Najafi, 2010).

According to Najafi (2010), he stressed that the most costly item in trenchless installation method is pipe installation; usually being estimated on a linear foot basis while open-cut method spend major cost on excavation, backfilling, pavement replacement, and

shielding or shoring; estimated on a cubic yard or square foot basis. Although trenchless technology being considered as higher short-term direct costs and remain as barrier to adopt, Hunt et al. (2012) stated that there would be lack of research to show where the economic tipping point between the two methods occurs and how it might be influenced by utility type, pipe number, pipe diameter, number of excavation and reinstatement procedures avoided, location and the choice of method of installation used.

1.3 PROBLEM STATEMENT

Projects involving underground installation of pipeline prefer to use conventional method which is open-cut as installation method. This method usually is practical for shallow tunnel in location with no important constraints on (David et al., 2010). Projects such as sewer, metro station and vehicular tunnel are often being constructed using open-cut method (David et al., 2010). Nevertheless, this method requires the trench excavation for pipe installation and subsequently backfilling. According to Najafi (2005), open-cut method may involve major effort before and after the pipes is being installed which can affects the overall costs for the project. Since the project is being done on ground and work sites may be needed, this may create disturbances to nearby area. Furthermore, using this method in urban area may cause traffic congestion and disruptive to nearby businesses (Najafi, 2005).

Since the open-cut method requires trench excavation, the project involved in pavement cuts need to have patches. In a study of installing utilities and road defects, Khairunnisa (2011) stated that using open-cut method may cause depression to the road after installing the utilities. Moreover, the patches may be uneven or easily deteriorated compared to undisturbed roads. Studied from Najafi (2010) have shown approximately up to 60 percent reduction in the life of pavement due to lateral cracking after pavement cuts. Besides, the installation processes also may cause the path of the pipeline became uneven. In addition, Hashemi (2008) stated that considering social and environmental factors, open-cut methods have negative impact on the communities, business and commuters due to

surface disruptions. Therefore, it is necessary to consider other technology which is trenchless technology as preference method other than open-cut method.

With the development in technology used for trenchless technology nowadays, the method can be less expensive rather than open-cut method in term of total construction cost regarding installation of the utility (Najafi, 2005). Furthermore, trenchless technology is safer than open-cut construction by considering the risks associated with deep and large section of open excavation. By providing minimal reinstatements, trenchless technology will not harm the existing vegetation (David, 2010). Typically, trenchless method will reduce the quantities of incoming and outgoing materials hence reduce the spoil produced. Besides, it would be beneficial if being used in urban centre because the operation will not interfere with pedestrian and motor traffic movements.

Since trenchless technology involves underground construction, this may reduce the interaction with the traffic and above environments. Regarding this matter, the method can be used to repair, upgrade, replace or install underground infrastructure systems with minimal disruption to the surface and offer viable alternative to existing open-cut method (Hashemi, 2008). In contrast, trenchless technology uses innovative methods, materials and equipment, which can be considered to be safer, efficient, productive and cost-effective (Hashemi, 2008).

Hence, by having comparison between open-cut method and trenchless technology may provide perspectives on which method can be considered as cost-effective method to be used. The question now, is it possible to adopt the trenchless technology as alternative for the old method used in Malaysia? Therefore, the research will provide information regarding this matter.

1.4 RESEARCH OBJECTIVES

The objectives for this research will resolve the stated problem. They are;

i. To identify the criteria to be considered in trenchless technology.

ii. To compare the cost effectiveness between trenchless technology and open-cut method.

1.5 RESEARCH QUESTIONS

Specific research questions are being constructed in order to guide research for reliable result. They are;

i. What is the cost requirement for each of installation construction method?

ii. What is the major different in cost requirement between trenchless technology and open-cut method?

iii. What are the criteria to be considered for an effective trenchless technology?

1.6 SCOPE OF STUDY

The research will emphasize on open-cut method and trenchless technology. The costing for each installation in construction method will be the focus for this research. By having this information, cost-effectiveness for trenchless technology can be compared with open-cut method. Besides, the research also looks into the criteria needed for an effective trenchless technology.

The study will be conducted in Malaysia, specifically in Pahang and Terengganu states. These states involve in East Cost Economic Region (ECER) development programme which stress on socio-economic growth of population, fair income distribution and sustainable development for the region. To achieve this, ECER development programme needs infrastructure and utilities such as electricity and water supply, telecommunication services and sewerage systems; as key enabler in upgrade the working, learning and living environment for ECER residents. Hence, the locations for respondents' selection are being made based on civil contractors' availability in those states.

The targeted respondents for this study are civil contractors who are doing on pipe installation work for "A" class contractor. The respondents will be chosen based on the type of installation method they used. There are two types of method that needs to be concerned which are open-cut and trenchless technology; for pipe jacking and horizontal directional drilling method.

1.7 LIMITATION OF STUDY

In this research, the civil contractors that being chosen must involve in the pipe installation project but the availability of civil contractors who are specialize on trenchless technology is limited. So, this will affect the data analysis for trenchless technology since there are only a few participations from civil contractors that expert on trenchless technology. Besides, the time provided to collect the data is short. Longer time period given to collect the survey from respondents may provide more reliable results for this research. Besides, the cooperation and secrecy from respondents are also may restrict the data collection in survey. The data collected depend on how the respondents answered the survey.

1.8 SIGNIFICANCE OF STUDY

The research provides the literature in costing based on the type of method used and comparison in cost for each method. With the result, the comparison reveals out the major cost items for each installation methods. This research also tries to highlight the cost effectiveness for trenchless technology, in which item that divergence from open-cut method. Therefore, it would give distinct perspectives on the cost for trenchless technology methods. The research also will provide knowledge on criteria needed in trenchless technology installation methods.

1.9 EXPECTED RESULT

The outcome for this research should be able to convey the information based on the objectives. Hence, the results obtain must shows the comparison of cost effectiveness between open-cut method and trenchless technology. This research will reveal which method is most cost effective. Besides, the most cost effective item in trenchless technology can be identified based on comparison with open-cut method. In the end of the research also, the expected criteria needed for an effective trenchless technology from literature study should be compatible with the practical use in Malaysia construction industry. Hence, the criteria for trenchless technology from this research can be applied in pipeline construction in Malaysia.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The chapter represents the past studies and literatures related to the area of this research. Briefly, the contents from this chapter will guide the research for better understanding on what information need to be achieved. This chapter will discuss on option for installing the underground pipelines and utilities. Open-cut method one of the common methods used in installing underground pipelines. This can be applied widely but considerations need to be taken to avoid improvidence for the project cost such as feasibility of the project under certain conditions. Trenchless technology may be an option for road crossing or river crossing project which is more preferable method in not only reduce the cost but also less impact on the surrounding environments. Trenchless bring beneficial for tunnelling underground without caused major disturbance to the surface. Throughout this chapter, brief explanations on the differences between these types of installation method: open-cut method and trenchless technology will be emphasized.

2.2 TUNNELS

Tunnelling, especially tunnel excavation by tunnel boring machines (TBM) has increased in the last three decades (Girmscheid and Schexnayder, 2002). Innovations on the technology provide more efficiency in tunnelling. Tunnels are unlike other civil engineering structures where building and bridge materials have defined and testable properties whereas not in tunnelling which faces uncertainty with the ground and the general inability to influence its properties. According to Kumar (2005), the development of countries has affected the engineering design and innovation in engineering which brought new technologies for tunnelling. Hence, those new technologies may be applied either in urban areas without major disturbance. Canto-Perello and Curiel-Esparza (2012b) stated the most comprehensive utility tunnel networks are located in city centre where traffic congestion is critical, utilities are dense, and the total cost of utility cuts and traffic interference is great.

2.2.1 Definition of tunnel

According to Oxforddictionaries.com, tunnel means an artificial underground passage, especially one built through a hill or under a building, road, or river. It also can be describe as an underground passageway, completely enclosed except for openings for entrance and exit, commonly at each end.

2.2.1 History of tunnels

Underground tunnels in early days are used especially in mining since beginning of the industry (Kumar, 2005). Before mining, tunnels in ancient history were used for water carriage in underground. According to Najafi (2010), the history of buried pipes to delivered water started about 2500 B.C., when the Chinese used bamboo as pipes (Najafi, 2010). Najafi (2010) stated some Mediterranean countries; clay pipes supplied water to villagers at a central well. While in cities such as ancient Rome, tunnels were designed to carry water supply from aqueduct nearby (Kumar, 2005).

The technology of tunnelling advanced from ancient time days until now (Kumar, 2005). There has been considerable development in tunnelling construction techniques in the last 200 years, especially since Marc Brunel's famous first use of a tunnelling shield when constructing the first tunnel under the River Thames at London in 1825 (David et al., 2010). Civil engineering as a profession was largely created in the United Kingdom by the development of the canal system, which itself was part of the industrial revolution of the eighteenth century (David et al., 2010). Two significant tunnels of this era included the 2090m Harecastle Tunnel, constructed using gunpowder as part of the Grand Trunk canal during the 1770s, and the 5000m long tunnel at Standedge, constructed through millstone grit (David et al., 2010).

The first tunnel underneath a navigable waterway was a tunnel under the River Thames in London, between Rotherine and Wapping (David et al., 2010). This tunnel involved tunnelling shield known as 'Brunel's shield', designed by Marc Brunel. The key function of the shield was support the face and provides safety to miners. The innovation of tunnelling construction technology brings the development of rotary tunnelling machine in 1880s that being used at Channel Tunnel, United Kingdom (David et al., 2010).

2.3 UNDERGROUND TUNNELING TECHNOLOGIES

Tunnelling can be constructed by using number of different techniques. Timer heading is one of the oldest methods of tunnel construction without shield involving the use of timbering to provide the temporary support for the ground during tunnelling (David et al., 2010). This technique is very useful in soft ground (ground that has some stand-up time, such as stiff clay) for constructing shorts sections of relatively small diameter access tunnels as part of metro station upgrading projects, for example passenger access tunnels between platforms and storage or plant room (David et al., 2010).

Another technique being used in tunnelling is tunnelling shield. In its simplest form a tunnelling shield is a steel or concrete frame with a cutting edge on the forward face. David et al. (2010) emphasized that there are two main types of tunnelling shields, one with

partial and one with full face excavation. Different face support techniques exist depending on the stand-up time of the ground and water flow into tunnel. The support usually adopted with shield tunnelling these days is circular segments. As the tunnel segments are connected together inside the shield tail, the diameter of the completed tunnel segment ring is smaller than that of the shield, presented in figure 2.1. So, it creates gaps and injected with mortar to close it. Tunnelling shield moves by push itself forward using hydraulic jacks with placing the jack around the circumference of the shield (David et al., 2010).

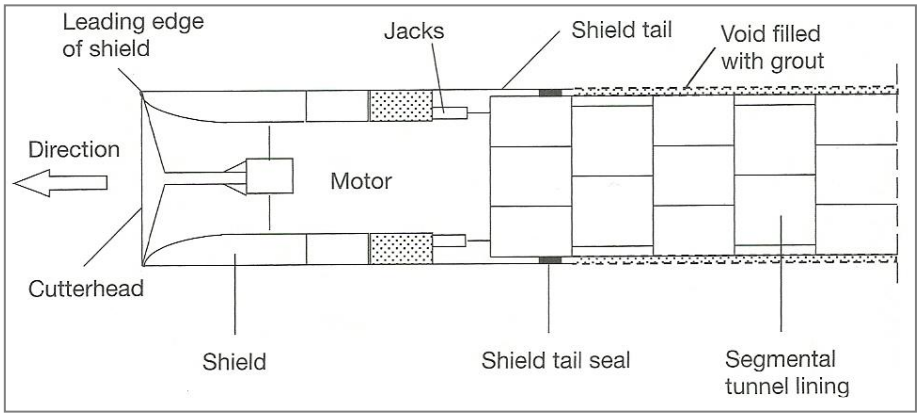

Figure 2.1: Tunnelling Shield: Circular Tunnel Shield with Segmental Linings

Source: David et al. (2010)

Tunnel boring machine (TBM) also one of the methods used for tunnelling. TBM exist in many different diameters, ranging from microtunneling boring machines with diameters smaller than 1m to machines for large tunnels, whose diameter greater than 15m and available for many geological conditions (Jung, 2007). One of the general requirements for the use of TBM is a consistent geology along the route of the tunnel as the different cutting tools are only suitable for a small variation in material characteristics while the combination of different cutting tools on cutter head can increase the application of machines to a greater range of ground conditions (David et al., 2010).

2.4 TUNNELING IN MALAYSIA

Tunnelling activities in Malaysia are related to a number of applications such as for civil engineering constructions like tunnels for highways and railways, and diversion tunnels in water supply and pressure tunnels in hydro power generation, underground mining and quarrying; storage facilities, etc. and of late sewage tunnels (Ting et al., 2006).

Table 2.1: Summaries of Tunnelling Activities in Malaysia: 1995-2005

ITEM	NAME OF THE PROJECT	APPLICATIONS	GEOLOGY	OBSERVATIONS
1	Sg. Selangor Dam (water supply)	Division Tunnel	Granite / faulting	Excessive overbreak D & B, completed 2003.
2	SMART	Dual Flood Mitigation / Roadway	Limestone / Alluvium	Sinkholes, etc. TBM, on-going
3	Karak Highway	Highway Twin Tunnels	Granite	D & B, 1997.
4	Kelinci Dam (water su-pply)	Water Transfer Tunnel	Granite / fault	TBM, 1996.
5	Pergau Dam (hydro-electric)	Division & Pressure Tunnels, Powerhouse	Granite mostly, minor meta-sediments	Low ground stresses, Hydrothermal alteration D & B, 1997.
6	Penchala Link	Highway Twin Tunnels	Granite / fault	Some collapse, add. support; D & B, 2004.
7	K.L.L.R.T.	Subway Twin Tunnels	Limestone / Kenny Hill fm (metasedm and skarn	Sinkholes / hard skarn of 270 MPa UCS. TBM, 2000.
8	Beris Dam (water supply)	Division Tunnel	Sedimentary	5m Dia x 200m long diversion tunnel D & B, 2001.
9	Kinta Dam (water supply)	Division Tunnel	Granite	D & B.
10	Bakun Dam (hydro-electric)	Division & Pressure Tunnels	Sandstone / shale	D & B.
11	Interstate Water Transfer Scheme	Water Transfer Tunnel	Granite	45km long tunnel connecting new dam in Pahang to Langat dam in Selangor-pending. TBM??

Source: Ting et al. (2005)