# TO PERFORM AN ECONOMIC ANALYSIS OF MICROTUNNELING WITH SPECIAL REFERENCE TO THE COLOMBO CITY

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# Declaration

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# Abstract

The city growth taken place with the economies, there had been a development of the infrastructure facilities such as water, electricity, sewer, storm water, gas, and telecommunication. Some of these services were in the form of overhead lines and some were underground. All of these services had to be provided in congested areas where no proper planning had been done in the past. Therefore, it is a tedious task for service providers to carry out open cut excavation and lay the necessary service lines as it would interfere with other facilities provided by the state such as roads and railways. In order to avoid public disturbances, various techniques have been developed by Engineers. One of the feasible solutions is Microtunneling technology without performing open cut excavations. Although tunnelling is expensive, comparatively, it causes minimum disturbances to the general public. It also minimises the interruption of other facilities and interference with routine traffic flows are minimum. Further in the recent past microtunnelling was used in a few project in the Colombo city. Therefore, it is important to perform research on the technology used and cost of construction to give information and guidance for future projects.

The study is a combination of case study method and document analysis of available survey data. Three case studies based on construction projects in Sri Lanka were chosen for the study. Qualitative interviews were also conducted with five key decision makers of these projects in order to collect unquantifiable and unmeasurable data. The findings revealed that even though the direct costs incurred in open-cut constructions are lower than Microtunneling constructions, when all the indirect costs are considered the total cost of open-cut construction method is significantly higher, unmeasurable and the cost-impact is very long-term compared with the open-cut construction method. The pipe jacking and thrust boring methods have been used in Colombo city projects. The microtunnlling is successful without much technical issues. This research study will provide insightful cost evaluations in terms of the direct and indirect costs (total cost) of the Microtunneling projects conducted in Sri Lanka, which in turn will support the decision-making process.

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# 1 INTRODUCTION

## 1.1 Background to the study

The industrial revolution caused a mass exodus of people from rural areas to industrial cities. As a result, population in the cities increased dramatically. Large townships were established and service industries were expanded in order to sustain the increased population. These services include the industries that provide all the infrastructure facilities required for cities in order to support this huge population growth. Some services had to be laid subterranean below the ground level in order to save space in the city as the city centres were confined areas. Continued population growth in cities has necessitated the development of strong water and sewerage network, many of this can be constructed underground. It was necessary to construct these underground pipelines in parallel with the existing road network and habitation.

The traditional method of installing underground pipelines has been dig/trench along the alignment of the pipeline and manually install the pipes and joints. This method is also referred to as open-cut method or open trench method. The features of open trench require many supplementary processes such as detour of roads, storage of excavated materials on the site, backfilling and compaction, ground water management, and restoration of surfaces post the installation (Gottipati 2011). These activities that are additional to the main process of installing pipes consume time, money and disrupt the movement of vehicles and pedestrians. Furthermore, there were many other technological, economic and social disadvantages associated with open trench excavations.

Therefore, other means of providing underground services that avoid mass scale open cut excavation were needed to be developed. As a result of this challenge, various techniques were developed by engineers which minimize the disturbances to the road surfaces and the surrounding areas that would also minimize the other negative aspects of open trench excavation. These technologies are together referred to as trenchless technologies. Trenchless technologies are characterized as those that minimize the need for personnel to be working in the trench below ground level (Gottipati 2011). Among the various trenchless technologies, Microtunneling is one of the feasible alternatives to open trench excavations.

## 1.2 Research problem

While Microtunneling offer various advantages when compared with the open cut excavation, there are also various challenges and risks associated with Microtunneling (Salem, Elwakil, and Hegab 2017). An important issue in increasing the acceptance of Microtunneling (and other trenchless technologies) compared to the traditional open cut construction was the acceptance that various forms of direct and indirect costs involved should be considered in addition to the direct construction costs (Sterling 2018). While direct costs of trenchless technology construction projects are well understood by practitioners, indirect costs including social, economic and environmental costs are often not well understood (Ormsby 2009). As the indirect costs are not well understood, there could be a tendency for incorrect cost evaluations. Direct and indirect costs incurred in Microtunneling construction should not disproportionately increase the cost of construction and therefore cost evaluation must be carried out before implementing such projects.

Microtunneling is a relatively new technology to Sri Lanka, however, some of the key construction projects in the city of Colombo have utilized Microtunneling technology. However, there is scarcity of research conducted in the Sri Lankan context in terms of the direct and indirect costs involved in Microtunneling construction. Indirect and socio-economic inconvenience costs of these projects must form part of the total cost of a project as it assists with the successful completion of the project without expensive unforeseen costs. Implications of social, economic and the environmental costs in the Sri Lankan context would be different to those of the Microtunneling constructions in other countries. Therefore, the present study is focused on the cost evaluation of Microtunneling method of pipe laying compared to the open cut excavation.

## 1.3 Research objectives

The main objective of this study is to review Microtunneling applications to establish the most suitable technologies by identifying costs of main tasks. This objective will be achieved through the following sub-objectives:

1. To review the technologies used in Microtunneling in Sri Lanka and other countries.
2. To establish the cost parameters of Microtunneling.
3. To propose a framework for critical analysis of Microtunneling in Sri Lanka.

## 1.4 Significance of the study

This research study will serve as a support tool to municipalities of Sri Lanka and other developing countries with similar context when selecting a Microtunneling construction method. This research will provide key technical merits and drawbacks of the traditional open trenching method versus Microtunneling method. In addition, this research study will provide insightful cost evaluations in terms of the direct and indirect costs (total cost) of the Microtunneling projects conducted in Sri Lanka, which in turn will support the decision-making process.

The decision-making process lies in the hands of the municipal technical managers. Therefore, their knowledge and experience of up to date information on cost evaluations of Microtunneling technology is vitally important. This research provides insights on various forms of costs involved in the Microtunneling method and its application and use in Sri Lanka. Hence, the present study would bridge the knowledge gap in the construction industry, which would facilitate more accurate cost estimations and effective decision making.

## 1.5 Research methodology

The main empirical work for this study utilizes a case study approach. Case study method permits selecting information-rich cases that allow an in-depth study of the selected projects and a case study approach has the capacity to accommodate a variety of research techniques, the flexibility to select appropriate information-rich cases to study holistically, the ability to investigate a contemporary phenomenon within its real-life context.

A very few construction projects in Sri Lanka that utilized Microtunneling method were chosen for the study. Drawing on qualitative research tools, a thematic analysis of participants' data gathered from in-depth interviews and documents analysis was employed. In addition to the first hand data collected by interviewing key decision makers such as engineers of the Microtunneling construction projects, various important documents of these projects were analysed to evaluate direct and indirect costs and influencing factors associated with these projects.

## 1.6 Thesis overview

Chapter one of this thesis provides the introduction to the study which consist of research background, research problem, objectives, significance and a brief introduction to the methodology of the study. Chapter two provides a literature review of the chosen research domain. It discusses traditional open trench method and introduces various types of tunnelling technologies used in pipe laying and subterranean constructions. The chapter further discusses trenchless technologies and Microtunneling technology with its history and advantages. The literature review chapter then focuses on economies of Microtunneling to review literature on various forms of costs associated with Microtunneling technology.

Chapter three of the thesis discusses the case study methodology with relevant information on how the cases were chosen and the ways in which data were gathered. The chapter then discusses the analysis methods used in the present study. Chapter five of the thesis presents findings and the analysis of the data. Chapter six discusses conclusions, recommendations and further research work.

# 2 LITERATURE REVIEW

This chapter evaluates the extant key literature in the research domains of construction related to open trench and trenchless technology, and Microtunneling technology. The chapter begins by briefly discussing traditional open trench technology. The chapter then evaluates alternatives to open trench technology to focus on a detailed evaluation of Microtunneling technology. The chapter discusses advantages of Microtunneling technology along with a brief history of Microtunneling technology development. The chapter then focuses on economics of Microtunneling to discuss and compare various kinds of costs associated with Microtunneling technology.

## 2.1 Types of tunnelling

Underground installation of pipelines consists of two main approaches; (1) traditional open trench approaches, and (2) trenchless approaches. Table 1 summarises key construction methods belonged to these two methods that are used in underground installation of pipelines.

**Table 1 - Type of tunneling (compiled by author based on several sources of literature)**

| Method | Where the method is used |
|---|---|
| Cut and cover | Shallow tunnels with wide cross sections |
| Drill and blast | Hard rock, mountainous areas |
| Soft ground TBMs: EPB machines | Soft ground, larger diameter tunnels such as metros and rail lines, ground with low permeability |
| Soft ground TBMs: slurry machines | Soft ground with unstable granular soils, high permeability |
| Hard rock TBMs: gripper, single and double shields | Varying types of rock |
| Immersed tube | Shallow water with soft bed conditions |
| Mining/NATM/sprayed concrete lining method | Competent soils and rock |
| Microtunneling | Diameters less than 3 metres |

## 2.2 Traditional open trench technology

The traditional method of installing underground pipelines has been to dig/trench along the alignment of the pipeline and manually install the pipes and joints. Open trench construction (also known as conventional trenching, open cut, cut and cover, and dig and replace) is a method in which access is gained by excavation from ground level to the required level underground for the installation, maintenance or inspection of a pipe, conduit or cable (Ormsby, 2009). Typical steps involved in this operation are outlined by (Parker, 2007) and include the following:

- Cut through surface and provide side slopes (usually 2:1) and bench, wall shoring or worker shielding.
- Excavate and remove the existing pipe with attention to special handling procedure and disposal regulations.
- Provide proper pipe bedding and compaction.
- Install warning tape and or identification wire where applicable.
- Backfill the trench providing adequate cover.
- Restore the surface conditions.
- Perform the required testing prior to commissioning of the pipe.

Figure 1 depicts a cross-section of typical construction elements associated with open trench excavation.

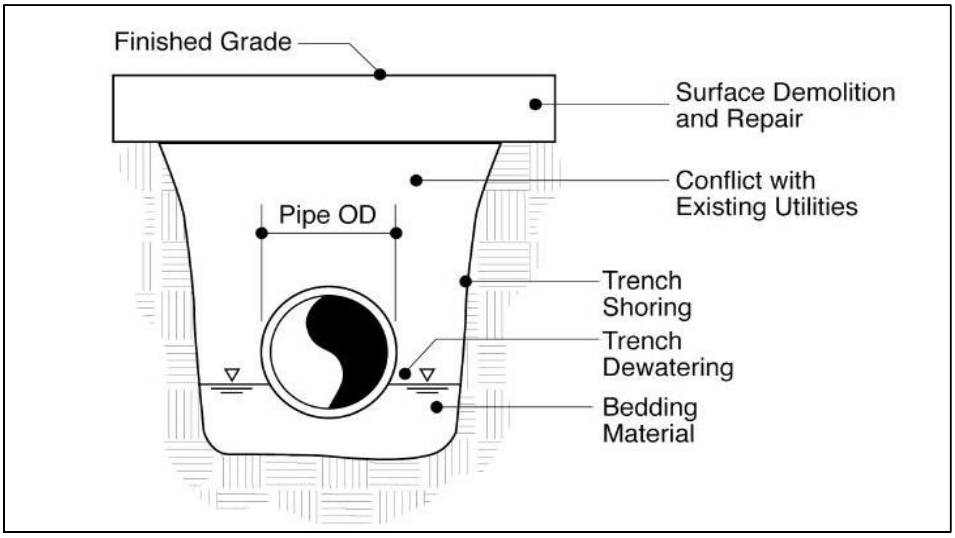


**Figure 1 - Typical open cut elements (Ormsby,2009)**

The features of open trench require many supplementary processes such as detour of roads, storage of excavated materials on the site, backfilling and compaction, ground water management, and restoration of surfaces post the installation. These activities that are additional to the main process of installing pipes consume time, money and disrupt the movement of vehicles and pedestrians (Gottipati, 2011). Cost of these constructions normally exceeds the direct costs to include indirect costs and socio-economic inconvenience. Accordingly, various sources of literature proclaim that traditional open trenching method has shown to be expensive and difficult to implement, particularly in congested high traffic use urban areas. The following are the most emphasised negative impacts of open trench technology (Hafez, Aziz, & Attia, 2015; Ormsby, 2009; Staheli & Hermanson, 1996).

- Vehicular/pedestrian traffic as roadways and sidewalks needed to be restricted from daily use in order to place pipes beneath them.
- Worker safety: Trench safety is a major concern for contractors when performing open-trench construction.
- Interruption of local businesses: Local businesses are likely to lose customers due to resulting traffic disruptions associated with open-trench pipe construction.
- Major inconvenience, congestion, and delays are often imposed on neighbourhoods and their residents due to open-trench pipe construction nearby.
- The increased number of pavement joints at patched surfaces necessitate frequent maintenance resulting in additional traffic impacts and higher life-cycle costs.
- Damage to existing utilities: Existing utilities near the trench are often damaged during the trench excavation and from subsequent soil settlement.
- Soil disposal: Contaminated soil is sometimes encountered during pipe construction.
- Air pollution: Fine soil particles from soil stockpiles created during open trench excavations may become airborne and cause air pollution.
- Water pollution: Water (rain or subsurface pumping discharge) can cause soil erosion and solids may runoff into streams, rivers, and storm sewers.
- Roadways: Open-trench construction often requires sawing, demolition, or removal of pavements followed by subsequent restoration. This significantly reduces pavement life by up to 40 per cent.
- Noise: Open-trench excavation requires the use of heavy equipment that produces levels of noise that cause disturbances to hospital, schools, business, and residences.

- Land defacement: Open-trench pipe construction frequently causes damage and can have adverse short-term effects on grass, trees, and other landscaping features.

Figure 2 describes the traditional open trenching scenario (International Society for Trenchless Technologies, 2019).


**Figure 2 - Traditional open-trenching approach (International Society for Trenchless Technologies, 2019)**

**Plate A**: Illustrates a typical city junction with traffic which is congested with vehicular and pedestrian traffic, yet flowing normally.

**Plate B**: Illustrates the unseen maze of existing underground service utilities beneath the roadways and walkways.

**Plate C**: Illustrates the chaos and disruption which occurs when the underground services need to be replaced using the traditional open trenching method. Streets have to be dug up, lanes closed, traffic backlog and unnecessary dust and noise generated.

Proper utilisation of the access points to underground constructions minimises the need to dip up streets and sidewalks, and minimise the negative impacts occurred in open-trench excavations. Taking this approach as an alternative to open trench, several methods have emerged over the years that minimise trench work. These technologies are together referred to as trenchless technologies. The following section discusses trenchless technologies in general with a special focus on Microtunneling technology.

## 2.3 Trenchless technology

Trenchless technology is a family of non-intrusive construction methods, materials and equipment, used for the installation, replacement or rehabilitation of underground infrastructure, while minimizing excavation and disruption at the ground surface (NASTT, 2007). Trenchless technologies are characterized as those that minimise the need for personnel to be working in the trench below ground level (Hay, 2013). Trenchless methods adopt the following procedures (Yemelin, 2011).

- Broaching a cable
- Pipeline drainage
- Transportation of clearing tools (brushed, scraper, pistons, etc.)
- Pipeline condition assessment (defects)
- Pulling in a new pipeline (liner)
- Connecting existing off-takes to houses etc.
- Disinfecting
- Commissioning the new pipeline.

Figure 3 reflects smooth flowing traffic with minimal disruption when trenchless methods are utilised.

**Figure 3 - Trenchless approach (International Society for Trenchless Technologies, 2019)**

The numerous trenchless methods available on the market today depend on client and contractor preference, expertise and equipment availability (R.L. Sterling, 2010). These methods differ under various factors such as the type of material and shape that the existing ageing deteriorating host pipe consists of in case of rehabilitation projects (Halloran & Slattery, 1999; Wrobel, Szymiczek, & Wierzbicki, 2004). Chin and Lee (2005) state that there are about eighty (80) forms of trenchless methods that have been developed. A detailed diagram indicating the many forms of trenchless methods available is shown in Figure 4

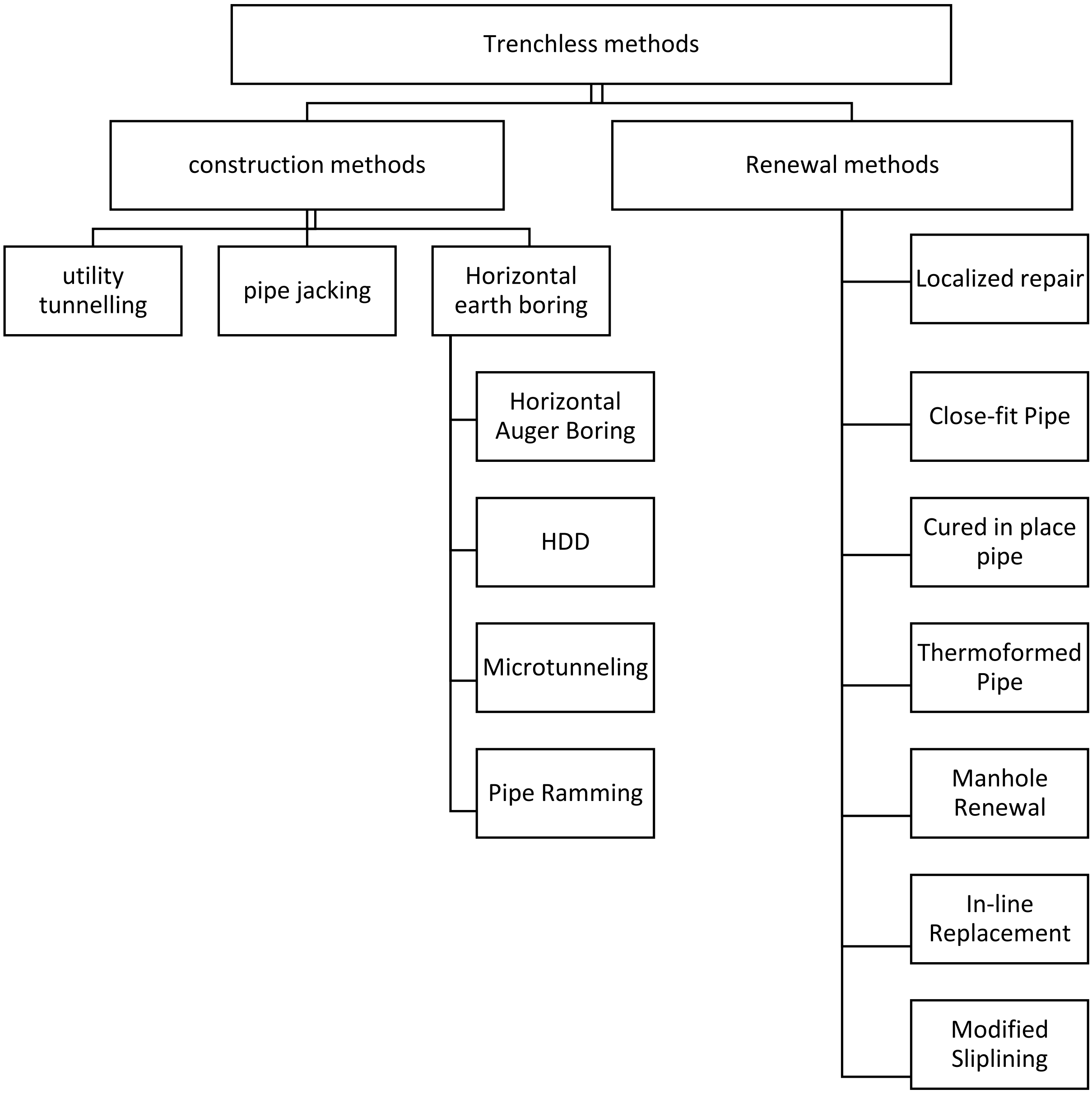


**Figure 4 - Underground construction techniques of trenchless nature**

The following sections briefly discuss each of these methods before focusing on Microtunneling technology.

### 2.3.1. Utility tunnelling method

Utility tunnelling is a trenchless construction method which requires workers to enter the borehole area. It is similar to pipe jacking. However, this technique involves liner plates to provide a shield for workers and to secure the tunnel (Sullivan, 2018).

- Performed in two steps
  - Excavation and Installation of Primary Support
  - Installation of pipe (Secondary Support/Liner System)
- Product pipe sizes 42" and larger
- Limitations on length and size based on logistical considerations and safety

Table 2 demonstrates characteristics of utility tunnelling and Figure 5 demonstrates the typical components of the Utility tunnelling method

**Table 2 - Characteristic of utility tunnelling**

| Method | Diameter Range (inches) | Typical Installatio n(feet) | Pipe Materials | Typical Applications | Accuracy (+ or -) |
|---|---|---|---|---|---|
| Utility Tunnelling | 42" & large | 1,600 | RCP, GRP, Steel | Pressure and Gravity Pipelines | ~ 1 |

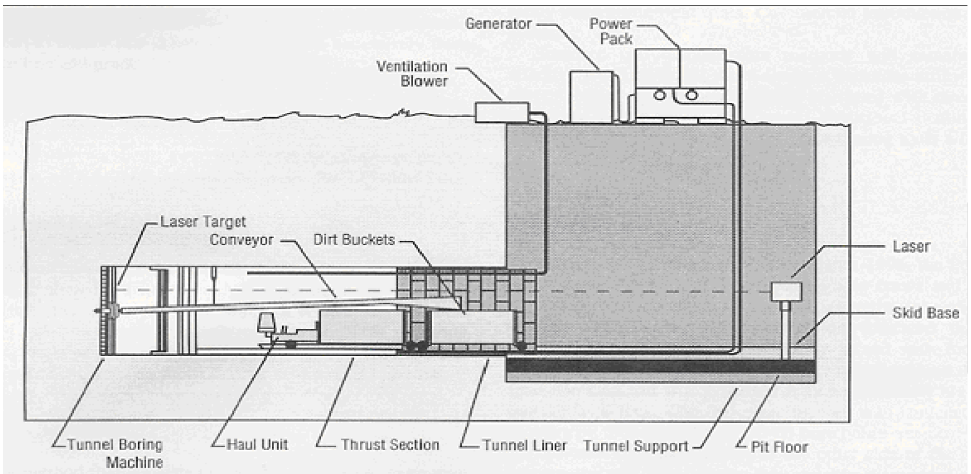


**Figure 5 - Typical components of utility tunnelling method**

### 2.3.2. Pipe jacking method

Pipe jacking is a trenchless technique for installing new underground pipelines and culverts. The essential element that distinguishes Pipe Jacking (as compared to other tunnelling methods) is that the lining of the resulting tunnel is pushed through the ground from the starting point rather than being built section-by-section just behind the excavation face or within the tail shield of a tunnel boring machine (Raymond L. Sterling, 2018). Pipe Jacking is similar to the Utility tunnelling method, with the exception that it combines the excavation and pipe installation into one step.

- Product pipe sizes 42 inches and larger.
- Limitations on length and size based on logistical considerations and safety.
- Pipe Jacking method can be identified in various forms including;
    - Conventional Pipe Jacking
    - Pilot Tube
    - Horizontal Auger Boring (Bore and Jack)
    - Microtunneling

Table 3 summarises the characteristics of Pipe Jacking method and Figure 6 demonstrates Pipe Jacking components.

**Table 3 - Characteristic of pipe jacking**

| Characteristic of pipe jacking | | | | | |
|---|---|---|---|---|---|
| **Method** | **Diameter Range (inches)** | **Typical Installation (feet)** | **Pipe Materials** | **Typical Applications** | **Accuracy (+ or -)** |
| Pipe Jacking | 42” & large | 1,600 | RCP, GRP, Steel | Pressure & Gravity Pipelines | ~ 1 |

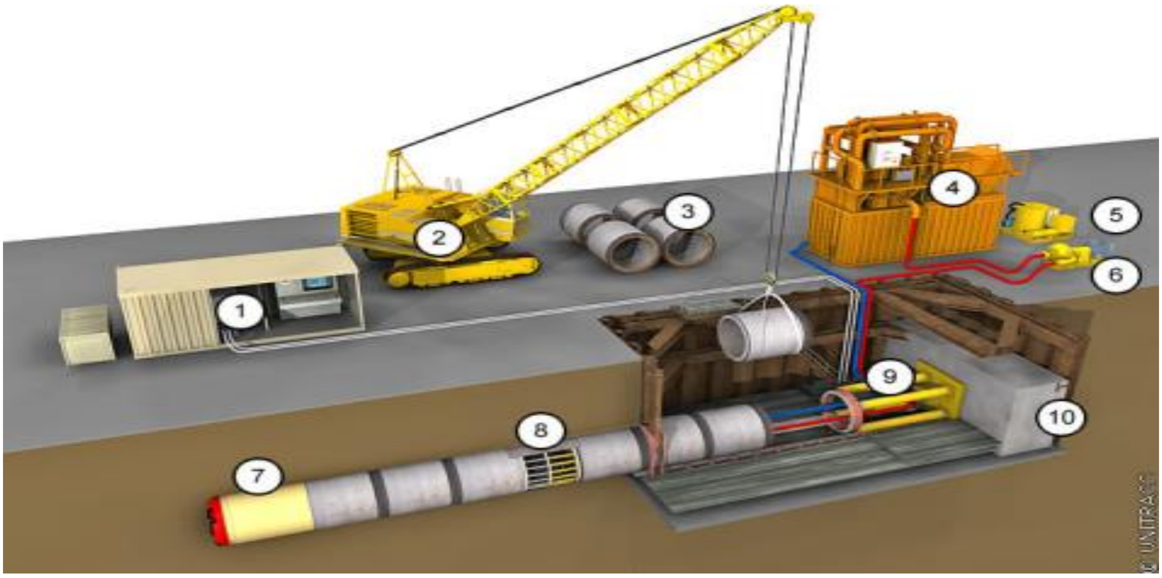


**Figure 6 - Pipe jacking components**

1. Control & steering desk
2. Crane
3. Jacking pipes
4. Separation plant
5. Mixing plant
6. Supply pump
7. Shield machine
8. Intermediate jacking station
9. Main jacking station
10. Abutment (Thrust block)

Figure 7 demonstrates typical components of a Pipe Jacking operation.

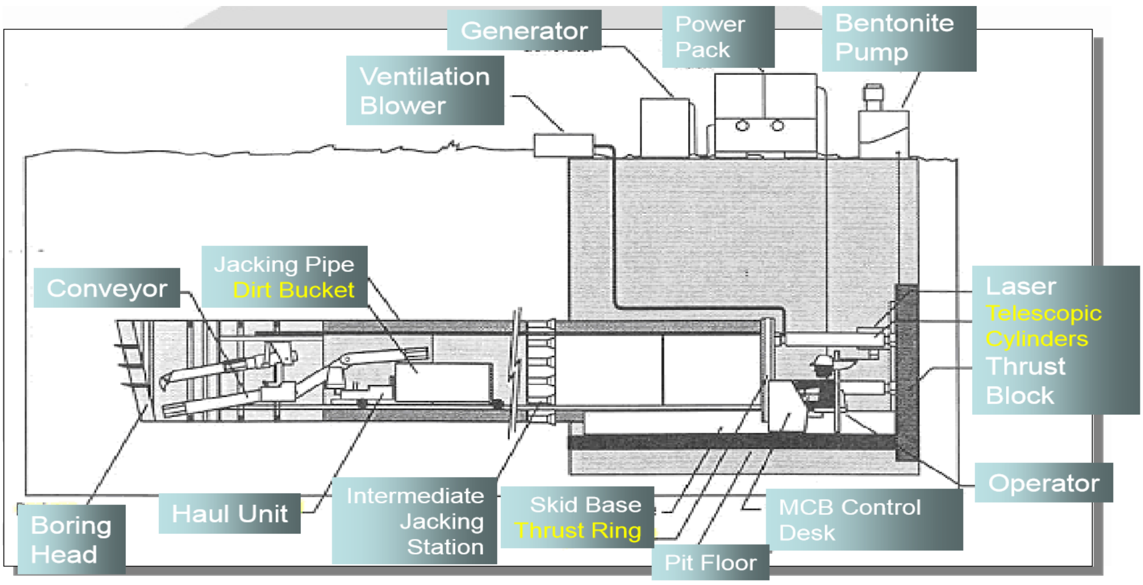


**Figure 7 - Typical components of a pipe jacking operation**

### 2.3.3. Horizontal auger boring method

Horizontal Auger Boring (HBA) method refers to the process of simultaneously jacking casing through the earth while removing the spoil inside the encasement by means of a rotating flight auger (Kendon, 2019). Horizontal auger boring is one of the oldest forms of trenchless technology and is suitable for use in a number of different applications. HAB is well suited for pipelines that begin and end on grade or have a gravity run off design as the steering requirements for these applications is quite limited. Furthermore, this method suits softer ground conditions as casing installation along with the excavation of soil minimizes the risk of seepage or soil collapse (Kendon, 2019). HAB is performed in two steps: excavation and installation of the casing pipe and Installation of carrier pipe and filling annular space with grout. This method is available with Dynamic grade control and Dynamic line and grade control. Table 4 summarises characteristics of Horizontal Auger Boring and Figure 8 demonstrates the process of Horizontal Auger Boring method.

**Table 4 - Characteristic of horizontal auger boring**

| **Characteristic of horizontal auger boring** | | | | | |
|---|---|---|---|---|---|
| **Method** | **Diameter Range (inches)** | **Typical Installation (feet)** | **Pipe Materials** | **Typical Applications** | **Accuracy (+ or -)** |
| Auger Boring | 4” -60” | 600’ | Steel | Road crossings | 1% of bore length |
| Auger Boring w/grade control | 4” -60” | 600’ | Steel | Road crossings | 12” |
| Auger Boring w/ line &grade control | 4” -60” | 600’ | Steel | Road crossings | 12” |

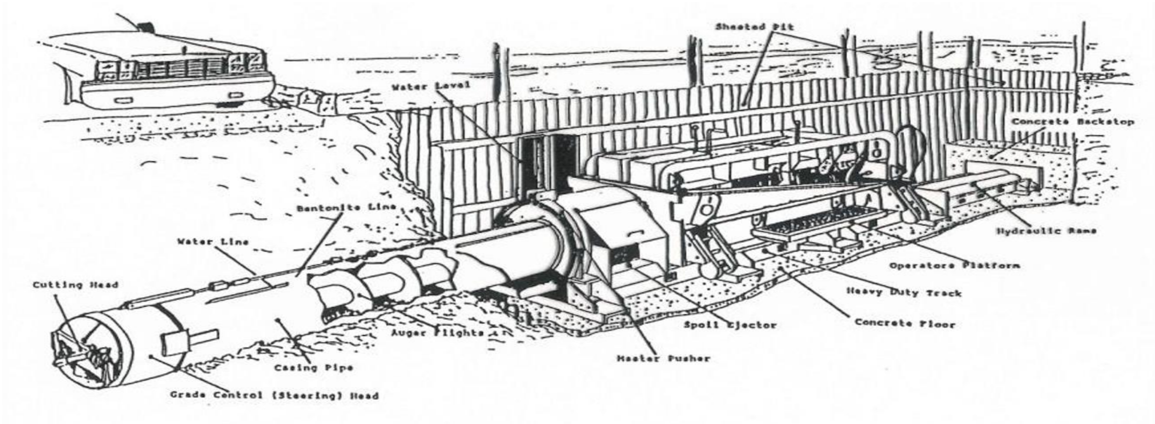


**Figure 8 - Auger boring process**

### 2.3.4. Horizontal directional drilling (HDD)

Horizontal directional drilling (HDD) is a minimal impact trenchless method of installing underground utilities such as pipe, conduit, or cables in a relatively shallow arc or radius along a prescribed underground path using a surface-launched drilling rig (Walsh, 2011). Usually performed in two (or more) steps to include; (1) Drilling of pilot hole using a steerable drill head and locator system; (2) Back reaming to increase pilot whole diameter and pullback of product pipe. This method could be used for product pipe sizes up to about 60 inches. HDD is typically used for road and river crossings. Table 5 summarises the characteristics of Horizontal Directional Drilling method and Figure 9 demonstrates the process of HDD method.

**Table 5 - Characteristics of horizontal directional drilling method**

| Method | Diameter Range (inches) | Maximum Installation (feet) | Pipe Materials | Typical Applications | Accuracy (+ or -) |
|---|---|---|---|---|---|
| Mini-HDD | 4”-12” | <600 | PE, PVC, DIP | Pressure Pipe &Cables | Varies |
| Midi-HDD | 12”-24” | 600-2000’ | PE, Steel | Pressure Pipe | Varies |
| Maxi-HDD | 24”-60’ | 2000’-6000’ | Steel | Pressure Pipe | Varies |

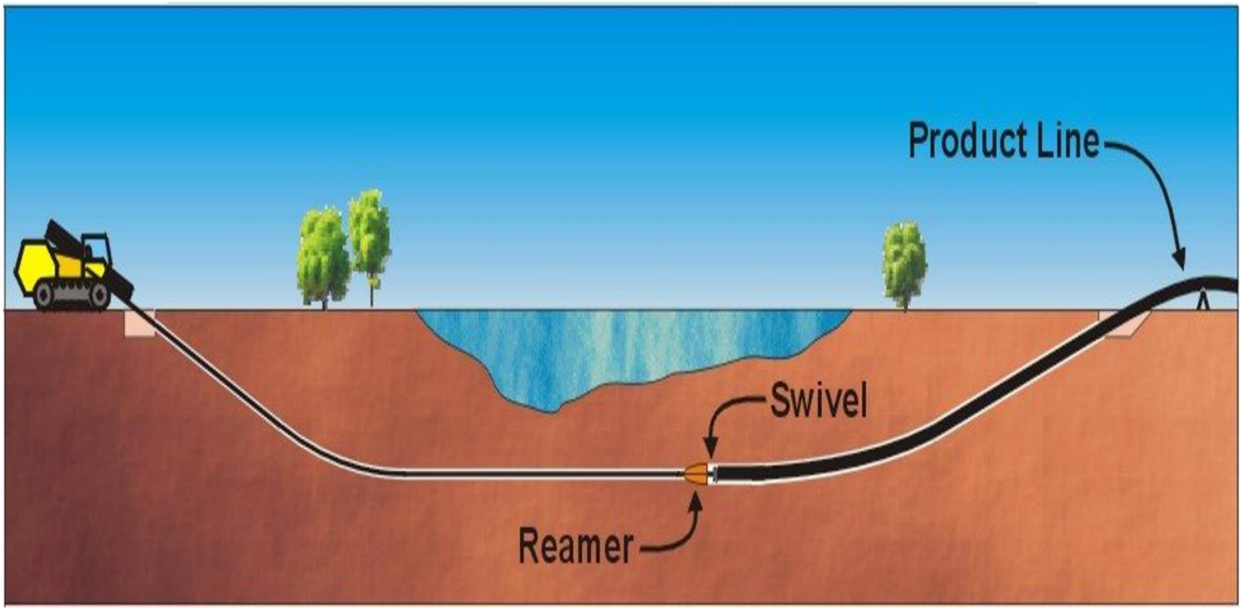


**Figure 9 - Horizontal directional drilling method (HDD)**

### 2.3.5. Pipe ramming method

Pipe ramming is a trenchless method for installation of steel pipes and casings over distances usually up to 150 feet up long and up to 55-inches in diameter, although the method can be used for much longer and larger installations. The method is the most useful for shallow installations under railways and roads, where other trenchless methods could cause surface settlement or heave. The majority of installations are horizontal, although the method can be applied for vertical installations as well (Simicevic & Sterling, 2001). This method is performed in two steps;

- Installation of the casing pipe by using an air hammer from a drive pit
- Use closed-end casing (<8" diameter)
- Use open-end casing for >8", clean spoil from casing after drive completed
- Installation of carrier pipe & filling annular space with grout

Table 6 summarises characteristics of Pipe Ramming method and Figure 10 demonstrates the process of pipe Ramming method.

**Table 6 - Pipe ramming method**

| Method | Diameter Range (inches) | Typical Installation (feet) | Pipe Materials | Typical Applications | Accuracy (+ or -) |
|---|---|---|---|---|---|
| Pipe Ramming | < 150” | 250 | Steel | Road crossings | Depends on setup |

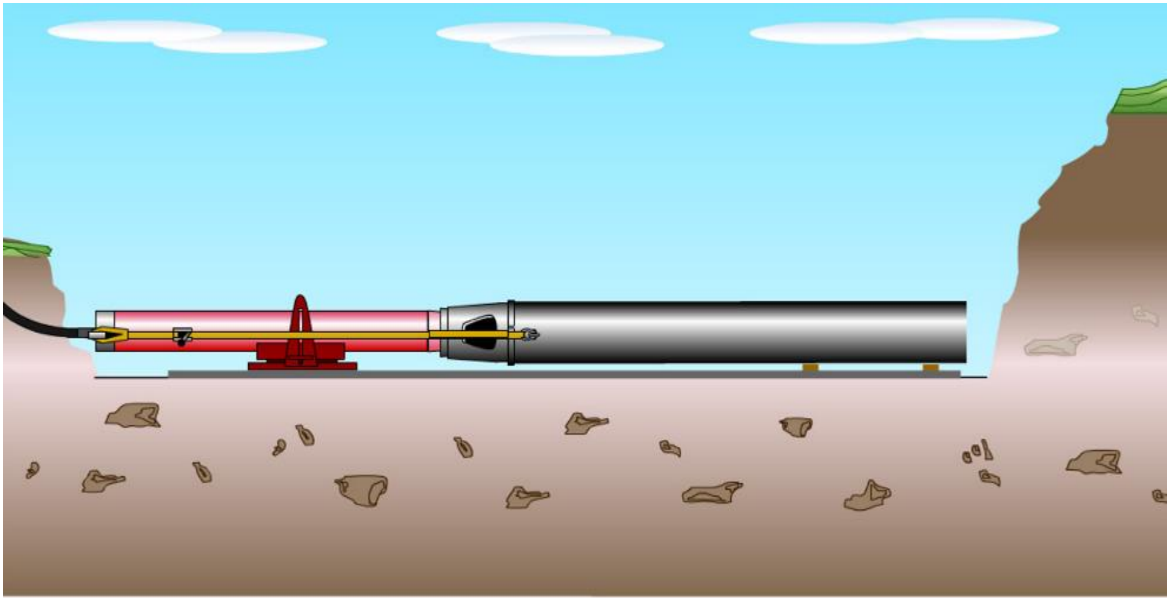

**Figure 10 - Pipe ramming method**

### 2.3.6. Microtunneling method (Gravity pipelines)

The concept of Microtunneling can be defined as "a trenchless construction method for installing pipelines with all of the following features utilised: remote-controlled from a control panel on ground surface, laser guided, pipe sections jacked simultaneously as spoil is excavated, and continuous support at the face of the excavation (Salem, Elwakil, & Hegab, 2017; Raymond L. Sterling, 2018). The differences between Microtunneling and the pipe jacking method can be demonstrated in the diameter of pipe installations. Microtunneling involves pipe installations up to 900 mm in diameter; whereas, pipe jacking involves pipe installations greater than 900 mm in diameter (Khondoker, Yi, & Bayat, 2016; PJA, 1995). This new ability of performing constructions in non-person entry diameters was given the name ‘‘Microtunneling" because it allowed a controlled tunnelling process in diameters below those permissible for person entry (Raymond L. Sterling, 2018). Also known as remote-controlled pipe jacking, Microtunneling method uses automation for processes performed by workers within the tunnel on pipe jacking, remote controlled excavation and spoil removal; and remote controlled guidance system (Salem *et al*., 2017). Table 7 summarises the characteristics of Microtunneling method and Figure11 demonstrates the characteristics of Microtunneling project.

**Table 7 - Microtunneling method**

| **Method** | **Diameter Range (inches)** | **Maximum Installation (feet)** | **Pipe Materials** | **Typical Applications** | **Accuracy (+ or -)** |
|---|---|---|---|---|---|
| Microtunneling | > 12" | 1,000' | RCP, GRP, VCP, DIP, Steel, PCP | Gravity Pipelines | ~1" |


**Figure 11 - Cut-away illustration of a microtunneling project (Raymond L. Sterling, 2018)**

Figure 12 & 13 demonstrate the Microtunneling boring machines.


**Figure 12 - Microtunnel boring machine (MTBM)**


**Figure 13 - Micro tunnel boring machine (MTBM)**

## 2.4 History of microtunneling

The developments leading to modern Microtunneling machine excavation occurred principally in Japan, Germany and the UK (Salem *et al.*, 2017). Microtunneling was developed by the Japanese in the early 1970's to replace open severs in urban areas with underground gravity sewers. The first Microtunneling project in the U.S occurred in south Florida in 1984 (Khandeshe, Ambhore, Kawade, Jaybhaye, & Supekar, 2018). Microtunneling technology rapidly developed along with the inventions such as slurry machine, mud shield and hydro shield

## 2.5 Microtunneling technology

Microtunneling operations involve a complex interaction of processes that require a variety of supporting equipment and personal experience. The processes of a Microtunneling construction project include planning, collecting data and subsurface exploration, laboratory testing, preparation of geotechnical reports such as geotechnical data report (GDR) and a geotechnical baseline report (GBR), preparation of bidding documents and Microtunneling construction (Kilduff & Wilkinson, 2017). Microtunneling constructions usually include the following steps (City of Portland, Oregon, 2018):

- Excavate launching and reception shafts at opposite ends of the tunnelling drive.
- Hydraulic jacks in the launch shaft push a micro tunnel boring machine (MTBM) into the earth.
- Pipes containing slurry water transport excavated spoils to the surface.
- Retract the jacks and disconnect slurry lines and control cables.
- Lower a pipe or casing into the shaft and insert it between the jacking frame and the MTBM.
- Reconnect slurry lines and control cables and advance the MTBM another drive.
- Repeat the process until the MTBM reaches the reception shaft.
- Retrieve the MTBM and trailing equipment.

Figure 14 demonstrate the Microtunneling system layout

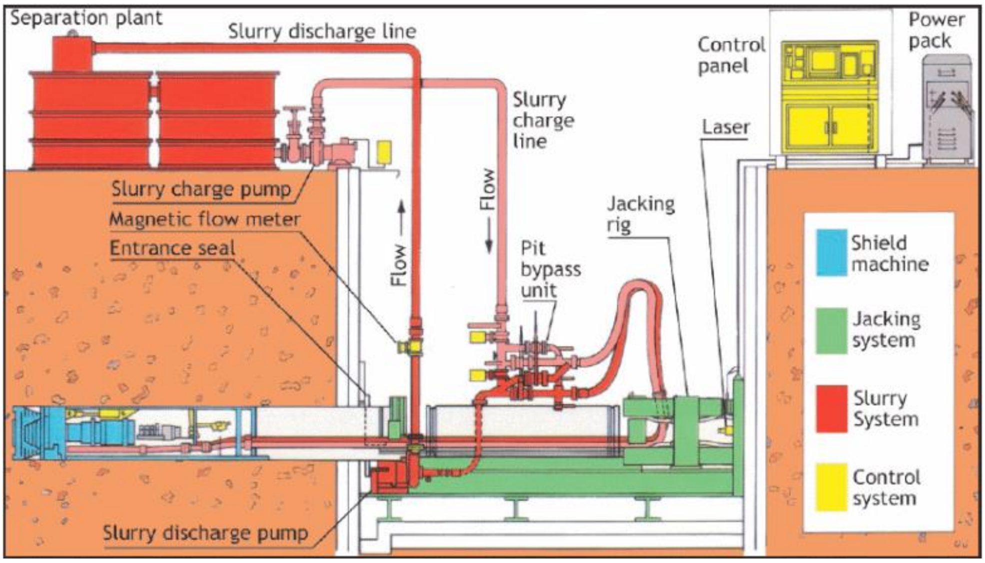


**Figure 14 - Microtunneling system layout (Nicholas, 2014)**

Figure 15 demonstrate the typical microtunneling site and Figure 16 demonstrate the Typical arrangement of microtunneling jacking shaft.

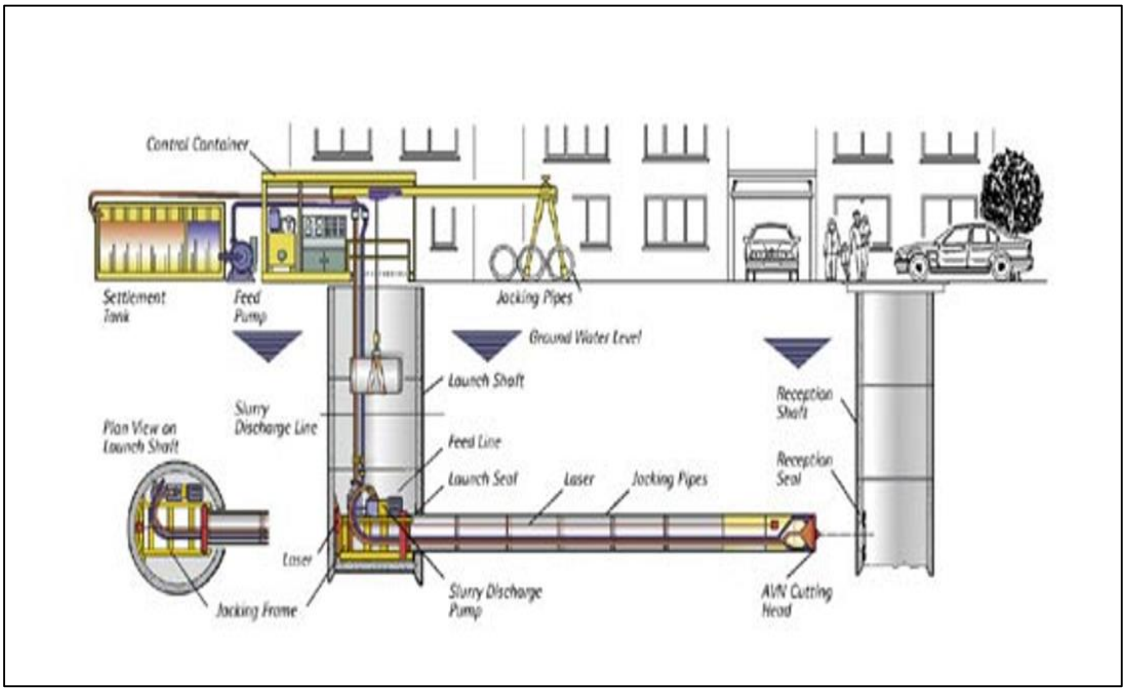


**Figure 15 - Typical microtunneling site**

**Figure 16 -Typical arrangement of microtunneling jacking shaft**

## 2.6 Economics of Microtunneling

Cost plays an important role in the decision-making process when undertaking a underground excavation based construction project. An economic evaluation involves the assessment of both the initial construction cost and associated benefits of each method under consideration (Hay, 2013). The goal of which is the selection of a single alternative with the greatest benefit at the lowest overall cost (Hay, 2013; Ormsby, 2009). These costs can be divided into the following categories (Ormsby, 2009).

- Direct costs;
- Indirect costs; and
- Socio-economic inconvenience costs.

It is often very difficult to use historical data to obtain average cost with acceptable variance as numerous factors come into play, such as;

- Soil type, Number of pits & Pipe diameter
- Degree of difficulty in meeting the performance requirements
- Location/country (lack of local labour and technical staff)
- Some rates include pipe cost as well (Percentage cost of pipes approximately 20)
- It may better to obtain guidance from a recent project implemented under similar condition and similar location;

It has been shown in past research that trenchless technologies have the potential to reduce costs, mainly because excavation volumes can be greatly reduced through these ‘low-dig’ or ‘no-dig’ methods. Figure 17 compares the costs involved in open-cut construction methods versus trenchless methods. Figure 18 demonstrates the cost-effective route selection method used in Microtunneling technology.

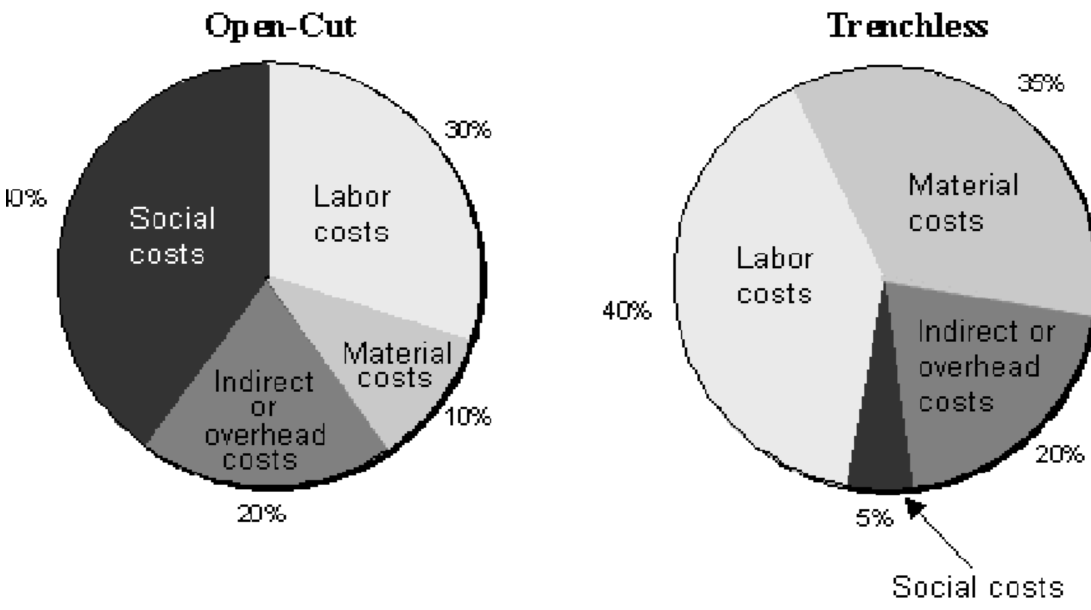


**Figure 17 - Comparison of cost-breakdown for open-cut and trenchless methods.**

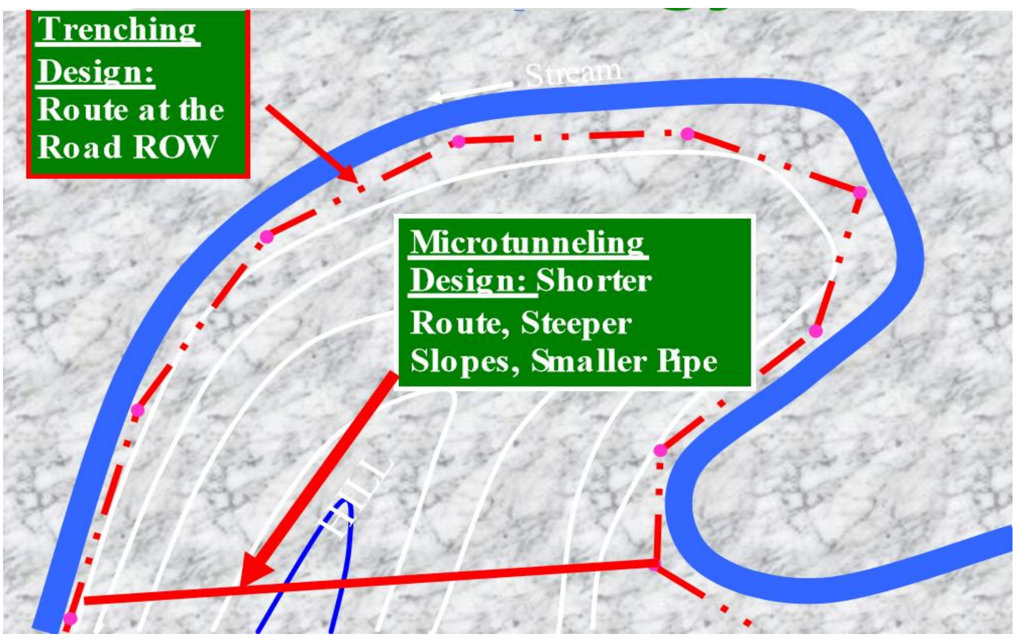


**Figure 18 - Cost-effective route selection.**

**Table 8- Comparison of cost factors between open-cut and trenchless technology**

| Factor | Open-Cut | Trenchless Technology |
|---|---|---|
| Depth | Major | Minor |
| Diameter | Moderate | Moderate |
| Soil Conditions | Major | Moderate to Minor |
| Obstructions | Major | Minor |
| Water Table | Major | Minor |
| Existing Utilities | Major | Major to Moderate |
| Damage to Pavement | Major | Minor |
| Reinstatement | Major | Minor |
| Traffic | Major | Minor |
| Safety Issues | Major | Minor |
| Productivity | Major | Minor |
| Environmental Issues | Major | Minor |

Table 8 describes the comparison of cost factors between open-cut and trenchless technology

### 2.6.1 Direct costs

Direct costs are the project specific costs of conception, development and implementation that are borne by the client organization and which are normally considered in the contract (Hay, 2013). Figure 19 demonstrates components of direct costs for underground utility projects.

Figure 19 demonstrates the cost identification for underground utility project.


**Figure 19 - Cost identification for underground utility project (Woodroffe & Ariaratnam, 2008)**

These include costs such as;

- Overhead,
- Construction costs (materials, equipment and labour),
- Restoration,
- Traffic control,
- Taxes,
- Insurance,
- Emergency and temporary services,
- Contingency.

### 2.6.2 Indirect costs

Indirect costs are the costs that are borne by the client organization that normally accrue during or after construction as a result of extraneous factors and actions performed in the project. Indirect costs include;

- Pavement service life reduction,
- Pavement damage due to excavation
- Pavement damage on alternate routes due to increased traffic

- Buried utility damage, unplanned property damage,
- Loss of parking metre and ticketing revenue, Compensation
- Loss of municipal tax revenue

### 2.6.3 Socio-economic inconvenience costs (External costs)

External costs are the sum of all social, environmental and economic costs, market priced and non- market priced, that accrue to third parties at any time as a result of actions promoted by the client organization. These kinds of costs could include;

- Increased travel time,
- Increased vehicle operating costs and collision rates;
- Obstruction of emergency vehicles;
- Lost business income and property value;
- Accidental injury and death;
- Air pollution and greenhouse gas emissions;
- Water and ground contamination;
- Loss of amenity and dust and dirt generation

Therefore, external cost of an excavation project could be understood in the following terms;

**Social inconvenience costs**

Increased vehicle travel time

Increased vehicle operating costs

Increased pedestrian travel time

Increased collision rate

Obstruction to emergency vehicles

Accidental injury and death

Property damage

Water and wastewater service interruption

Psychological and physical ailments

**Economic costs**

Lost business income

Lost property value due to noise

**Environmental costs**

Air pollutant and greenhouse gas emissions

Environmental damage and contamination

Dust and dirty pollution

Damage and lost amenity of recreational facilities

**Total cost = Direct cost + Indirect cost + Social cost**

Figure 20 illustrates cost components of indirect and social costs.

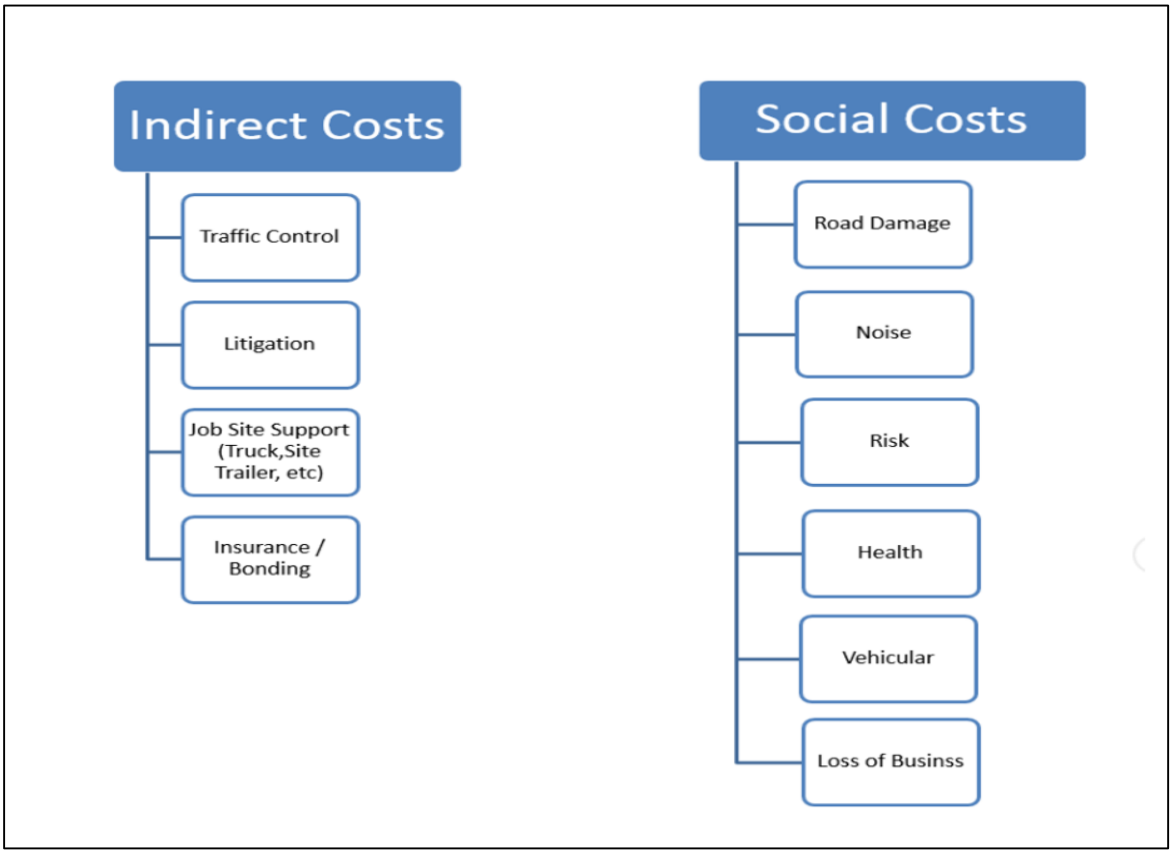


**Figure 20 - Cost components of indirect and social costs**

A study of the existing literature has revealed that, particularly in the area of buried municipal infrastructure renewal projects, many definitions of social costs have been proposed over the past 12 years (Allouche, Ariaratnam, & AbouRizk, 2000; Ormsby, 2009). For instance, some researchers have considered social costs to be only the costs incurred by third parties who do not engage in the contractual agreement, to include unmeasured costs such as the damage to the environment caused by air pollution, noise, vibration and also the loss of amenity and the disruption to commercial and private traffic. Other costs accrued during the lifecycle of a project are termed either direct or indirect costs to the municipality. Thus, the total cost of a project would be the sum of direct, indirect and social costs.

Working on this notion and based on the area of impact, such as traffic, economic activities, pollution and ecological/social/health related impacts, Gilchrist and Allouche (2005) further separate the social costs into four categories as demonstrated in Figure 21 and 22.

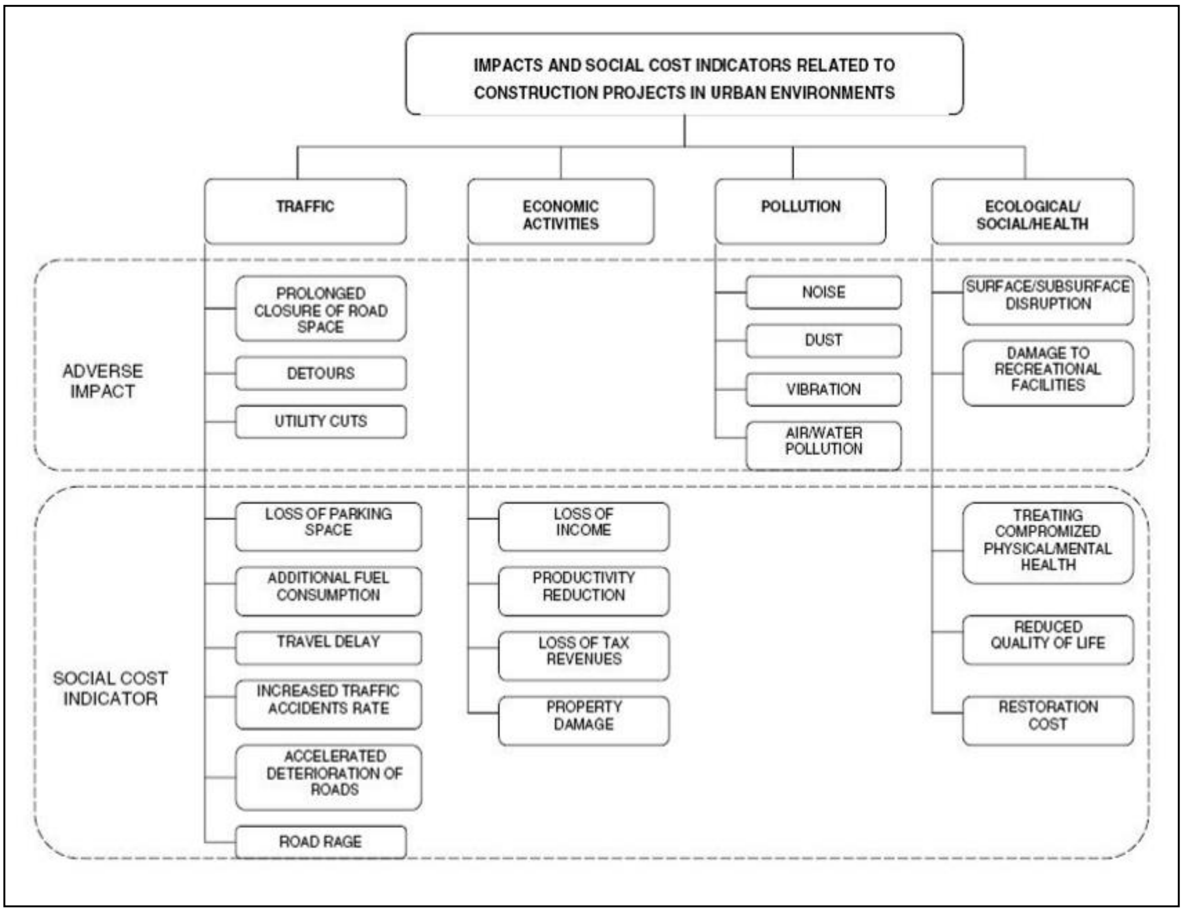


**Figure 21 - Social impacts and cost indicators according to Gilchrist and Allouche (2005)**

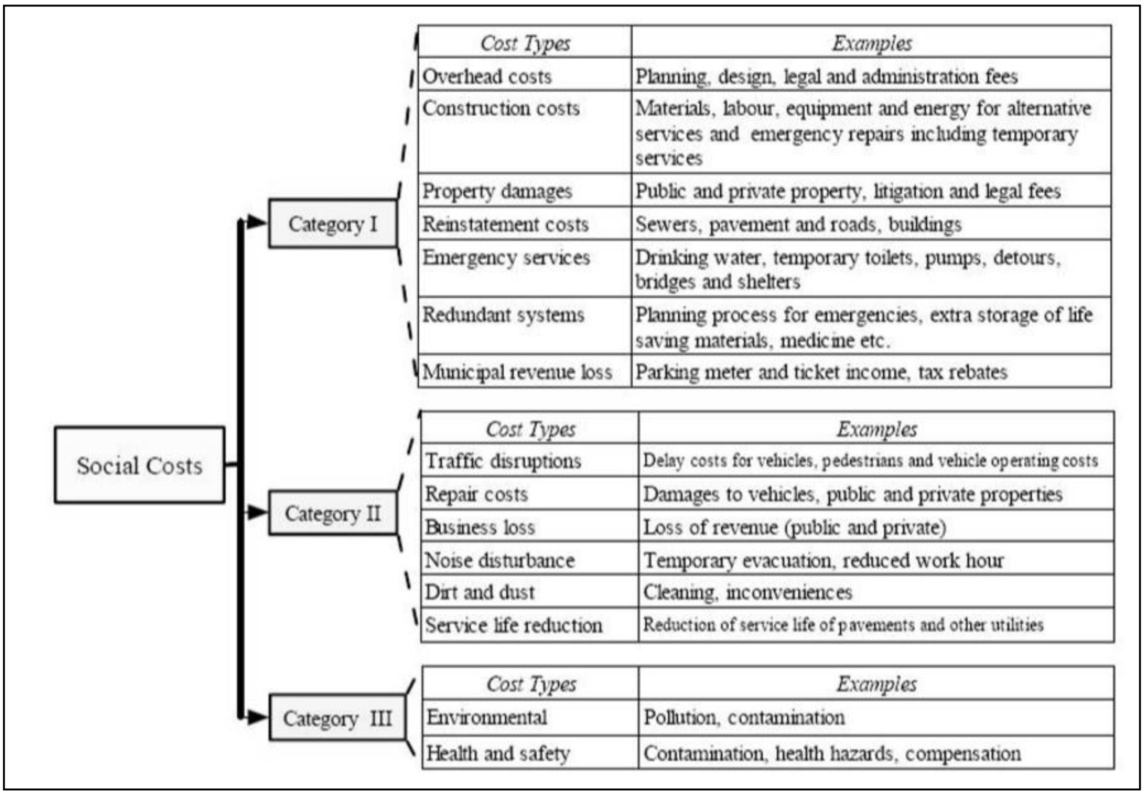


**Figure 22 - Social cost categories according to Rahman, Newton and Vanier (2005)**

## 2.7 Summary

This chapter evaluated literature in current excavation technology to discuss open-trench construction method versus trenchless technology. The chapter introduced open-trench construction methods and discussed their disadvantages to focus on trenchless technology and their advantages. The chapter then discussed key forms of trenchless technology before moving into a discussion of the concern of the present study; Microtunneling technology. Microtunneling technology was briefly discussed with the key steps involved in the process. Various forms of costs incurred in the excavation-based construction projects were discussed to establish that the total costs of trenchless technologies are significantly lower compared with the open-trench constructions.

The literature review chapter concludes that the indirect and socio-economic inconvenience costs which were often ignored resulted in costly expenses to the municipalities. Therefore, this literature review proclaims that these indirect and socio-economic inconvenience costs must form part of the total cost of a project as it assists with the successful completion of the project without expensive unforeseen costs to the municipalities.

# 3 RESEARCH METHODOLOGY

The purpose of this chapter is to clarify the methodological framework used to conduct this research. This chapter outlines the steps undertaken to design, plan and implement this research. It will cover the methodological approach and methods used to select and design research instruments; collect and analyse data. Because the background and context of the subject matter are influences on all aspects of this study, they are discussed. Finally, the ethical considerations for the undertaking of the study are outlined as a conclusion to the chapter.

## 3.1 Research design

A case study approach was implemented in this research and priority was given to identify different forms of costs incurred in Microtunneling construction projects in Colombo, Sri Lanka to establish a conceptual framework for critical analysis of Microtunneling in Sri Lanka. Reviewing relevant literature on buried infrastructure installation, maintenance and rehabilitation projects helped limit the scope of the research, to identify theories, frameworks, models and findings by other researchers.

## 3.2 Nature of the inquiry

The case study, according to Creswel (1998), explores a bounded system or case over time "through detailed, in-depth data collection involving multiple sources of information rich in context". In investigating complex situation, such as construction projects, case study approach has been proven reliable to capture the rich information for the purpose of the investigation. Case study method has been regarded allowing investigators to retain the holistic and meaningful characteristics of real-life events (Sutrisna & Abbott, 2007).

Case study approach has been widely used in the research involving buried municipal infrastructure construction projects for various different research purposes. The researcher reviewed the methodologies implemented in several past researchers to identify substantial number of studies that have used the case study methodology. Table 9 summarises methodologies been used in the aforementioned past studies.

**Table 9 - Methodologies used in research involving buried municipal infrastructure construction projects**

| Author/s | Study | Methodology |
|---|---|---|
| Ormsby (2009) | A framework for estimating the total cost of buried municipal infrastructure renewal projects | Case study |
| Hashemi (2008) | Construction cost of underground infrastructure renewal: A comparison of traditional open-cut and pipe bursting technology | Literature analysis, Survey, Regression analysis Case study |
| Hafez, Aziz, & Attia (2015) | Exploring critical factors affecting upon Microtunneling equipment productivity | Questionnaire/ factor analysis |
| Hay (2013) | A comparative study of trenchless technology versus traditional open trenching for the replacement of ageing potable water pipelines | Survey |
| Ranasinghe (2015) | Implications of Microtunneling on wastewater pipeline constructions: A case study from Muscat wastewater system: Al Khuwair project | Case study |
| Nicholas (2014) | Microtunneling in India | Case study |
| Gottipati (2011) | Pilot tube Microtunneling: Profile of an emerging industry | Survey |
| Salem, Elwakil, & Hegab (2017) | Risk level problems affecting Microtunneling projects<br>Installation | Cluster analysis of survey and literature data |
| Khandeshe, Ambhore, Kawade, Jaybhaye, & Supekar (2018) | Trenchless technology: Microtunneling | Case study |

| | | |
|---|---|---|
| (Chung, Abraham, & Gokhale (2004) | Decision support system for Microtunneling applications | Case study Decision support system (DSS) |

Even though Microtunneling technology is highly sophisticated and regularly used in buried infrastructure related projects in developed countries, its use in Sri Lanka is recent and limited. Furthermore, research conducted on Microtunneling projects in the Sri Lankan context are very limited. Descriptive case studies are appropriate in this kind of setting where only a little research has been conducted (Sutrisna & Abbott, 2007).

Therefore, the case study method was chosen to examine Microtunneling construction projects implemented in Sri Lanka. The aim of this research was to establish the cost parameters of Microtunneling and to propose a framework for critical analysis of Microtunneling in Sri Lanka. Accordingly, the research problem could be developed as "what are the costs incurred in Microtunneling projects in Sri Lanka and what are the factors affecting different types of costs?" Accordingly, the researcher implemented case study methodology to collect quantitative as well as qualitative data from aforementioned Microtunneling construction projects implemented in Sri Lanka.

## 3.3 Data collection

Literature review was undertaken initially to help establish a rationale for the research questions and to ascertain the extent and depth of existing knowledge on cost parameters of Microtunneling technology. Primary data were collected in the form of semi-structured interviews and document analysis.

**Semi-structured interviews**

Semi-structured interviews of varying durations (30 minutes to 1.5 hours) were conducted with key decision makers and engineers involved in the Microtunneling construction projects implemented in Sri Lanka. The focuses of the interviews were to obtain first hand data regarding;

(1) Nature of the constructions involved.

(2) Processes and procedures during the planning stage

(3) Processes and procedures during the construction stage
(4) Processes and procedures after the completion of the project
(5) Identification of direct costs incurred
(6) Identification of indirect costs involved
(7) Measures taken to establish social and environment cost

**Document analysis**

Documents relevant to the cases under investigation were collated, reviewed and analysed to gather data pertinent to aforementioned aspects.

## 3.4 Data analysis

Field notes that were taken during the interviews were organised with reflective comments and further questions. The field notes were transcribed into Microsoft Word and sought for emerging codes, patterns and themes. Different types of cost components were analysed using the methodology proposed by (Ormsby, 2009). The strong themes emerged through the analysis of qualitative data gathered through the interviews were linked with the cost component analysis to establish cost parameters of Microtunneling projects implemented in Sri Lanka.

## 3.5 Ethical considerations

Construction organisations' confidential data were not disclosed in the case studies. Interview participants were ensured of their anonymity when they wanted. The researcher adhered to the ethical conducts when obtaining written data from the participants.

## 3.6 Summary

This chapter has presented research approach and research process used in this research study. The next chapter analyses and discusses the findings from the study in detail.

# 4 CASE STUDY OF MICROTUNNELING IN COLOMBO CITY

The case study focused on three aspects

1. Technology used
2. Cost Comparison
3. Parameters for analysis for applications in Sri Lanka.

## 4.1 History and projects

1. The Asian Development Bank (ADB) approved a loan to upgrade the services of the Wastewater Division of the Colombo Municipal Council, The executive agency is Ministry of Local Government & Provincial Councils and the implementing agency is the Colombo Municipal Council.

   The expected impact of the project included an improved urban environment and better public health for residents in the Colombo City and suburbs connected to the sewer system through improved marine and inland water quality and a resulting improvement in hygiene and sanitary conditions. The expected project outcome was improved wastewater management services provided to residents within the project area through upgraded sewerage infrastructure and enhanced institutional and operational capacity of the service provider

2. In the Colombo basin there are five main storm water drainage outlets, namely Ambatale, North lock, Mutwal tunnel, Dehiwala and Wellawatta. The conveyance capacity of the outfalls and main canals are found to be inadequate with the increasing intensity of the peak flows, to cope with the extreme flood peaks. Acquisition of land to enhance retention capacity had been restricted by rapid urbanisation and development of infrastructure Thus, finding new discharge outlets using tunnelling techniques in the densely populated city of Colombo is considered to be the most feasible solution, in order to minimize the flood impacts.

One of the Storm Water projects funded by World Bank, proposed to reduce flooding in Colombo is commenced to drain rain water accumulated from Thummulla area. The proposed Torrington Tunnel which forms part of the macro drainage system that integrates with the micro drainage system within the catchment areas. The storm water is to be diverted into the sea through the proposed network of tunnels, under this scheme. One of the primary objectives is to transfer into the Tunnel network, most of the storm water that would have flowed into the main canal system.

## 4.2 Microtunneling projects in Sri Lanka

### 4.2.1 Case Study 01

**Rehabilitation and Upsize 10 kilometres of identified problematic and critical sewers of the Colombo sewerage system within the Colombo Municipal Council area under ADB funds.**

Figure 23 illustrates the Schematic Diagram of the Colombo Sewer System

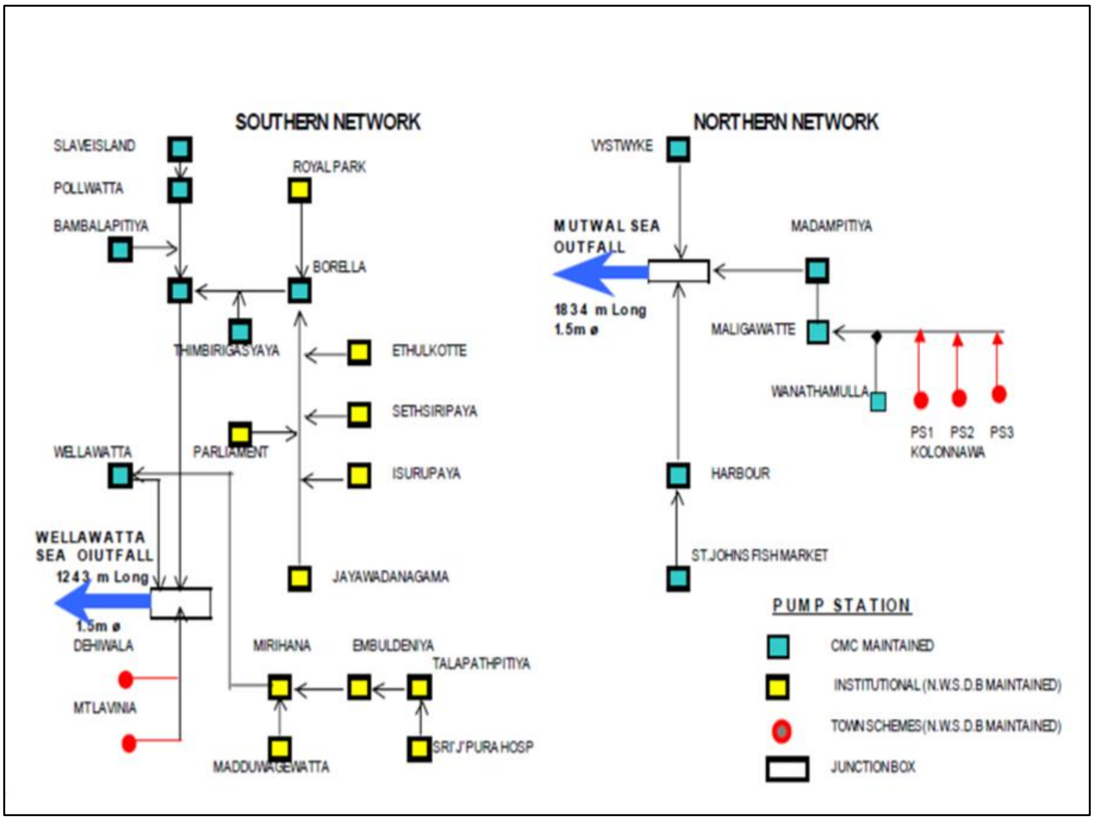


**Figure 23 Schematic Diagram of the Colombo Sewer System**

Figure 24 illustrates the Sewer System of Colombo.


**Figure 24 Sewer System of Colombo**

### 4.2.2 Case Study 02

**Design and building of Torrington Tunnel within the Colombo Municipal Council area under World Bank funds.**

The catchment areas to be drained and the proposed Torrington Tunnel network are given below. Figure 25 illustrates the proposed site layout of the Torrington tunnel and Figure 26 illustrates the sub catchment area map Torrington tunnel.


**Figure 25 - Sub catchment area map Torrington tunnel**

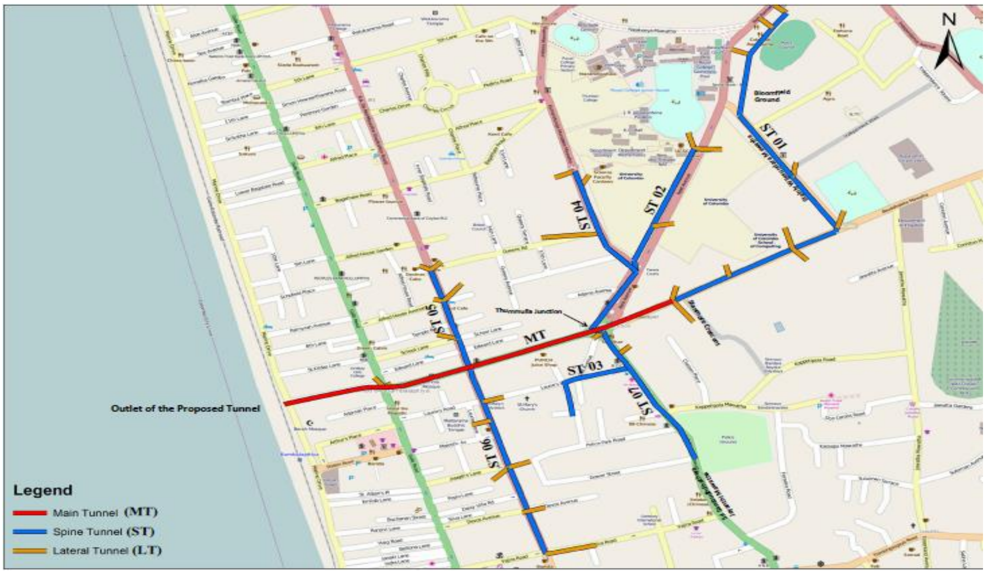


**Figure 26 - Proposed site layout of the Torrington tunnel**

## 4.3 Technology used

**Rehabilitation and Upsize 10 kilometres of identified problematic and critical sewers of the Colombo sewerage system within the Colombo Municipal Council area under ADB funds.**

The Colombo city is overcrowded and streets are narrow and full of traffic even in the night. Under these circumstances it is really challenging to rehabilitate a 100-year-old sewer system. Therefore, it was more appropriate to adopt in situ No Dig techniques for the rehabilitation of this sewer system.

Figure 27 illustrates the Typical Microtunneling site.

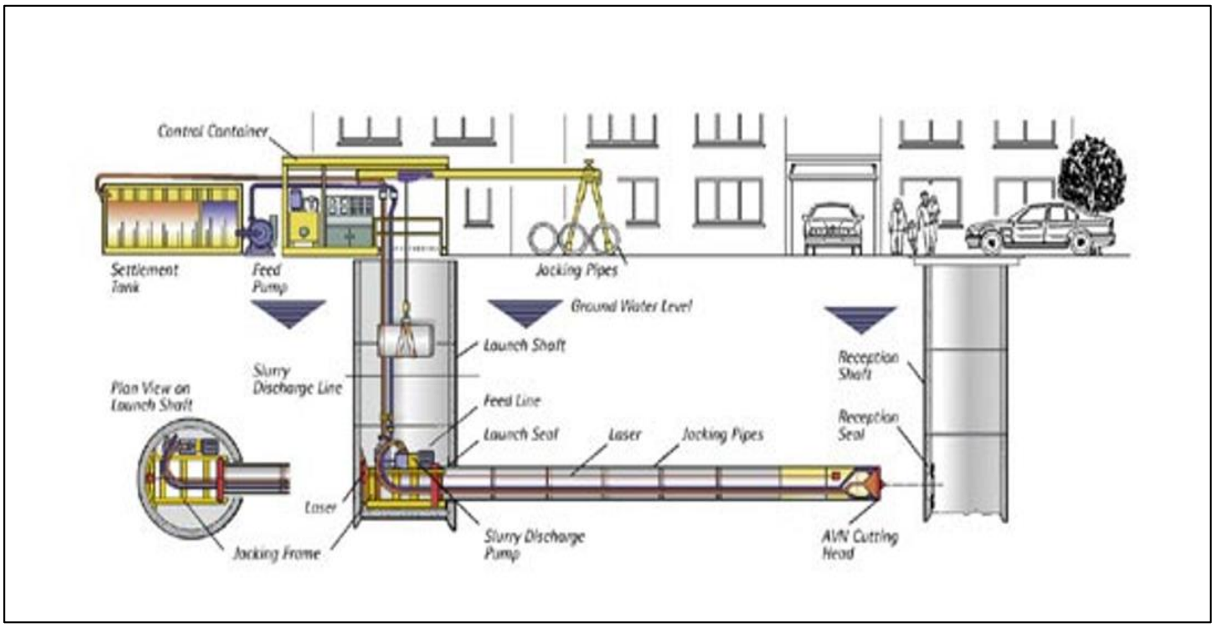


**Figure 27 - Typical Microtunneling site**

**For gravity sewers**- The Microtunneling technique used for the installation of the trenchless pipeline is pipe jacking and machine used is MTBM.

**For Force mains**- The Microtunneling technique used for the installation of the trenchless pipeline is Horizontal Directional Drilling (HDD) and machine used is MTBM.

Figure 28 illustrates the Route Plan of Wanathamulla Forcemain Area.

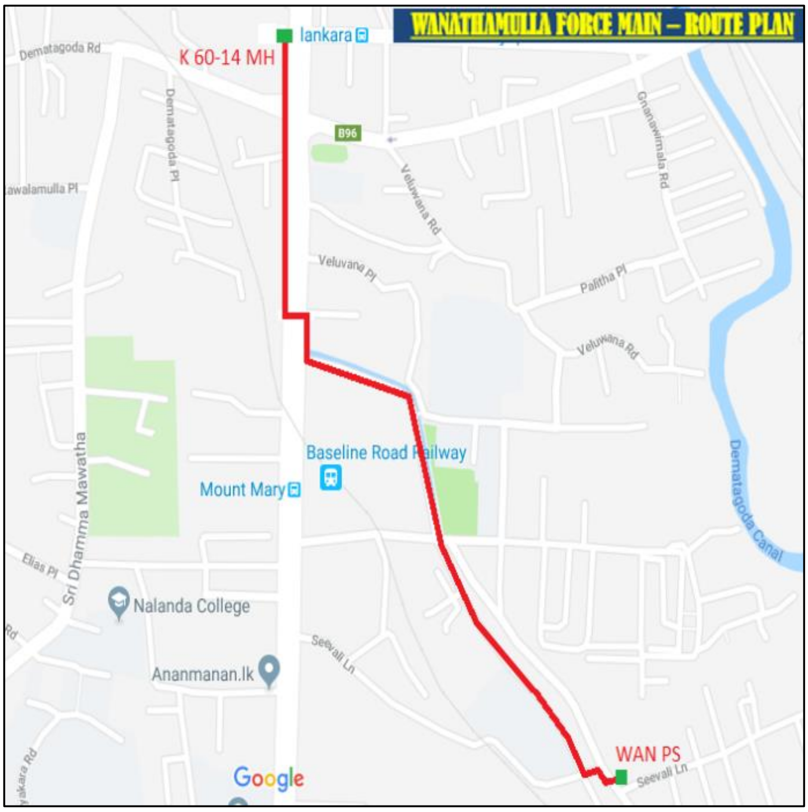


**Figure 28 - Route Plan of Wanathamulla Forcemain Area**

**Pipe jacking technology is used for bellow mentioned conditions**,

- Most suitable for gravity sewers.
- Applied for either soft or hard ground.
- Suitable for a range of soil, from medium to coarse grain sand clayey gravels.
- Suitable for rigid pipes & need to be sharp alignment.
- Minimum working space requirement.
- Suitable for either larger or smaller diameter pipes.

Figure 29 illustrates the Installation of Jacking Machine and Figure 30 illustrates the operation of the Jacking machine.

**Figure 29 Installation of Jacking Machine**

**Figure 30 Jacking machine is in operation**

**HDD technology is used for bellow mentioned conditions**,

- Most suitable for force main sewers.
- Suitable for flexible pipes & no need to be sharp alignment.
- More working space requirement.
- Applied for either soft or hard ground.
- can be utilized with various pipe materials such as PVC, polyethylene, polypropylene, ductile iron,
- Suitable for a variety of soil conditions including clay, silt, sand, and rock

Figure 31 illustrates the Carryover of TBM from one place to another.

**Figure 31 -Carryover of TBM from one place to another**

Figure 32 illustrates the Preparation of driving shaft at Manhole No.18 and Figure 33 illustrates the Checking the pipe alignment.

**Figure 32 - Preparation of driving shaft at Manhole No.18**

**Figure 33 - Checking the pipe alignment**

**Design and building of Torrington Tunnel within the Colombo Municipal Council area under World Bank funds.**

The Microtunneling technique used for the installation of the trenchless pipeline is pipe jacking and machine used is Horizontal Jacking and Boring Unit.

The pipe jacking technique, as described above is to be used for the installation of a trenchless pipeline along Bauddhaloka Mawatha from Stanmore Crescent to the sea outfall. This section of the tunnel runs through the Thummulla junction (a large multi-exit round-about), Duplication Road, Galle Road and Marine Drive. (Micro Tunnelling concept paper, 2016)

The required increase in capacity of the system has been modelled and verified using Mike Urban software, accredited for micro drainage under the World Bank funded projects, in Sri Lanka. Hydraulic modelling for the extended micro drainage networks of the CMC area has been developed, by the Sri Lanka Land Reclamation &Development Corporation (SLLRDC) and Colombo Municipal Council (CMC), with the assistance of the COWI Consultant, using the said software.

The initial phase of the feasibility studies stipulated a main tunnel internal diameter of 2.5m. Subsequently, the addition of flows from certain critical locations of the bordering catchment areas demanded an enhanced internal diameter of 3.0m. It has been proposed that this section of the tunnel be constructed using pipe jacking. It has been found appropriate that the previously intended cut-and-cover tunnel sections, to be integrated into this scheme, be constructed using the auger boring technique The latter technique, adopted in place of the previously intended cut-and-cover tunnel sections will save a considerable amount of time and money, on the overall scheme. Rehabilitation of the surface drains to channel water into the auger bored tunnels will be undertaken by the CMC, at the earliest opportunity, in order to obtain the optimum use of the Torrington Tunnel network

The output and model conceptualization details are given below in Figures 34 and 35.

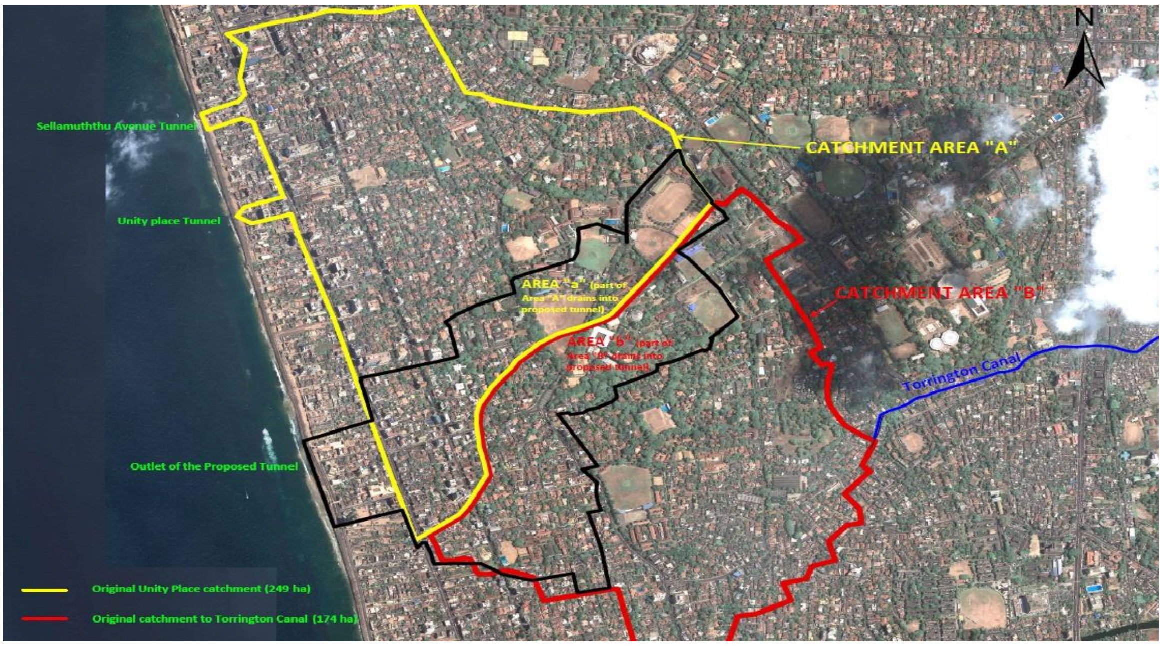


**Figure 34 - Model conceptualisation**

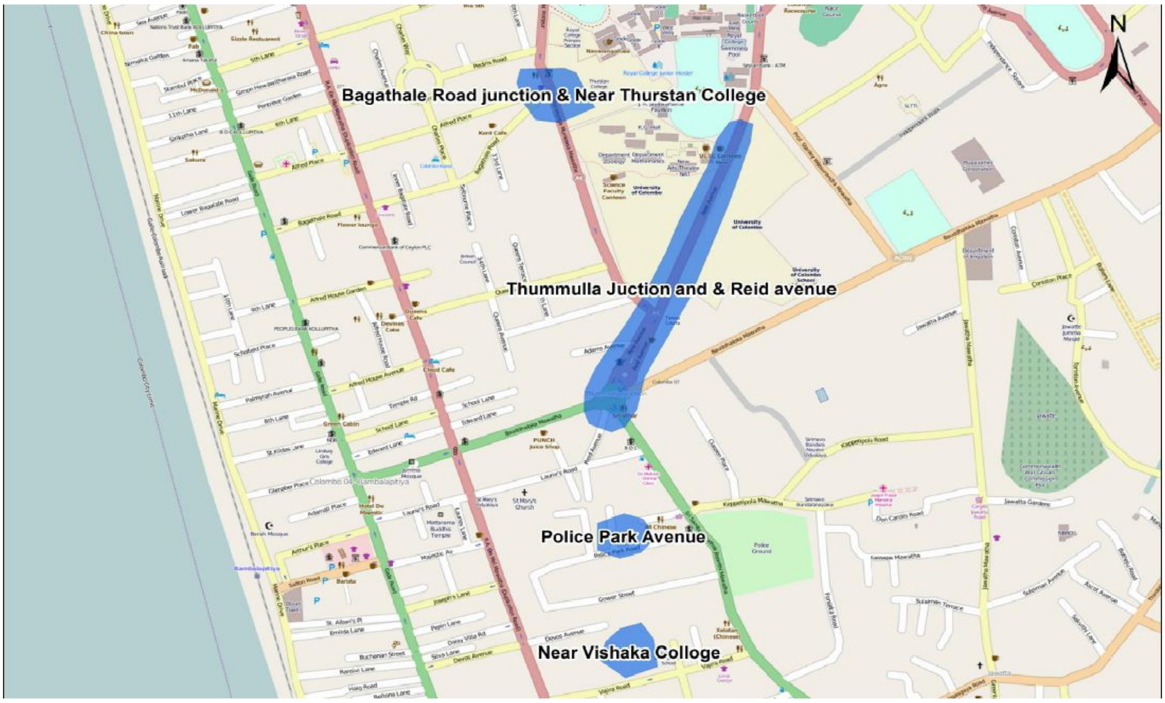


**Figure 35 - Model conceptualisation**

## 4.4 Methodology

**Rehabilitation and Upsize 10 kilometres of identified problematic and critical sewers of the Colombo sewerage system within the Colombo Municipal Council area under ADB funds.**

### 4.4.1 Pipe jacking Methodology

Figure 36 illustrates the setting-up of guide rails and jacking rig and Figure 37 illustrates setting up of TBM Shield.

**Figure 36 - setting-up of guide rails and jacking rig**

**Figure 37 - setting up of TBM Shield**

Two types of methods have been used in this project

- Pressurized Slurry Micro-Tunneling (PSMT)
- Pilot Tube Micro-Tunneling (PTMT)

**Pressurized Slurry Micro-Tunneling (PSMT)**

MTBM connected with an adopter trailed by a string of high strength product pipe segments either vitrified clay or reinforced concrete will be jacked in to the ground whilst maintaining the precise line and grade.

Figure 38 illustrates the Jacking of TBM Shield and Figure 39 illustrates the Jacking of product pipe.

**Figure 38 - Jacking of TBM Shield**


**Figure 39 - Jacking of product pipe**

**Pilot Tube Micro-Tunneling (PTMT)**

In the first stage, a slanted-face lead steering head trailed by guiding pipe segments will be installed to the precise line and grade. In the second stage, a soil expansion/ displacing double-coned lead trailed by high strength product pipe segments will be jacked into the ground.

Figure 40 illustrates the operation of VC pipe Jacking and Figure 41 illustrates the Jacking of steering head and pilot tubes from jacking pit.

**Figure 40 - VC pipe Jacking in operation**

**Figure 41 - Jacking of steering head and pilot tubes from jacking pit**

### 4.4.2 HDD Methodology

- First, a small diameter pilot hole is drilled along a directional path from one surface point to another.

  Figure 42 illustrates the Pilot Hole Drilling.

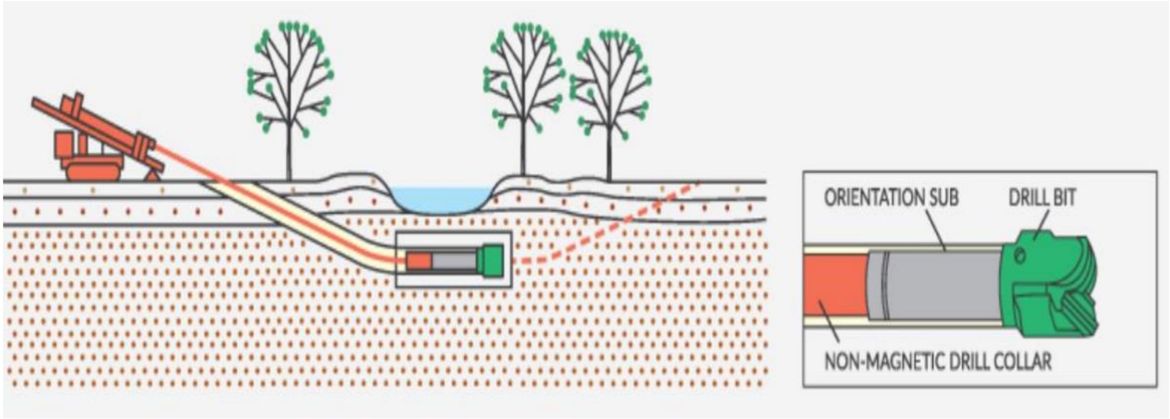


**Figure 42 - Pilot Hole Drilling**

- Next, the bore created during pilot hole drilling is enlarged to a diameter that will facilitate installation of the desired pipeline.

  Figure 43 illustrates the Reaming.

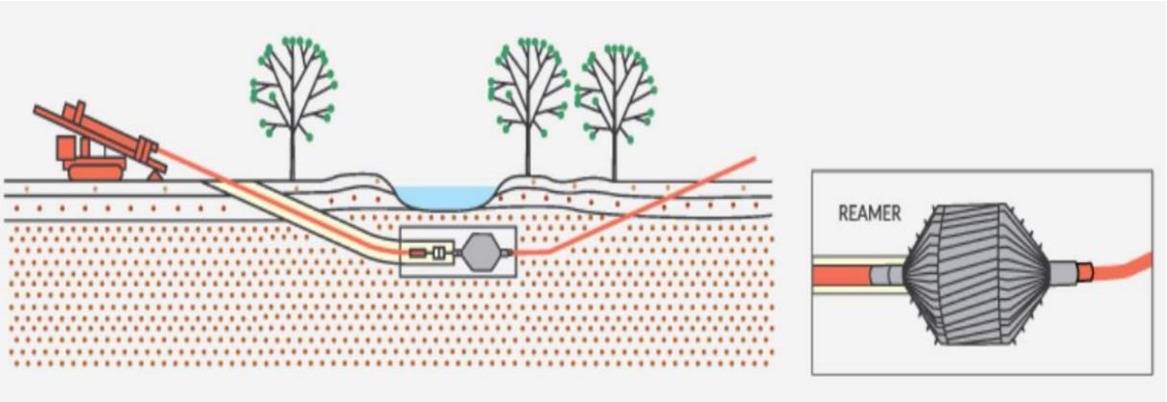


**Figure 43 – Reaming**

- Upon completion of the reaming process, the HDPE pipe shall be pulled in and installed inside the HDD borehole. This process is done by connecting a pulling head to the leading end of the HDPE pipe and attaching the pulling head to the pullback assembly.

  The pullback assembly, together with the HDPE pipe, shall then be pulled in the HDD borehole by the HDD Rig.

  The process is completed once the pullback assembly together with the HDPE pipeline reaches at the entry pit. The pullback assembly shall be dismantled from the HDPE pipe for pipe tie-in or other works to follow.

  Figure 44 illustrates the Pipe Pull Back.

  .

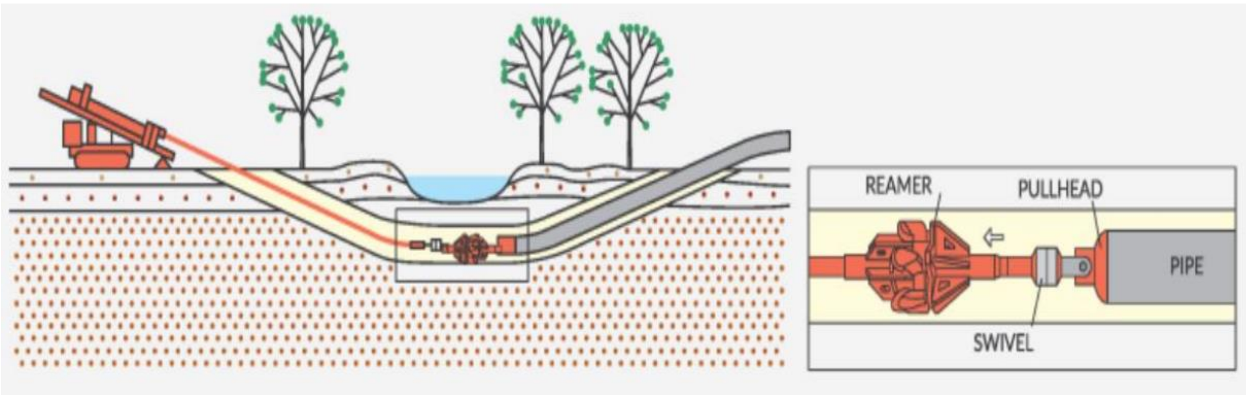


**Figure 44 – Pipe Pull Back**

### 4.4.3 Horizontal Pipe jacking Methodology

- Equipment installation
- Safety ladder installation
- Track installation
- Back wall installation
- Water stop ring installation
- Pipe Jacking set-up
- Pipe assemble and launching
- Tunnel Excavation and bentonite injection
- Tunnel finish
- Pipe jacking machine head out of the hole
- Facility disassembly

Figure 45 illustrates the Jacking alignment of Torrington Tunnel.

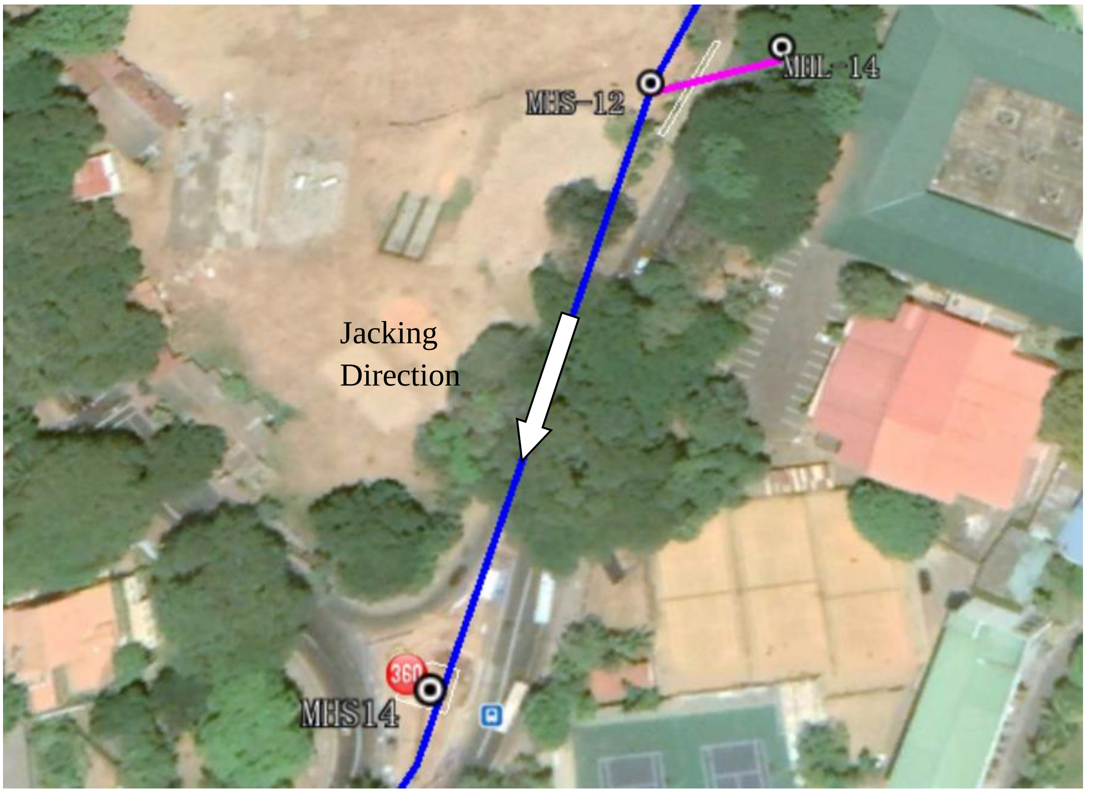


**Figure 45 Jacking alignment of Torrington Tunnel**

Figure 46 illustrates the General layout of Torrington Tunnel.

**Figure 46 - General layout of Torrington Tunnel**

## 4.5 Economic analysis

It is common practice, in densely populated and heavily built-up cities such as Colombo, for storm water to be channelled either through cut-and-cover or bored tunnels. Any open-cut construction technique would be costly and time consuming, owing to the following factors that are insurmountable, in some situations.

- Social/environmental issues.
- Service disruptions.
- Costly and time-consuming traffic management requirements.
- Very slow construction progress, particularly during inclement weather periods.
- Higher health and safety hazards to the operators and public.
- Denial and inconvenience of access to residential and business premises.
- Temporary or permanent utility diversions.
- Dewatering and water disposal issues and consequent structure movements.
- Re-instatement of affected road furniture and signage.
- Higher surface settlements, causing damage to structures.
- Backfilling and re-instatement.
- Disposal of considerable quantities of excavated material (the volume of excavated material from an equivalent cut-and-cover tunnel would be approximately fifteen times more than for the proposed tunnel).
- Much higher material, labour and plant usage.
- Physical constraints (restricted access, immovable obstacles etc.).
- Noise, vibrations and dust pollution.

For cut-and-cover construction technique to be feasible, the alignment must ideally follow an existing roadway that ought to be wide enough to maintain an uninterrupted two-way traffic flow, to permit material handling and transport. Very often, a complete road closure during construction would be essential, as many congested traffic routes would not be able to sacrifice sufficient space for construction activities, while maintaining traffic movement.

In view of the aforementioned unfavourable factors, it has been decided to examine the Microtunneling (trenchless) options, as the most suitable, in preference to cut-and-cover techniques. This technique will eliminate or minimise the above problems and offer tremendous time and cost savings.

The utilities information has been obtained, in collaboration with the following organisations. Sufficient clearance to the utility services has been provided during the selection of the final tunnel alignments.

- National Water Supply and Drainage Board (NWSDB)
- Ceylon Electricity Board (CEB)
- Sri Lanka Telecom (SLT)
- Dialog Cable TV Company
- Colombo Municipal Council (CMC)

The input data for modelling of the sewerage system has been obtained from the records maintained by the CMC, since the sewer system is owned and maintained by them.

Several probable alignments have been examined, in order to choose the best one that offers cost and time savings. Consideration has been given to the safety of the existing buildings, mature/established trees and utility services that are within the corridor of influence of the proposed micro tunnel.

The project area is located, in close proximity to the coast and consequently, the vertical alignment is constrained by the Mean Sea Level (MSL) and the surface contours. The tunnel invert level had a lower limit governed by the MSL and the crest level by the cover requirements. Thus, the tunnel diameters and vertical alignments, apart from hydraulic requirements were chosen with consideration given to the said limitations. Lining up of the horizontal alignment away from the buildings, services and mature plants was the main criterion used in selecting the proposed alignment. This primarily prevented the unnecessary costs and delays in dealing with land acquisitions, protective work during construction and service diversions, claims for probable service disruptions and property damage.

The optimum diameter for the 1100-metre-long (approximate) main Torrington Tunnel, as formulated through hydraulic modelling is 3.0m. In addition, approximately 3890 metres of spine tunnels with diameter varying from 0.6m to 2.0mhave been proposed, under this project. These spine tunnels, effectively replace the costly and time-consuming cut-and-cover tunnels.

Channelling of flows from the shallow trenches from the catchment areas, into the proposed spine tunnels was through the lateral tunnels of diameters varying from 0.6m to 1.2m between manholes, located at strategic positions. It has been proposed that such short connections also be carried out using auger boring or similar Microtunneling methods.

The connection to the main tunnel would be directly into the main tunnel or using an off-set or tunnel aligned manholes. The shafts and lateral connections that involve contractor's working space have been located at positions of least traffic movement. Where it is necessary to deviate from a straight horizontal alignment, to ease build ability or provide clearance from major obstacles or sensitive structures, curved alignments have been introduced.
The details of the general layout are given in above diagrams

The sea-outfall, adjacent to the twin-track railway line would be approximately 50 metres in length.

The hydraulic and hydrodynamic effects at the sea out-falls have also been studied, in collaboration with the Department of Coast Conservation and Coastal Resources Management, to eliminate the possible sand-bar formation and any adverse consequences. This ensures sustainability and maintenance aspects.

Since the outlet is a sea outfall, the tide level has an influence on the discharge through the tunnel. Therefore, a separate analysis was carried out by comparing the discharge through the tunnel having different time lags to the applied time series data of tide levels. Although minor fluctuations in discharge have been observed, the effective discharge through the tunnel was acceptable.

Historical information and a few readily available boreholes, in close proximity to the proposed tunnel alignment have been used, in conjunction with experience of the CMC and SLLRDC, to assess the ground conditions for Microtunneling, tentatively, subject to more accurate borehole information becoming available, on completion of the exploratory work, currently in progress.

The following durability and performance requirements will be written into the Bidding Documents, under preparation.

- Appropriate plant, equipment, material and skills shall be selected.
- Water conveying and retaining structures shall be designed for self-cleansing.
- All finished surfaces of structures (concrete and steel) that are prone to abrasion and chemical attack shall be protected for durability and performance. Screening of undesirable grit and debris shall form part of the design.
- Clear guidelines shall be set out for tunnel inspection and maintenance of man-entry tunnels, non-man-entry tunnels and confined spaces. This should also include access requirements, inspection frequency, appropriate equipment, contingency measures, rescue facilities and recording/reporting methods.
- Provision must be made for flow diversions for inspection (usually during dry weather periods).
- An integrated, real time flow monitoring and data logging system, remotely accessible shall be introduced.

## 4.6 Proposed construction sequence

The construction sequence is subject to the prospective Design and Build Contractors choice of plant/equipment, material and labour inputs. Therefore, specific sizes of the components and a rigid construction sequence cannot be laid down.

However, the following sequence of construction has been proposed, in order to give priority to flood mitigation in critical areas. It is to be noted that the Spine Tunnels have been numbered sequentially, following the said order of priority.

If open cut method was selected the following consequences would have been faced

- Materials delivered and stored in the right of way
- Pavement cut to trench width using a pavement saw
- Trenches dug to the curb to install laterals, which connect the individual properties to the sewer mains
- Pavement and material removed by large equipment and loaded into dump trucks
- Pipe installed in trench
- Trench backfilled with sand or gravel and compacted
- Temporary pavement installed as work progresses forward
- Curb and sidewalk repaired or replaced if necessary or specified in plans
- Trenches permanently paved when there is enough distance between the paving crew and the pipe crew
- Impacted planting, streets cleaned, and other remaining restoration completed as paving is finished

By selecting Microtunneling methodology for the above project the following benefits were created

- Reduced disruption of the community.
- Reduced liability for personal injury and property damage.
- Increased service life and asset value for the utility owner.
- Increased worker safety.
- Reduced restoration costs.
- Precise installation.
- Faster rate of progress than conventional tunneling
- Minimum interruption to traffic
- High quality rehabilitated sewer
- Time saving, minimum earth disturbances
- Fifty years of design life, easy ground water handling

## 4.7 Cost effectiveness

Microtunneling is economically competitive with direct burial when depths exceed five meter due to the costs of deep trench excavation and trench support. This method is cost effective when faced with unstable soil conditions and work below the groundwater level. These conditions increase the risk of surface settlement during a direct burial or conventional tunnel installation. These conditions also increase liability for all parties with regard to property damage and personal injury. Microtunneling is the safest tunnelling option when faced with these conditions, because workers and the public are not directly exposed to hazardous conditions.

- The equipment is noiseless and no disturbance to public
- Both preparation and post micro-tunneling work can take a few weeks to complete.
- Shafts are usually too large to cover safely with steel plates during non-construction hours. Site fencing was done to secure these areas during non-construction hours.
- No road closures and lane restrictions.
- Construction of Jacking shaft took about six months.
- No work hour restriction and pipe jacking only took three weeks
- Reduced over pumping costs
- Reduced costs for traffic regulation
- Less social disruptions
- No utility involvement

## 4.8 Cost comparison

This section presents the analysis of the data that has been collected in this research.

### Comparisons of methods used microtunneling and open cut – type

An analysis was performed to compare the cost of construction of open cut method and microtunnelling using recent projects of Colombo Municipality. The data was obtained from the submitted tenders and cost estimates of Project Management unit. Table gives the comparison.

### Table 10 - Sri saddarma mawatha 375mm dia. pipe - open cut

| Item No. | CESSM 3 Code No. | Description | Quantity | Unit | Rate (LKR) | Amount (LKR) | Remarks |
|---|---|---|---|---|---|---|---|
| Bill No. 4.1 - M26 (Siri Saddarma Mawatha)375mm dia. Pipe Open Cut | | | | | | | |
| | CLASS A - GENERAL ITEMS | | | | | | |
| | | Field Test | | | | | |
| | | Perform Field Test and Furnish | | | | | |
| 4.1.1 | A270 | 375mm dia. Clay pipe | 10 | m | 165.61 | 165.61 | |
| 4.1.4 | A271 | Road traffic and safety management | Item | sum | 20,107.96 | 20,107.96 | |
| 4.1.5 | A273 | Assess road maintenance | Item | sum | 5,745.13 | 5,745.13 | |
| 4.1.6 | A279 | Tidiness of sites | Item | sum | 2,872.57 | 2,872.57 | |
| | CLASS E - EARTH WORKS | | | | | | |
| | | Excavation and backfill with imported material and warning tape | | | | | |
| | | Trench depth not exceeding 5-10m | | | | | |
| 4.1.12 | E425 | Earth, Other than topsoil, rock or artificial hard material | 50.63 | m3 | 21,557.07 | 1,091,434.45 | 70% paid |
| 4.1.13 | E435 | Rock required safety blasting. | 2 | m3 | 3,746.82 | 7,493.64 | |
| 4.1.14 | E495 | Artificial hard material. | 2 | m3 | 2,914.20 | 5,828.40 | |
| | CLASS I - PIPE WORK - PIPES | | | | | | |
| | | Supply, Laying and Fixing of Pipe | | | | | |
| | | In trench depth 2-5m | | | | | |
| 4.1.15 | I139 | 375mm dia. Clay pipe | 10 | m | 19,878.98 | 198,789.80 | 100% paid Due to preliminary testing report |
| | | Road Reinstatement | | | | | |
| 4.1.22 | K732 | Open trench for 375mm dia pipe | 10 | m | 5,116.36 | 51,163.60 | paid 75 %, wearing course not comp. |
| | CLASS L - PIPE WORK - SUPPORTS AND PROTECTION ANCILLARIES TO LAYING AND EXCAVATION | | | | | | |
| | | Pipe bedding for open cut laying | | | | | |
| | | Trench & Bedding Type - A (375mm dia pipe) | | | | | |
| 4.1.28 | L313 | 150mm thick ABC or compacted sand or selected material bad | 10 | m | 393.42 | 3,934.20 | |
| 4.1.29 | L513 | Surrounding wet sand or selected as dug material | 10 | m | 3,147.33 | 31,473.30 | |
| | | | | | | | |
| | | | | | | | |
| | | **Total for 10.0m length** | | | | 1,738,181.18 | |
| | | **Total for 1.0m length** | | | | 173,818.12 | |

Table 10 analyses a cost estimation to lay 375 mm diameter pipeline along Sri Saddarma mawatha, Colombo 09. It demonstrates direct costs incurred if the project had been carried out in open cut method.

**Table 11 - Sri saddarma mawatha 375mmdia. pipe microtunneling**

| Item No. | CESSM 3 Code No. | Description | Quantity | Unit | Rate (LKR) | Amount (LKR) | Remarks |
|---|---|---|---|---|---|---|---|
| **Bill No. 4.5 - M26 (Dematagoda Road) 375mm dia. Pipe Micro Tunnelling** | | | | | | | |
| | CLASS A - GENERAL ITEMS | | | | | | |
| | | Field Test | | | | | |
| | | Perform Field Test and Furnish | | | | | |
| 4.5.3 | A270 | **375mm dia. Clay pipe from Existing M102** | 10 | m | 165.61 | 1,656.10 | |
| | | Temporary Works | | | | | |
| 4.5.4 | A271 | Road traffic and safety management | Item | sum | 13,988.14 | 26,810.61 | |
| 4.5.5 | A273 | Assess road maintenance | Item | sum | 3,996.61 | 7,660.17 | |
| 4.5.6 | A279 | Tidiness of sites | Item | sum | 1,998.31 | 3,830.09 | |
| | CLASS I - PIPE WORK - PIPES | | | | | | |
| | | Supply, Laying and Fixing Pipes | | | | | |
| | | In trench depth 5-10m | | | | | |
| 4.5.9 | I139 | 375mm dia. Clay pipe from Existing M102 | 10 | m | 19,878.98 | 198,789.80 | |
| | CLASS L - PIPE WORK - SUPPORTS AND PROTECTION ANCILLARIES TO LAYING AND EXCAVATION | | | | | | |
| | | Trenchless Excavation | | | | | |
| | | Micro tunneling | | | | | |
| | | In depth 5-10m | | | | | |
| 4.5.16 | L292 | 375mm dia. Clay pipe from Existing M102 | 10 | m | 238,680.32 | 2,386,803.20 | |
| | | | | | | | |
| | | **Total for 10.0m length** | | | | 2,625,549.97 | |
| | | **Total for 1.0m length** | | | | 262,555.00 | |

Table 11 analyses cost estimation of the same project if it had been conducted by implementing Microtunneling technology.

## Table 12 - Maligawatte railway quarters road 600mm dia. pipe open cut

| Item No. | CESSM 3 Code No. | Description | Quantity | Unit | Rate (LKR) | Amount (LKR) | Remarks |
|---|---|---|---|---|---|---|---|
| **Bill No. 4.2 - M26 (Railway Quarters Road) 600mm dia. Pipe Open cut** | | | | | | | |
| | CLASS A - GENERAL ITEMS | | | | | | |
| | | Field Test | | | | | |
| | | Perform Field Test and Furnish | | | | | |
| 4.2.1 | A270 | 600mm dia. Clay pipe | 287 | m | 327.97 | 94,127.39 | |
| | | Temporary Works | | | | | |
| 4.2.2 | A271 | Road traffic and safety management | Item | sum | 167,274.88 | 167,274.88 | |
| 4.2.3 | A273 | Assess road maintenance | Item | sum | 47,792.82 | 47,792.82 | |
| 4.2.4 | A279 | Tidiness of sites | Item | sum | 23,896.41 | 23,896.41 | |
| | CLASS E - EARTH WORKS | | | | | | |
| | | Excavation trench depth not exceeding 5-10m | | | | | |
| 4.2.6 | E425 | Earth, Other than topsoil, rock or artificial hard material | 2583 | m3 | 22,565.02 | 58,285,446.66 | |
| 4.2.7 | E435 | Rock required safety blasting | 50 | m3 | 3,746.82 | 187,341.00 | |
| 4.2.8 | E495 | Artificial hard material | 50 | m3 | 2,914.20 | 145,710.00 | |
| | CLASS I - PIPE WORK - PIPES | | | | | | |
| | | Supply, Laying and Fixing of Pipe | | | | | |
| | | In trench depth 5-10m | | | | | |
| 4.2.9 | I129 | 600mm dia. Clay pipe | 287 | m | 39,461.55 | 11,325,464.85 | |
| | | Road Reinstatement | | | | | |
| 4.2.12 | K732 | Open trench for 600mm dia pipe | 287 | m | 6,297.06 | 1,807,256.22 | |
| | CLASS L - PIPE WORK - SUPPORTS AND PROTECTION ANCILLARIES TO LAYING AND EXCAVATION | | | | | | |
| | | Trench & Bedding Type - E (600mm dia pipe) | | | | | |
| 4.2.16 | L322 | 75mm thick stabilized beds | 287 | m | 240.42 | 69,000.54 | |
| 4.2.17 | L542 | G20 concrete for pipe encasement | 287 | m | 19,583.40 | 5,620,435.80 | |
| 4.2.18 | L522 | Surrounding graded granular fill | 287 | m | 1,223.96 | 351,276.52 | |
| | | | | | | | |
| | | | | | | | |
| | | **Total for 287.0m length** | | | | 78,125,023.09 | |
| | | **Total for 1.0m length** | | | | 272,212.62 | |

Table 12 analyses a cost estimation to lay 600 mm diameter pipeline along Maligawatte Railway Quarters Road, Colombo 09. It demonstrates direct costs incurred if the project had been carried out in open cut method.

**Table 13 - Maligawatte railway quarters road 600mm dia. pipe microtunneling**

| Item No. | CESSM 3 Code No. | Description | Quantity | Unit | Rate (LKR) | Amount (LKR) | Remarks |
|---|---|---|---|---|---|---|---|
| **Bill No. 4.3 - M26 (Railway Tracks)600mm dia. Pipe Micro Tunnelling** | | | | | | | |
| | CLASS A - GENERAL ITEMS | | | | | | |
| | | Field Test | | | | | |
| | | Perform Field Test and Furnish | | | | | |
| 4.3.1 | A270 | 600mm dia. Clay pipe | 126 | m | 327.97 | 41,324.22 | |
| | | Temporary Works | | | | | |
| 4.3.2 | A271 | Road traffic and safety management | Item | sum | | 73,437.75 | |
| 4.3.3 | A273 | Assess road maintenance | Item | sum | | 20,982.21 | |
| 4.3.4 | A279 | Tidiness of sites | Item | sum | | 10,491.11 | |
| | CLASS D - DEMOLITION AND SITE CLEARANCE | | | | | | |
| | CLASS I - PIPE WORK - PIPES | | | | | | |
| | | Supply, Laying and Fixing of Pipe | | | | | |
| | | In trench depth 5-10m | | | | | |
| 4.3.5 | I129 | 600mm dia. Clay pipe | 126 | m | 39,461.55 | 4,972,155.30 | |
| | CLASS L - PIPE WORK - SUPPORTS AND PROTECTION ANCILLARIES TO LAYING AND EXCAVATION | | | | | | |
| | | Trenchless Excavation | | | | | |
| | | Micro tunneling | | | | | |
| | | In depth 5-10m | | | | | |
| 4.3.6 | L293 | 600mm dia.Clay pipe | 126 | m | 274,822.18 | 34,627,595.18 | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | **Total for 126.0m length** | | | | 39,745,985.77 | |
| | | **Total for 1.0m length** | | | | 315,444.33 | |

Table 13 analyses cost estimation of the same project if it had been conducted by implementing Microtunneling technology.

Accoriding these analyeses (pesented in Table 10, 11, 12 and 13), it is evidenced that direct costs involved in the construction when carried out by implementing microtunneling technology is higher than when the same construction was carried out by implementing open-cut method.

### 4.8.2. Summary of comparison

**M26 Sewer line along Siri Saddamma Mawatha - 375mm dia. Pipe**

- Open cut – total cost for 1m length Rs. 173,818.12
- Microtunneling – total cost for 1m length Rs. 262,555.00

**M26 Sewer line along Railway Quarters Road - 600mm dia. Pipe**

- Open cut – total cost for 1m length Rs. 272,212.62
- Microtunneling – total cost for 1m length Rs. 315,444.33

However, it could be also seen that this the cost diffference between the two methods is generally less than LKR 100,00.00 to lay a pipe of 1 metre length.

Analysis of qualitative data gathered in interviews conducted with five experts involved in these construction projects revealed the following benefits;

- Reduced disruption of the community.
- Reduced liability for personal injury and property damage.
- Increased service life and asset value for the utility owner.
- Increased worker safety.
- Reduced restoration costs.
- Precise installation.
- Faster rate of progress than conventional tunneling
- Minimum interruption to traffic.
- High quality rehabilitated sewer
- Time saving, minimum earth disturbances
- Fifty years of design life, easy ground water handling

It is a complicated and complex task to calculate numerical values of costs incurred in each of these themes. For an example, costs incurred in interruption to traffic is difficult to quantify and calculate. However, it was also evidenced through these interviews that the indirect costs incurred in the aforementioned key themes when compared with the difference between the costs of open-cut and Microtunneling methods were significantly higher. Therefore, the total costs (direct costs, indirect costs and social costs) incurred in open-cut method is significantly higher when compared with the total cost of Microtunneling method.

## 4.9 Parameters for analysis for applications in Sri Lanka

Traffic related data can be obtained from Traffic Division CMC. Data related to usual traffic condition is available. However data related to delays due to construction obstacles is not available. Hence I could not calculate the impact of traffic delays. Project feasibility reports also do not have analysis of traffic delays and other social parameters.

Therefore, these analysis and data need to be collected in future studies for viability of microtunneling.

### Vehicle turning movements at the traffic light junctions

Information based on the survey conducted to calculate vehicle turning movements at the following traffic light junctions are illustrated in Figures 47-55.

- R A De Mel Mawatha / Bauddhaloka Mawatha Junction
- Vajira Road / Sri Sambuddhathva Jayanthi Mawatha Junction
- Sri Sambuddhathva Jayanthi Mawatha / Thimbirigasyaya Road Junction
- Isipathana Mawatha / Fife Road Junction
- Galle Road / Bauddhaloka Mawatha Junction
- Kanaththa Junction
- Borella Junction
- Rajagiriya Junction
- Panchikawatta Junction

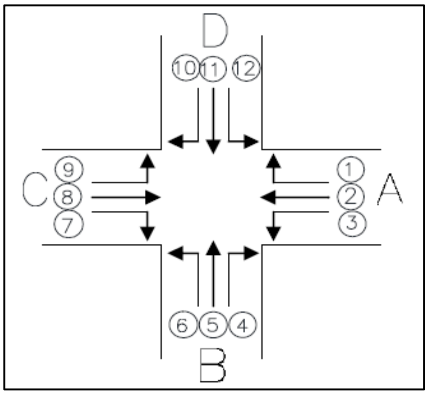


**Figure 47 - R A D Mel mawatha Bullers road junction**

A. R A De Mel Mw (From Kollupitiya)
B. Bauddhaloka Mw (From Thunmulla Jn)
C. R A De Mel Mw (From Wellawatta )
D. Bauddhaloka Mw (From Bambalapitiya Jn

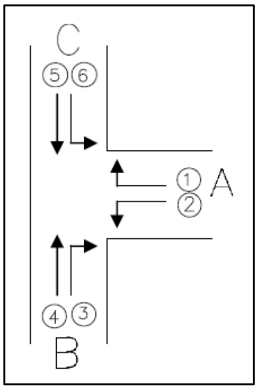


**Figure 48 - Vajira road / R A D Mel mawatha junction**

A. Vajira Rd (From R A De Mel Mw Jn)
B. Sri Sambuddhathva Jayanthi Mw (From Thummulla Jn)
C. Sri Sambuddhathva Jayanthi Mw (From Thimbirigasyaya Jn)

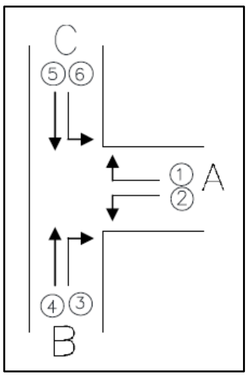


**Figure 49 - Thimbirigasyaya road / Sri Sambuddhathva Jayanthi mawatha junction**

A. Thimbirigasyaya Rd (From Thimbirigasyaya Jn)
B. Sri Sambuddhathva Jayanthi Mw (From Dickmans Rd)
C. Sri Sambuddhathva Jayanthi Mw (From Thummulla Jn)

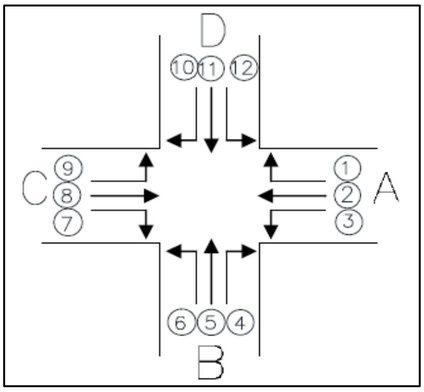


**Figure 50- Sri Sambuddhathva Jayanthi mawatha / Isipathana mawatha junction**

A. Sri Sambuddhathva Jayanthi Mw (From Kirulapone Jn)
B. Dr Lester James Peries Mw (From R A De Mel Mw Jn)
C. Sri Sambuddhathva Jayanthi Mw (From Thimbirigasyaya Jn)
D. Isipathana Mw (From Fife Rd Jn)

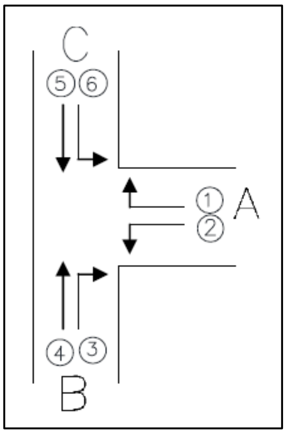


**Figure 51 - Bambalapitiya junction**

A. Bauddhaloka Mw (From Duplication Road Jn)
B. Galle Rd (From Wellawatta Jn)
C. Galle Rd (From Kollupitiya Jn)

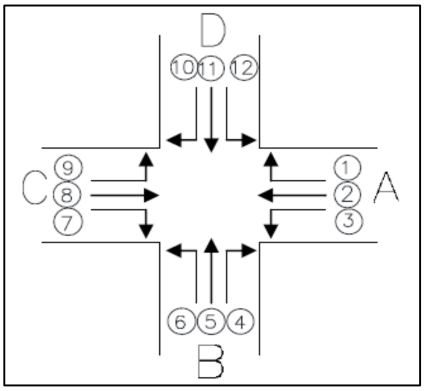


**Figure 52 - Ayurveda junction**

A. Sri Jayawardanapura Mawatha (From Rajagiriya Jn)
B. Sri Jayawardanapura Mawatha (From Kanatta Jn)
C. Dr.N. M. Perera Mawatha (From Borella Jn)
D. Borella - Rajagiriya Road (From Rajagiriya Jn)

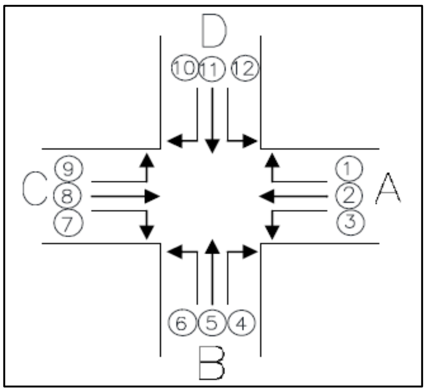


**Figure 53 - Devi Balika junction**

A. Sri Jayawardanapura Mawatha (From Rajagiriya Jn)
B. Bauddaloka Mawatha (From Kanatta Jn)
C. Dudly Senanayaka Mawatha (From Elvitigala MW Jn)
D. Bauddaloka Mawatha (From Dr. N. M. Perera Mw Jn)

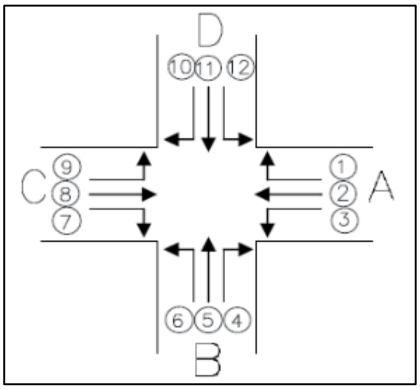


**Figure 54 - Kanaththa junction**

D S Senanayake Mw (From Kanatta Jn)

A. Dudly Senanayake Mw (From Kinsey Rd Jn)
B. D S Senanayake Mw (From Borella Jn)
C. Dudly Senanayake Mw (From Bauddhaloka Mw Jn)

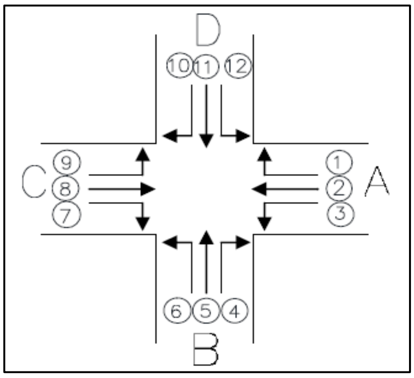


**Figure 55 - Panchikawaththa junction**

A. Sri Sumanatissa Mw. (From Panchikawatta)
B. M J M Lafeer Mw.
C. Sri Sumanatissa Mw. (From Armour Street Jn)
D. M Vincent Perera Mw.

Appendix 1 summarises travelling movements at each hour of the day at each of these junctions to present number of vehicles travelled through the traffic light junctions. These data clearly demonstrate the magnitude of traffic occurred at each of these junctions. During the expert interviews, interviewees pointed out that to pass a traffic flow of this magnitude through an open-cut construction excavation at these junctions would result in extremely huge traffic. This kind of extremely huge traffic would result in high indirect costs in areas including but not limited to, travelling time, mental and physical fatigue of travellers. These indirect costs are unmeasurable and unquantifiable, and therefore its impact is unpredictable when calculating the total cost.

Analysing all of these factors, it could be concluded that even though the direct costs incurred in open-cut constructions are lower than Microtunneling constructions, when all the indirect costs are considered the total cost of open-cut construction method is significantly higher, unmeasurable and the cost-impact is very long-term compared with the open-cut construction method.

# 5 CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Technology

The following technologies have been used in Sri Lanka and recorded success.

- Pipe jacking method used by MTBM – Mainly used for gravity storm water project, sewer projects & for when using rigid pipes
- Other methods -Horizontal Directional Drilling mainly used for force main part in sewer projects
- Pipe jacking method and machine used is horizontal jacking and Boring Unit.

Although Engineers are responsible for the development of new construction methods and technology, there is also resistance among the Engineering community to accept new technologies. The resistance to adopt new technology could be due to many reasons such as, risk involved, un-familiarity with the new technology and the misconception that new technology is always expensive than the traditional methods. In respect of the new technology of which I intend to research does not have much information of the cost involved?

## 5.2 Cost parameters

Even though the direct costs incurred in open-cut constructions are lower than Microtunneling constructions, when all the indirect & social costs are considered, the total cost of open-cut construction method is significantly higher, unmeasurable and the cost-impact of the Microtunneling method is very long-term compared with the open-cut construction method.

## 5.3 Framework for critical analysis of Microtunneling in Sri Lanka.

I believe that further studies shall be necessary in order to evaluate the advantages and disadvantages of Microtunneling technology. Therefore, I believe that a cost comparison would be extremely beneficial comparing trenchless technology and open cut method could be beneficial for future projects. I also wish to state that some of the costs that are available are not comparable with the cost as in developing countries, cost of technology while be expensive, cost of labour is comparatively less expensive.

Furthermore, people are demanding for better quality of life, efficient and effective service facilities and time has come to replace and expand the underground utility facilities, specially provided by the water sector. In order to expand the water and waste water facilities, open cut excavation methods have become obsolete and therefore, more emphasis has to be given to Microtunneling techniques which would save existing aboveground facilities such as, sidewalks, pavements, landscaping etc.

Furthermore, there is an additional social and environmental factors in the open trench methods. Trenchless technologies minimises surface excavation and this method could be used to repair, upgrade, replace and renovate underground infrastructure systems. This technology is very commonly used in developing countries and it is a viable option for Sri Lankan cities as well.

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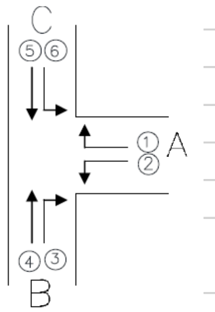
# Appendix 1

**Table 14 - hourly distribution of traffic movements by all approach links at junction No. 5**



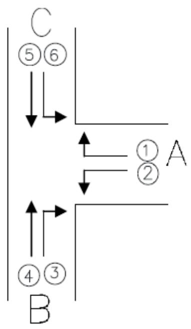

**Technical Assistance for ATMS in Colombo Metropolitan Region**

**Hourly Distribution of Traffic Movements By All Approach Links at Junction No 5**

| | Thimbirigasyaya Rd (From Thimbirigasyaya Jn) | | | | | | Sri Sambuddhathva Jayanthi Mw (From Dickmans Rd) | | | | | | Sri Sambuddhathva Jayanthi Mw (From Thummulla Jn) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Link "A" | | | | | | Link "B" | | | | | | Link "C" | | | | | |
| | Out Bound | | | In Bound | | | Out Bound | | | In Bound | | | Out Bound | | | In Bound | | |
| Time | 3 | 6 | Total | 1 | 2 | Total | 2 | 5 | Total | 3 | 4 | Total | 1 | 4 | Total | 5 | 6 | Total |
| 06:00 - 07:00 | 270 | 146 | 416 | 289 | 190 | 479 | 190 | 714 | 904 | 270 | 1204 | 1474 | 289 | 1204 | 1493 | 714 | 146 | 860 |
| 07:00 - 08:00 | 481 | 303 | 784 | 595 | 400 | 995 | 400 | 1199 | 1599 | 481 | 1892 | 2373 | 595 | 1892 | 2487 | 1199 | 303 | 1502 |
| 08:00 - 09:00 | 415 | 275 | 690 | 418 | 406 | 824 | 406 | 754 | 1160 | 415 | 2252 | 2667 | 418 | 2252 | 2670 | 754 | 275 | 1029 |
| 09:00 - 10:00 | 375 | 290 | 665 | 504 | 478 | 982 | 478 | 702 | 1180 | 375 | 1544 | 1919 | 504 | 1544 | 2048 | 702 | 290 | 992 |
| 10:00 - 11:00 | 327 | 280 | 607 | 383 | 349 | 732 | 349 | 1260 | 1609 | 327 | 1433 | 1760 | 383 | 1433 | 1816 | 1260 | 280 | 1540 |
| 11:00 - 12:00 | 376 | 375 | 751 | 548 | 493 | 1041 | 493 | 1279 | 1772 | 376 | 2885 | 3261 | 548 | 2885 | 3433 | 1279 | 375 | 1654 |
| 12:00 - 13:00 | 377 | 375 | 752 | 527 | 417 | 944 | 417 | 1413 | 1830 | 377 | 1816 | 2193 | 527 | 1816 | 2343 | 1413 | 375 | 1788 |
| 13:00 - 14:00 | 411 | 389 | 800 | 528 | 411 | 939 | 411 | 1721 | 2132 | 411 | 2359 | 2770 | 528 | 2359 | 2887 | 1721 | 389 | 2110 |
| 14:00 - 15:00 | 359 | 341 | 700 | 494 | 318 | 812 | 318 | 1473 | 1791 | 359 | 1438 | 1797 | 494 | 1438 | 1932 | 1473 | 341 | 1814 |
| 15:00 - 16:00 | 290 | 242 | 532 | 333 | 299 | 632 | 299 | 1058 | 1357 | 290 | 1217 | 1507 | 333 | 1217 | 1550 | 1058 | 242 | 1300 |
| 16:00 - 17:00 | 414 | 294 | 708 | 421 | 424 | 845 | 424 | 1873 | 2297 | 414 | 1600 | 2014 | 421 | 1600 | 2021 | 1873 | 294 | 2167 |
| 17:00 - 18:00 | 411 | 379 | 790 | 454 | 513 | 967 | 513 | 2345 | 2858 | 411 | 1375 | 1786 | 454 | 1375 | 1829 | 2345 | 379 | 2724 |
| 18:00 - 19:00 | 323 | 322 | 645 | 342 | 462 | 804 | 462 | 1959 | 2421 | 323 | 1135 | 1458 | 342 | 1135 | 1477 | 1959 | 322 | 2281 |
| 19:00 - 20:00 | 357 | 284 | 641 | 273 | 328 | 601 | 328 | 1528 | 1856 | 357 | 663 | 1020 | 273 | 663 | 936 | 1528 | 284 | 1812 |
| 20:00 - 21:00 | 235 | 226 | 461 | 178 | 219 | 397 | 219 | 1111 | 1330 | 235 | 686 | 921 | 178 | 686 | 864 | 1111 | 226 | 1337 |
| 21:00 - 22:00 | 145 | 74 | 219 | 97 | 52 | 149 | 52 | 499 | 551 | 145 | 220 | 365 | 97 | 220 | 317 | 499 | 74 | 573 |
| **Totals** | **5566** | **4595** | **10161** | **6384** | **5759** | **12143** | **5759** | **20888** | **26647** | **5566** | **23719** | **29285** | **6384** | **23719** | **30103** | **20888** | **4595** | **25483** |

| | |
|---|---|
| **Total In Bound** | **66911** |
| **Total Out Bound** | **66911** |

## Table 15 - hourly distribution of traffic movements by all approach links at junction No. 7



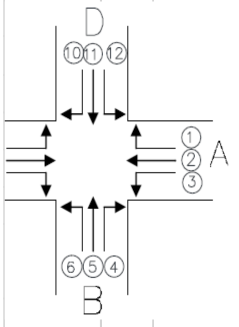

**Technical Assistance for ATMS in Colombo Metropolitan Region**

**Hourly Distribution of Traffic Movements By All Approach Links at Junction No 7**

| Time | | | Vajira Rd (From R A De Mel Mw Jn) | | | | | | Sri Sambuddhathva Jayanthi Mw (From Thummulla Jn) | | | | | | Sri Sambuddhathva Jayanthi Mw (From Thimbirigasyaya Jn) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Link "A" | | | | | | Link "B" | | | | | | Link "C" | | | | | |
| | | | Out Bound | | | In Bound | | | Out Bound | | | In Bound | | | Out Bound | | | In Bound | | |
| | | | 3 | 6 | Total | 1 | 2 | Total | 2 | 5 | Total | 3 | 4 | Total | 1 | 4 | Total | 5 | 6 | Total |
| 06:00 | - | 07:00 | 139 | 139 | 278 | 158 | 293 | 451 | 293 | 1423 | 1716 | 139 | 644 | 783 | 158 | 644 | 802 | 1423 | 139 | 1562 |
| 07:00 | - | 08:00 | 194 | 158 | 352 | 346 | 567 | 913 | 567 | 1985 | 2552 | 194 | 1040 | 1234 | 346 | 1040 | 1386 | 1985 | 158 | 2143 |
| 08:00 | - | 09:00 | 206 | 79 | 285 | 266 | 556 | 822 | 556 | 1953 | 2509 | 206 | 1042 | 1248 | 266 | 1042 | 1308 | 1953 | 79 | 2032 |
| 09:00 | - | 10:00 | 180 | 70 | 250 | 163 | 410 | 573 | 410 | 1905 | 2315 | 180 | 1225 | 1405 | 163 | 1225 | 1388 | 1905 | 70 | 1975 |
| 10:00 | - | 11:00 | 203 | 103 | 306 | 221 | 335 | 556 | 335 | 1278 | 1613 | 203 | 1180 | 1383 | 221 | 1180 | 1401 | 1278 | 103 | 1381 |
| 11:00 | - | 12:00 | 222 | 117 | 339 | 220 | 489 | 709 | 489 | 1860 | 2349 | 222 | 1041 | 1263 | 220 | 1041 | 1261 | 1860 | 117 | 1977 |
| 12:00 | - | 13:00 | 278 | 113 | 391 | 315 | 412 | 727 | 412 | 1757 | 2169 | 278 | 1213 | 1491 | 315 | 1213 | 1528 | 1757 | 113 | 1870 |
| 13:00 | - | 14:00 | 263 | 125 | 388 | 336 | 359 | 695 | 359 | 1824 | 2183 | 263 | 1140 | 1403 | 336 | 1140 | 1476 | 1824 | 125 | 1949 |
| 14:00 | - | 15:00 | 278 | 116 | 394 | 291 | 427 | 718 | 427 | 1517 | 1944 | 278 | 1104 | 1382 | 291 | 1104 | 1395 | 1517 | 116 | 1633 |
| 15:00 | - | 16:00 | 177 | 89 | 266 | 196 | 296 | 492 | 296 | 1089 | 1385 | 177 | 983 | 1160 | 196 | 983 | 1179 | 1089 | 89 | 1178 |
| 16:00 | - | 17:00 | 326 | 137 | 463 | 282 | 447 | 729 | 447 | 1012 | 1459 | 326 | 1576 | 1902 | 282 | 1576 | 1858 | 1012 | 137 | 1149 |
| 17:00 | - | 18:00 | 309 | 133 | 442 | 339 | 433 | 772 | 433 | 1019 | 1452 | 309 | 2174 | 2483 | 339 | 2174 | 2513 | 1019 | 133 | 1152 |
| 18:00 | - | 19:00 | 286 | 94 | 380 | 240 | 298 | 538 | 298 | 779 | 1077 | 286 | 2048 | 2334 | 240 | 2048 | 2288 | 779 | 94 | 873 |
| 19:00 | - | 20:00 | 185 | 79 | 264 | 141 | 173 | 314 | 173 | 766 | 939 | 185 | 1549 | 1734 | 141 | 1549 | 1690 | 766 | 79 | 845 |
| 20:00 | - | 21:00 | 112 | 67 | 179 | 117 | 147 | 264 | 147 | 659 | 806 | 112 | 857 | 969 | 117 | 857 | 974 | 659 | 67 | 726 |
| 21:00 | - | 22:00 | 53 | 43 | 96 | 44 | 50 | 94 | 50 | 291 | 341 | 53 | 408 | 461 | 44 | 408 | 452 | 291 | 43 | 334 |
| **Totals** | | | **3411** | **1662** | **5073** | **3675** | **5692** | **9367** | **5692** | **21117** | **26809** | **3411** | **19224** | **22635** | **3675** | **19224** | **22899** | **21117** | **1662** | **22779** |

| | |
|---|---|
| **Total In Bound** | **54781** |
| **Total Out Bound** | **54781** |

## Table 16 - hourly distribution of traffic movements by all approach links at junction No. 6



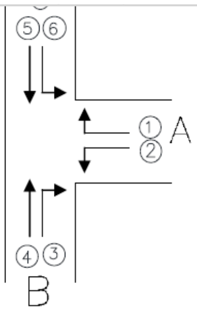

**Technical Assistance for ATMS in Colombo Metropolitan Region**

**Hourly Distribution of Traffic Movements By All Approach Links at Intersection No 6**

| Time | Sri Sambuddhathva Jayanthi Mw (From Kirulapone Jn) | | | | | | | | Dr Lester James Peries Mw (From R A De Mel Mw Jn) | | | | | | | | Sri Sambuddhathva Jayanthi Mw (From Thimbirigasyaya Jn) | | | | | | | | Isipathana Mw (From Fife Rd Jn) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Link "A" | | | | | | | | Link "B" | | | | | | | | Link "C" | | | | | | | | Link "D" | | | | | | | |
| | Out Bound | | | | In Bound | | | | Out Bound | | | | In Bound | | | | Out Bound | | | | In Bound | | | | Out Bound | | | | In Bound | | | |
| Time | 4 | 8 | 12 | Total | 1 | 2 | 3 | Total | 3 | 7 | 11 | Total | 4 | 5 | 6 | Total | 2 | 6 | 10 | Total | 7 | 8 | 9 | Total | 1 | 5 | 9 | Total | 10 | 11 | 12 | Total |
| 06:00 - 07:00 | 70 | 579 | 54 | 703 | 0 | 1195 | 53 | 1248 | 53 | 108 | 167 | 328 | 70 | 193 | 111 | 374 | 1195 | 111 | 115 | 1421 | 108 | 579 | 45 | 732 | 0 | 193 | 45 | 238 | 115 | 167 | 54 | 336 |
| 07:00 - 08:00 | 142 | 926 | 115 | 1183 | 0 | 1707 | 47 | 1754 | 47 | 212 | 353 | 612 | 142 | 284 | 255 | 681 | 1707 | 255 | 256 | 2218 | 212 | 926 | 175 | 1313 | 0 | 284 | 175 | 459 | 256 | 353 | 115 | 724 |
| 08:00 - 09:00 | 166 | 916 | 118 | 1200 | 0 | 1588 | 55 | 1643 | 55 | 230 | 329 | 614 | 166 | 233 | 274 | 673 | 1588 | 274 | 177 | 2039 | 230 | 916 | 95 | 1241 | 0 | 233 | 95 | 328 | 177 | 329 | 118 | 624 |
| 09:00 - 10:00 | 168 | 1005 | 110 | 1283 | 0 | 1707 | 85 | 1792 | 85 | 273 | 238 | 596 | 168 | 199 | 213 | 580 | 1707 | 213 | 153 | 2073 | 273 | 1005 | 93 | 1371 | 0 | 199 | 93 | 292 | 153 | 238 | 110 | 501 |
| 10:00 - 11:00 | 190 | 1146 | 126 | 1462 | 0 | 1162 | 84 | 1246 | 84 | 190 | 216 | 490 | 190 | 210 | 195 | 595 | 1162 | 195 | 141 | 1498 | 190 | 1146 | 97 | 1433 | 0 | 210 | 97 | 307 | 141 | 216 | 126 | 483 |
| 11:00 - 12:00 | 225 | 929 | 121 | 1275 | 0 | 1670 | 146 | 1816 | 146 | 217 | 217 | 580 | 225 | 168 | 256 | 649 | 1670 | 256 | 165 | 2091 | 217 | 929 | 120 | 1266 | 0 | 168 | 120 | 288 | 165 | 217 | 121 | 503 |
| 12:00 - 13:00 | 239 | 1255 | 155 | 1649 | 0 | 1454 | 150 | 1604 | 150 | 212 | 256 | 618 | 239 | 274 | 279 | 792 | 1454 | 279 | 168 | 1901 | 212 | 1255 | 117 | 1584 | 0 | 274 | 117 | 391 | 168 | 256 | 155 | 579 |
| 13:00 - 14:00 | 271 | 1222 | 144 | 1637 | 0 | 1324 | 121 | 1445 | 121 | 256 | 317 | 694 | 271 | 370 | 309 | 950 | 1324 | 309 | 228 | 1861 | 256 | 1222 | 134 | 1612 | 0 | 370 | 134 | 504 | 228 | 317 | 144 | 689 |
| 14:00 - 15:00 | 201 | 1021 | 106 | 1328 | 0 | 1244 | 127 | 1371 | 127 | 175 | 254 | 556 | 201 | 248 | 244 | 693 | 1244 | 244 | 157 | 1645 | 175 | 1021 | 111 | 1307 | 0 | 248 | 111 | 359 | 157 | 254 | 106 | 517 |
| 15:00 - 16:00 | 164 | 981 | 112 | 1257 | 0 | 986 | 73 | 1059 | 73 | 167 | 192 | 432 | 164 | 184 | 170 | 518 | 986 | 170 | 127 | 1283 | 167 | 981 | 86 | 1234 | 0 | 184 | 86 | 270 | 127 | 192 | 112 | 431 |
| 16:00 - 17:00 | 281 | 1772 | 176 | 2229 | 0 | 1323 | 103 | 1426 | 103 | 223 | 271 | 597 | 281 | 304 | 208 | 793 | 1323 | 208 | 165 | 1696 | 223 | 1772 | 153 | 2148 | 0 | 304 | 153 | 457 | 165 | 271 | 176 | 612 |
| 17:00 - 18:00 | 308 | 1975 | 233 | 2516 | 0 | 1301 | 81 | 1382 | 81 | 324 | 287 | 692 | 308 | 388 | 212 | 908 | 1301 | 212 | 188 | 1701 | 324 | 1975 | 137 | 2436 | 0 | 388 | 137 | 525 | 188 | 287 | 233 | 708 |
| 18:00 - 19:00 | 283 | 2064 | 239 | 2586 | 0 | 1031 | 91 | 1122 | 91 | 208 | 215 | 514 | 283 | 211 | 166 | 660 | 1031 | 166 | 150 | 1347 | 208 | 2064 | 91 | 2363 | 0 | 211 | 91 | 302 | 150 | 215 | 239 | 604 |
| 19:00 - 20:00 | 212 | 1556 | 150 | 1918 | 0 | 785 | 64 | 849 | 64 | 196 | 137 | 397 | 212 | 121 | 149 | 482 | 785 | 149 | 95 | 1029 | 196 | 1556 | 66 | 1818 | 0 | 121 | 66 | 187 | 95 | 137 | 150 | 382 |
| 20:00 - 21:00 | 149 | 917 | 101 | 1167 | 0 | 556 | 48 | 604 | 48 | 120 | 101 | 269 | 149 | 107 | 120 | 376 | 556 | 120 | 73 | 749 | 120 | 917 | 57 | 1094 | 0 | 107 | 57 | 164 | 73 | 101 | 101 | 275 |
| 21:00 - 22:00 | 66 | 807 | 56 | 929 | 0 | 129 | 15 | 144 | 15 | 46 | 35 | 96 | 66 | 32 | 61 | 159 | 129 | 61 | 35 | 225 | 46 | 807 | 26 | 879 | 0 | 32 | 26 | 58 | 35 | 35 | 56 | 126 |
| **Totals** | **3135** | **19071** | **2116** | **24322** | **0** | **19162** | **1343** | **20505** | **1343** | **3157** | **3585** | **8085** | **3135** | **3526** | **3222** | **9883** | **19162** | **3222** | **2393** | **24777** | **3157** | **19071** | **1603** | **23831** | **0** | **3526** | **1603** | **5129** | **2393** | **3585** | **2116** | **8094** |

| | |
|---|---|
| **Total In Bound** | **62313** |
| **Total Out Bound** | **62313** |

## Table 17 - hourly distribution of traffic movements by all approach links at junction No. 56

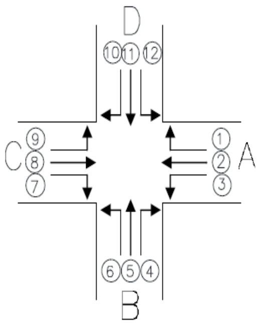



**Hourly Distribution of Traffic Movements By All Approach Links at Junction No 56**

| | Bauddhaloka Mw (From Duplication Road Jn) | | | | | | Galle Rd (From Wellawatta Jn) | | | | | | Galle Rd (From Kollupitiya Jn) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Link "A" | | | | | | Link "B" | | | | | | Link "C" | | | | | |
| | Out Bound | | | In Bound | | | Out Bound | | | In Bound | | | Out Bound | | | In Bound | | |
| Time | 3 | 6 | Total | 1 | 2 | Total | 2 | 5 | Total | 3 | 4 | Total | 1 | 4 | Total | 5 | 6 | Total |
| 06:00 - 07:00 | 0 | 0 | 0 | 468 | 0 | 468 | 0 | 0 | 0 | 0 | 909 | 909 | 468 | 909 | 1377 | 0 | 0 | 0 |
| 07:00 - 08:00 | 0 | 0 | 0 | 1146 | 0 | 1146 | 0 | 0 | 0 | 0 | 1807 | 1807 | 1146 | 1807 | 2953 | 0 | 0 | 0 |
| 08:00 - 09:00 | 0 | 0 | 0 | 1047 | 0 | 1047 | 0 | 0 | 0 | 0 | 1934 | 1934 | 1047 | 1934 | 2981 | 0 | 0 | 0 |
| 09:00 - 10:00 | 0 | 0 | 0 | 1060 | 0 | 1060 | 0 | 0 | 0 | 0 | 1543 | 1543 | 1060 | 1543 | 2603 | 0 | 0 | 0 |
| 10:00 - 11:00 | 0 | 0 | 0 | 826 | 0 | 826 | 0 | 0 | 0 | 0 | 1369 | 1369 | 826 | 1369 | 2195 | 0 | 0 | 0 |
| 11:00 - 12:00 | 0 | 0 | 0 | 1088 | 0 | 1088 | 0 | 0 | 0 | 0 | 1757 | 1757 | 1088 | 1757 | 2845 | 0 | 0 | 0 |
| 12:00 - 13:00 | 0 | 0 | 0 | 1199 | 0 | 1199 | 0 | 0 | 0 | 0 | 1625 | 1625 | 1199 | 1625 | 2824 | 0 | 0 | 0 |
| 13:00 - 14:00 | 0 | 0 | 0 | 1168 | 0 | 1168 | 0 | 0 | 0 | 0 | 2292 | 2292 | 1168 | 2292 | 3460 | 0 | 0 | 0 |
| 14:00 - 15:00 | 0 | 0 | 0 | 1035 | 0 | 1035 | 0 | 0 | 0 | 0 | 1054 | 1054 | 1035 | 1054 | 2089 | 0 | 0 | 0 |
| 15:00 - 16:00 | 0 | 0 | 0 | 727 | 0 | 727 | 0 | 0 | 0 | 0 | 1178 | 1178 | 727 | 1178 | 1905 | 0 | 0 | 0 |
| 16:00 - 17:00 | 0 | 0 | 0 | 1013 | 0 | 1013 | 0 | 0 | 0 | 0 | 1305 | 1305 | 1013 | 1305 | 2318 | 0 | 0 | 0 |
| 17:00 - 18:00 | 0 | 0 | 0 | 1045 | 0 | 1045 | 0 | 0 | 0 | 0 | 1510 | 1510 | 1045 | 1510 | 2555 | 0 | 0 | 0 |
| 18:00 - 19:00 | 0 | 0 | 0 | 788 | 0 | 788 | 0 | 0 | 0 | 0 | 1446 | 1446 | 788 | 1446 | 2234 | 0 | 0 | 0 |
| 19:00 - 20:00 | 0 | 0 | 0 | 686 | 0 | 686 | 0 | 0 | 0 | 0 | 1223 | 1223 | 686 | 1223 | 1909 | 0 | 0 | 0 |
| 20:00 - 21:00 | 0 | 0 | 0 | 513 | 0 | 513 | 0 | 0 | 0 | 0 | 848 | 848 | 513 | 848 | 1361 | 0 | 0 | 0 |
| 21:00 - 22:00 | 0 | 0 | 0 | 311 | 0 | 311 | 0 | 0 | 0 | 0 | 691 | 691 | 311 | 691 | 1002 | 0 | 0 | 0 |
| **Totals** | **0** | **0** | **0** | **14120** | **0** | **14120** | **0** | **0** | **0** | **0** | **22491** | **22491** | **14120** | **22491** | **36611** | **0** | **0** | **0** |

| | |
|---|---|
| **Total In Bound** | **36611** |
| **Total Out Bound** | **36611** |

## Table 18 - hourly distribution of traffic movements by all approach links at junction No. 44



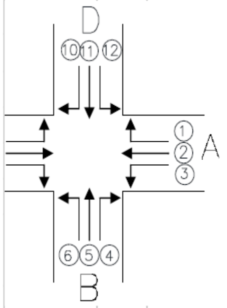

**Technical Assistance for ATMS in Colombo Metropolitan Region**

**Hourly Distribution of Traffic Movements By All Approach Links at Intersection No 44**

| Time | Sri Jayawardanapura Mawatha (From Rajagiriya Jn) Link "A" Out Bound 4 | 8 | 12 | Total | In Bound 1 | 2 | 3 | Total | Sri Jayawardanapura Mawatha (From Kanatta Jn) Link "B" Out Bound 3 | 7 | 11 | Total | In Bound 4 | 5 | 6 | Total | Dr.N. M. Perera Mawatha (From Borella Jn) Link "C" Out Bound 2 | 6 | 10 | Total | In Bound 7 | 8 | 9 | Total | Borella - Rajagiriya Road (From Rajagiriya Jn) Link "D" Out Bound 1 | 5 | 9 | Total | In Bound 10 | 11 | 12 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 06:00 - 07:00 | 633 | 430 | 29 | 1092 | 13 | 234 | 1386 | 1633 | 1386 | 140 | 421 | 1947 | 633 | 97 | 22 | 752 | 234 | 22 | 644 | 900 | 140 | 430 | 364 | 934 | 13 | 97 | 364 | 474 | 644 | 421 | 29 | 1094 |
| 07:00 - 08:00 | 887 | 596 | 38 | 1521 | 35 | 456 | 2038 | 2529 | 2038 | 213 | 637 | 2888 | 887 | 164 | 22 | 1073 | 456 | 22 | 1022 | 1500 | 213 | 596 | 609 | 1418 | 35 | 164 | 609 | 808 | 1022 | 637 | 38 | 1697 |
| 08:00 - 09:00 | 934 | 536 | 12 | 1482 | 19 | 555 | 2452 | 3026 | 2452 | 99 | 543 | 3094 | 934 | 236 | 21 | 1191 | 555 | 21 | 943 | 1519 | 99 | 536 | 617 | 1252 | 19 | 236 | 617 | 872 | 943 | 543 | 12 | 1498 |
| 09:00 - 10:00 | 1302 | 395 | 18 | 1715 | 28 | 585 | 2466 | 3079 | 2466 | 58 | 504 | 3028 | 1302 | 217 | 43 | 1562 | 585 | 43 | 625 | 1253 | 58 | 395 | 559 | 1012 | 28 | 217 | 559 | 804 | 625 | 504 | 18 | 1147 |
| 10:00 - 11:00 | 1285 | 671 | 23 | 1979 | 27 | 348 | 1507 | 1882 | 1507 | 79 | 308 | 1894 | 1285 | 182 | 29 | 1496 | 348 | 29 | 500 | 877 | 79 | 671 | 739 | 1489 | 27 | 182 | 739 | 948 | 500 | 308 | 23 | 831 |
| 11:00 - 12:00 | 980 | 719 | 11 | 1710 | 22 | 397 | 1868 | 2287 | 1868 | 74 | 390 | 2332 | 980 | 229 | 35 | 1244 | 397 | 35 | 553 | 985 | 74 | 719 | 692 | 1485 | 22 | 229 | 692 | 943 | 553 | 390 | 11 | 954 |
| 12:00 - 13:00 | 1399 | 840 | 10 | 2249 | 27 | 358 | 1799 | 2184 | 1799 | 74 | 387 | 2260 | 1399 | 218 | 31 | 1648 | 358 | 31 | 565 | 954 | 74 | 840 | 818 | 1732 | 27 | 218 | 818 | 1063 | 565 | 387 | 10 | 962 |
| 13:00 - 14:00 | 1576 | 1124 | 15 | 2715 | 14 | 271 | 1756 | 2041 | 1756 | 119 | 358 | 2233 | 1576 | 255 | 29 | 1860 | 271 | 29 | 518 | 818 | 119 | 1124 | 1146 | 2389 | 14 | 255 | 1146 | 1415 | 518 | 358 | 15 | 891 |
| 14:00 - 15:00 | 1954 | 807 | 18 | 2779 | 19 | 352 | 1599 | 1970 | 1599 | 121 | 286 | 2006 | 1954 | 201 | 30 | 2185 | 352 | 30 | 430 | 812 | 121 | 807 | 1325 | 2253 | 19 | 201 | 1325 | 1545 | 430 | 286 | 18 | 734 |
| 15:00 - 16:00 | 1287 | 651 | 22 | 1960 | 27 | 333 | 1498 | 1858 | 1498 | 79 | 303 | 1880 | 1287 | 181 | 28 | 1496 | 333 | 28 | 488 | 849 | 79 | 651 | 716 | 1446 | 27 | 181 | 716 | 924 | 488 | 303 | 22 | 813 |
| 16:00 - 17:00 | 1988 | 827 | 19 | 2834 | 17 | 377 | 1513 | 1907 | 1513 | 42 | 299 | 1854 | 1988 | 274 | 30 | 2292 | 377 | 30 | 514 | 921 | 42 | 827 | 883 | 1752 | 17 | 274 | 883 | 1174 | 514 | 299 | 19 | 832 |
| 17:00 - 18:00 | 2267 | 828 | 24 | 3119 | 63 | 405 | 1473 | 1941 | 1473 | 50 | 226 | 1749 | 2267 | 247 | 26 | 2540 | 405 | 26 | 554 | 985 | 50 | 828 | 985 | 1863 | 63 | 247 | 985 | 1295 | 554 | 226 | 24 | 804 |
| 18:00 - 19:00 | 2087 | 790 | 39 | 2916 | 42 | 490 | 1113 | 1645 | 1113 | 41 | 202 | 1356 | 2087 | 220 | 24 | 2331 | 490 | 24 | 284 | 798 | 41 | 790 | 1155 | 1986 | 42 | 220 | 1155 | 1417 | 284 | 202 | 39 | 525 |
| 19:00 - 20:00 | 1904 | 938 | 37 | 2879 | 13 | 310 | 1451 | 1774 | 1451 | 38 | 155 | 1644 | 1904 | 175 | 16 | 2095 | 310 | 16 | 373 | 699 | 38 | 938 | 878 | 1854 | 13 | 175 | 878 | 1066 | 373 | 155 | 37 | 565 |
| 20:00 - 21:00 | 971 | 509 | 19 | 1499 | 8 | 144 | 902 | 1054 | 902 | 36 | 119 | 1057 | 971 | 118 | 16 | 1105 | 144 | 16 | 296 | 456 | 36 | 509 | 468 | 1013 | 8 | 118 | 468 | 594 | 296 | 119 | 19 | 434 |
| 21:00 - 22:00 | 774 | 333 | 5 | 1112 | 9 | 71 | 932 | 1012 | 932 | 10 | 60 | 1002 | 774 | 79 | 7 | 860 | 71 | 7 | 106 | 184 | 10 | 333 | 335 | 678 | 9 | 79 | 335 | 423 | 106 | 60 | 5 | 171 |
| **Totals** | 22228 | 10994 | 339 | 33561 | 383 | 5686 | 25753 | 31822 | 25753 | 1273 | 5198 | 32224 | 22228 | 3093 | 409 | 25730 | 5686 | 409 | 8415 | 14510 | 1273 | 10994 | 12289 | 24556 | 383 | 3093 | 12289 | 15765 | 8415 | 5198 | 339 | 13952 |

| | |
|---|---|
| **Total In Bound** | **96060** |
| **Total Out Bound** | **96060** |

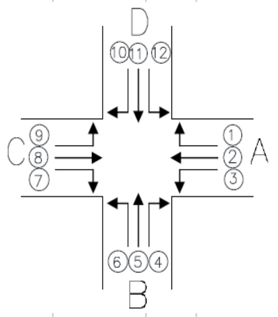
# Table 19 - hourly distribution of traffic movements by all approach links at junction No. 27




| | | | Technical Assistance for ATMS in Colombo Metropolitan Region | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Hourly Distribution of Traffic Movements By All Approach Links at Intersection No 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | Sri Jayawardanapura Mawatha (From Rajagiriya Jn) | | | | | | | | Bauddaloka Mawatha (From Kanatta Jn) | | | | | | | | Dudly Senanayaka Mawatha (From Elvitigala MW Jn) | | | | | | | | Bauddaloka Mawatha (From Dr. N. M. Perera Mw Jn) | | | | | | | | |
| | | | Link "A" | | | | | | | | Link "B" | | | | | | | | Link "C" | | | | | | | | Link "D" | | | | | | | | |
| | | | Out Bound | | | | In Bound | | | | Out Bound | | | | In Bound | | | | Out Bound | | | | In Bound | | | | Out Bound | | | | In Bound | | | |
| Time | | | 4 | 8 | 12 | Total | 1 | 2 | 3 | Total | 3 | 7 | 11 | Total | 4 | 5 | 6 | Total | 2 | 6 | 10 | Total | 7 | 8 | 9 | Total | 1 | 5 | 9 | Total | 10 | 11 | 12 | Total |
| 06:00 | - | 07:00 | 209 | 525 | 0 | 734 | 0 | 640 | 1296 | 1936 | 1296 | 47 | 0 | 1343 | 209 | 58 | 3 | 270 | 640 | 3 | 82 | 725 | 47 | 525 | 22 | 594 | 0 | 58 | 22 | 80 | 82 | 0 | 0 | 82 |
| 07:00 | - | 08:00 | 461 | 939 | 0 | 1400 | 1 | 821 | 1606 | 2428 | 1606 | 159 | 0 | 1765 | 461 | 136 | 12 | 609 | 821 | 12 | 66 | 899 | 159 | 939 | 54 | 1152 | 1 | 136 | 54 | 191 | 66 | 0 | 0 | 66 |
| 08:00 | - | 09:00 | 569 | 803 | 0 | 1372 | 0 | 1259 | 1779 | 3038 | 1779 | 117 | 0 | 1896 | 569 | 137 | 9 | 715 | 1259 | 9 | 95 | 1363 | 117 | 803 | 39 | 959 | 0 | 137 | 39 | 176 | 95 | 0 | 0 | 95 |
| 09:00 | - | 10:00 | 499 | 667 | 0 | 1166 | 0 | 1783 | 2064 | 3847 | 2064 | 73 | 0 | 2137 | 499 | 98 | 4 | 601 | 1783 | 4 | 81 | 1868 | 73 | 667 | 36 | 776 | 0 | 98 | 36 | 134 | 81 | 0 | 0 | 81 |
| 10:00 | - | 11:00 | 678 | 929 | 0 | 1607 | 0 | 949 | 1010 | 1959 | 1010 | 75 | 0 | 1085 | 678 | 140 | 16 | 834 | 949 | 16 | 66 | 1031 | 75 | 929 | 59 | 1063 | 0 | 140 | 59 | 199 | 66 | 0 | 0 | 66 |
| 11:00 | - | 12:00 | 466 | 747 | 0 | 1213 | 1 | 1208 | 1114 | 2323 | 1114 | 104 | 0 | 1218 | 466 | 110 | 21 | 597 | 1208 | 21 | 63 | 1292 | 104 | 747 | 89 | 940 | 1 | 110 | 89 | 200 | 63 | 0 | 0 | 63 |
| 12:00 | - | 13:00 | 870 | 1133 | 0 | 2003 | 0 | 1436 | 1400 | 2836 | 1400 | 114 | 0 | 1514 | 870 | 142 | 30 | 1042 | 1436 | 30 | 85 | 1551 | 114 | 1133 | 99 | 1346 | 0 | 142 | 99 | 241 | 85 | 0 | 0 | 85 |
| 13:00 | - | 14:00 | 1240 | 1073 | 0 | 2313 | 0 | 1311 | 1658 | 2969 | 1658 | 116 | 0 | 1774 | 1240 | 189 | 16 | 1445 | 1311 | 16 | 78 | 1405 | 116 | 1073 | 141 | 1330 | 0 | 189 | 141 | 330 | 78 | 0 | 0 | 78 |
| 14:00 | - | 15:00 | 1132 | 707 | 0 | 1839 | 0 | 1174 | 1337 | 2511 | 1337 | 99 | 0 | 1436 | 1132 | 262 | 10 | 1404 | 1174 | 10 | 76 | 1260 | 99 | 707 | 143 | 949 | 0 | 262 | 143 | 405 | 76 | 0 | 0 | 76 |
| 15:00 | - | 16:00 | 667 | 919 | 0 | 1586 | 0 | 931 | 975 | 1906 | 975 | 73 | 0 | 1048 | 667 | 135 | 15 | 817 | 931 | 15 | 65 | 1011 | 73 | 919 | 57 | 1049 | 0 | 135 | 57 | 192 | 65 | 0 | 0 | 65 |
| 16:00 | - | 17:00 | 871 | 1305 | 0 | 2176 | 0 | 1197 | 970 | 2167 | 970 | 78 | 0 | 1048 | 871 | 173 | 8 | 1052 | 1197 | 8 | 87 | 1292 | 78 | 1305 | 28 | 1411 | 0 | 173 | 28 | 201 | 87 | 0 | 0 | 87 |
| 17:00 | - | 18:00 | 1148 | 1820 | 0 | 2968 | 0 | 1114 | 961 | 2075 | 961 | 67 | 0 | 1028 | 1148 | 232 | 36 | 1416 | 1114 | 36 | 68 | 1218 | 67 | 1820 | 47 | 1934 | 0 | 232 | 47 | 279 | 68 | 0 | 0 | 68 |
| 18:00 | - | 19:00 | 1156 | 1790 | 0 | 2946 | 0 | 754 | 0 | 754 | 0 | 0 | 0 | 0 | 1156 | 208 | 3 | 1367 | 754 | 3 | 34 | 791 | 0 | 1790 | 41 | 1831 | 0 | 208 | 41 | 249 | 34 | 0 | 0 | 34 |
| 19:00 | - | 20:00 | 820 | 1373 | 0 | 2193 | 0 | 566 | 0 | 566 | 0 | 0 | 0 | 0 | 820 | 144 | 3 | 967 | 566 | 3 | 24 | 593 | 0 | 1373 | 42 | 1415 | 0 | 144 | 42 | 186 | 24 | 0 | 0 | 24 |
| 20:00 | - | 21:00 | 405 | 671 | 0 | 1076 | 0 | 485 | 501 | 986 | 501 | 35 | 0 | 536 | 405 | 65 | 8 | 478 | 485 | 8 | 31 | 524 | 35 | 671 | 26 | 732 | 0 | 65 | 26 | 91 | 31 | 0 | 0 | 31 |
| 21:00 | - | 22:00 | 221 | 415 | 0 | 636 | 0 | 491 | 294 | 785 | 294 | 40 | 0 | 334 | 221 | 40 | 4 | 265 | 491 | 4 | 33 | 528 | 40 | 415 | 21 | 476 | 0 | 40 | 21 | 61 | 33 | 0 | 0 | 33 |
| **Totals** | | | 11412 | 15816 | **0** | 27228 | **2** | 16119 | 16965 | 33086 | 16965 | **1197** | **0** | 18162 | 11412 | **2269** | **198** | 13879 | 16119 | **198** | **1034** | 17351 | **1197** | 15816 | **944** | 17957 | **2** | **2269** | **944** | **3215** | **1034** | **0** | **0** | **1034** |

| | |
|---|---|
| **Total In Bound** | **65956** |
| **Total Out Bound** | **65956** |

## Table 20 - hourly distribution of traffic movements by all approach links at junction No.. 46



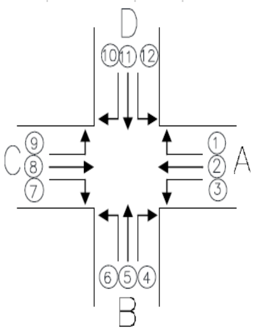

**Technical Assistance for ATMS in Colombo Metropolitan Region**

**Hourly Distribution of Traffic Movements By All Approach Links at Intersection No 46**

| | D S Senanayake Mw (From Kanatta Jn) | | | | | | | | Dudly Senanayake Mw (From Kinsey Rd Jn) | | | | | | | | D S Senanayake Mw (From Borella Jn) | | | | | | | | Dudly Senanayake Mw (From Baudhhaloka Mw Jn) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Link "A" | | | | | | | | Link "B" | | | | | | | | Link "C" | | | | | | | | Link "D" | | | | | | | |
| | Out Bound | | | | In Bound | | | | Out Bound | | | | In Bound | | | | Out Bound | | | | In Bound | | | | Out Bound | | | | In Bound | | | |
| Time | 4 | 8 | 12 | Total | 1 | 2 | 3 | Total | 3 | 7 | 11 | Total | 4 | 5 | 6 | Total | 2 | 6 | 10 | Total | 7 | 8 | 9 | Total | 1 | 5 | 9 | Total | 10 | 11 | 12 | Total |
| 06:00 - 07:00 | 0 | 630 | 29 | 659 | 0 | 581 | 10 | 591 | 10 | 0 | 641 | 651 | 0 | 969 | 22 | 991 | 581 | 22 | 181 | 784 | 0 | 630 | 36 | 666 | 0 | 969 | 36 | 1005 | 181 | 641 | 29 | 851 |
| 07:00 - 08:00 | 0 | 1309 | 30 | 1339 | 0 | 1016 | 16 | 1032 | 16 | 0 | 1310 | 1326 | 0 | 1346 | 22 | 1368 | 1016 | 22 | 262 | 1300 | 0 | 1309 | 41 | 1350 | 0 | 1346 | 41 | 1387 | 262 | 1310 | 30 | 1602 |
| 08:00 - 09:00 | 0 | 1341 | 18 | 1359 | 0 | 1272 | 13 | 1285 | 13 | 0 | 1592 | 1605 | 0 | 861 | 37 | 898 | 1272 | 37 | 269 | 1578 | 0 | 1341 | 60 | 1401 | 0 | 861 | 60 | 921 | 269 | 1592 | 18 | 1879 |
| 09:00 - 10:00 | 0 | 1374 | 18 | 1392 | 0 | 1200 | 22 | 1222 | 22 | 0 | 1559 | 1581 | 0 | 943 | 27 | 970 | 1200 | 27 | 326 | 1553 | 0 | 1374 | 80 | 1454 | 0 | 943 | 80 | 1023 | 326 | 1559 | 18 | 1903 |
| 10:00 - 11:00 | 0 | 1072 | 104 | 1176 | 0 | 862 | 17 | 879 | 17 | 0 | 822 | 839 | 0 | 1035 | 39 | 1074 | 862 | 39 | 191 | 1092 | 0 | 1072 | 83 | 1155 | 0 | 1035 | 83 | 1118 | 191 | 822 | 104 | 1117 |
| 11:00 - 12:00 | 0 | 1216 | 88 | 1304 | 0 | 977 | 21 | 998 | 21 | 0 | 1046 | 1067 | 0 | 1001 | 62 | 1063 | 977 | 62 | 237 | 1276 | 0 | 1216 | 105 | 1321 | 0 | 1001 | 105 | 1106 | 237 | 1046 | 88 | 1371 |
| 12:00 - 13:00 | 0 | 1230 | 95 | 1325 | 0 | 1128 | 20 | 1148 | 20 | 0 | 1061 | 1081 | 0 | 1154 | 65 | 1219 | 1128 | 65 | 264 | 1457 | 0 | 1230 | 110 | 1340 | 0 | 1154 | 110 | 1264 | 264 | 1061 | 95 | 1420 |
| 13:00 - 14:00 | 0 | 1238 | 86 | 1324 | 0 | 949 | 13 | 962 | 13 | 0 | 939 | 952 | 0 | 1318 | 36 | 1354 | 949 | 36 | 276 | 1261 | 0 | 1238 | 84 | 1322 | 0 | 1318 | 84 | 1402 | 276 | 939 | 86 | 1301 |
| 14:00 - 15:00 | 0 | 1330 | 80 | 1410 | 0 | 968 | 13 | 981 | 13 | 0 | 918 | 931 | 0 | 1438 | 54 | 1492 | 968 | 54 | 193 | 1215 | 0 | 1330 | 82 | 1412 | 0 | 1438 | 82 | 1520 | 193 | 918 | 80 | 1191 |
| 15:00 - 16:00 | 0 | 1034 | 101 | 1135 | 0 | 830 | 18 | 848 | 18 | 0 | 824 | 842 | 0 | 1037 | 37 | 1074 | 830 | 37 | 191 | 1058 | 0 | 1034 | 82 | 1116 | 0 | 1037 | 82 | 1119 | 191 | 824 | 101 | 1116 |
| 16:00 - 17:00 | 0 | 1082 | 79 | 1161 | 0 | 841 | 21 | 862 | 21 | 0 | 846 | 867 | 0 | 1204 | 33 | 1237 | 841 | 33 | 191 | 1065 | 0 | 1082 | 76 | 1158 | 0 | 1204 | 76 | 1280 | 191 | 846 | 79 | 1116 |
| 17:00 - 18:00 | 0 | 1035 | 83 | 1118 | 0 | 1007 | 22 | 1029 | 22 | 0 | 846 | 868 | 0 | 1586 | 39 | 1625 | 1007 | 39 | 182 | 1228 | 0 | 1035 | 99 | 1134 | 0 | 1586 | 99 | 1685 | 182 | 846 | 83 | 1111 |
| 18:00 - 19:00 | 0 | 1409 | 337 | 1746 | 0 | 981 | 18 | 999 | 18 | 0 | 658 | 676 | 0 | 1562 | 36 | 1598 | 981 | 36 | 176 | 1193 | 0 | 1409 | 170 | 1579 | 0 | 1562 | 170 | 1732 | 176 | 658 | 337 | 1171 |
| 19:00 - 20:00 | 0 | 1189 | 336 | 1525 | 0 | 812 | 10 | 822 | 10 | 0 | 657 | 667 | 0 | 1122 | 10 | 1132 | 812 | 10 | 125 | 947 | 0 | 1189 | 91 | 1280 | 0 | 1122 | 91 | 1213 | 125 | 657 | 336 | 1118 |
| 20:00 - 21:00 | 0 | 705 | 101 | 806 | 0 | 503 | 11 | 514 | 11 | 0 | 384 | 395 | 0 | 718 | 22 | 740 | 503 | 22 | 83 | 608 | 0 | 705 | 60 | 765 | 0 | 718 | 60 | 778 | 83 | 384 | 101 | 568 |
| 21:00 - 22:00 | 0 | 413 | 75 | 488 | 0 | 337 | 7 | 344 | 7 | 0 | 157 | 164 | 0 | 430 | 17 | 447 | 337 | 17 | 49 | 403 | 0 | 413 | 52 | 465 | 0 | 430 | 52 | 482 | 49 | 157 | 75 | 281 |
| **Totals** | **0** | 17607 | **1660** | 19267 | **0** | 14264 | **252** | 14516 | **252** | **0** | 14260 | 14512 | **0** | 17724 | **558** | 18282 | 14264 | **558** | **3196** | 18018 | **0** | 17607 | **1311** | 18918 | **0** | 17724 | **1311** | 19035 | **3196** | 14260 | **1660** | 19116 |

| | |
|---|---|
| **Total In Bound** | **70832** |
| **Total Out Bound** | **70832** |

## Table 21 - hourly distribution of traffic movements by all approach links at junction No. 38



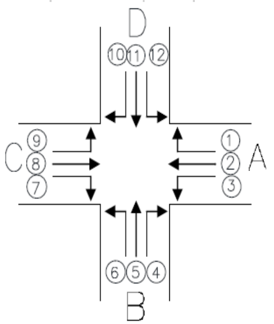

**Technical Assistance for ATMS in Colombo Metropolitan Region**

**Hourly Distribution of Traffic Movements By All Approach Links at Intersection No 38**

| | Sri Sumanatissa Mw. (From Panchikawatta) | | | | | | | | M J M Lafeer Mw. | | | | | | | | Sri Sumanatissa Mw. (From Armour Street Jn) | | | | | | | | M Vincent Perera Mw. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Link "A" | | | | | | | | Link "B" | | | | | | | | Link "C" | | | | | | | | Link "D" | | | | | | | |
| | Out Bound | | | | In Bound | | | | Out Bound | | | | In Bound | | | | Out Bound | | | | In Bound | | | | Out Bound | | | | In Bound | | | |
| Time | 4 | 8 | 12 | Total | 1 | 2 | 3 | Total | 3 | 7 | 11 | Total | 4 | 5 | 6 | Total | 2 | 6 | 10 | Total | 7 | 8 | 9 | Total | 1 | 5 | 9 | Total | 10 | 11 | 12 | Total |
| 6:00 - 7:00 | 67 | 45 | 33 | 145 | 33 | 692 | 56 | 781 | 56 | 45 | 272 | 373 | 67 | 153 | 30 | 250 | 692 | 30 | 115 | 837 | 45 | 45 | 39 | 129 | 33 | 153 | 39 | 225 | 115 | 272 | 33 | 420 |
| 7:00 - 8:00 | 244 | 83 | 202 | 529 | 203 | 1172 | 96 | 1471 | 96 | 83 | 294 | 473 | 244 | 551 | 45 | 840 | 1172 | 45 | 237 | 1454 | 83 | 83 | 91 | 257 | 203 | 551 | 91 | 845 | 237 | 294 | 202 | 733 |
| 8:00 - 9:00 | 206 | 98 | 173 | 477 | 173 | 1153 | 122 | 1448 | 122 | 98 | 416 | 636 | 206 | 359 | 31 | 596 | 1153 | 31 | 287 | 1471 | 98 | 98 | 99 | 295 | 173 | 359 | 99 | 631 | 287 | 416 | 173 | 876 |
| 9:00 - 10:00 | 172 | 119 | 165 | 456 | 165 | 1088 | 159 | 1412 | 159 | 119 | 397 | 675 | 172 | 422 | 17 | 611 | 1088 | 17 | 316 | 1421 | 119 | 119 | 180 | 418 | 165 | 422 | 180 | 767 | 316 | 397 | 165 | 878 |
| 10:00 - 11:00 | 209 | 96 | 161 | 466 | 161 | 842 | 132 | 1135 | 132 | 96 | 280 | 508 | 209 | 445 | 34 | 688 | 842 | 34 | 231 | 1107 | 96 | 96 | 119 | 311 | 161 | 445 | 119 | 725 | 231 | 280 | 161 | 672 |
| 11:00 - 12:00 | 269 | 126 | 225 | 620 | 225 | 1121 | 283 | 1629 | 283 | 126 | 334 | 743 | 269 | 416 | 48 | 733 | 1121 | 48 | 293 | 1462 | 126 | 126 | 119 | 371 | 225 | 416 | 119 | 760 | 293 | 334 | 225 | 852 |
| 12:00 - 13:00 | 306 | 143 | 196 | 645 | 196 | 1078 | 252 | 1526 | 252 | 143 | 236 | 631 | 306 | 415 | 28 | 749 | 1078 | 28 | 265 | 1371 | 143 | 143 | 104 | 390 | 196 | 415 | 104 | 715 | 265 | 236 | 196 | 697 |
| 13:00 - 14:00 | 320 | 152 | 164 | 636 | 162 | 929 | 122 | 1213 | 122 | 152 | 325 | 599 | 320 | 530 | 32 | 882 | 929 | 32 | 314 | 1275 | 152 | 152 | 149 | 453 | 162 | 530 | 149 | 841 | 314 | 325 | 164 | 803 |
| 14:00 - 15:00 | 359 | 120 | 222 | 701 | 222 | 1185 | 143 | 1550 | 143 | 120 | 369 | 632 | 359 | 532 | 27 | 918 | 1185 | 27 | 291 | 1503 | 120 | 120 | 150 | 390 | 222 | 532 | 150 | 904 | 291 | 369 | 222 | 882 |
| 15:00 - 16:00 | 159 | 73 | 129 | 361 | 129 | 706 | 101 | 936 | 101 | 73 | 208 | 382 | 159 | 328 | 26 | 513 | 706 | 26 | 173 | 905 | 73 | 73 | 90 | 236 | 129 | 328 | 90 | 547 | 173 | 208 | 129 | 510 |
| 16:00 - 17:00 | 213 | 93 | 241 | 547 | 241 | 1095 | 118 | 1454 | 118 | 93 | 302 | 513 | 213 | 462 | 28 | 703 | 1095 | 28 | 236 | 1359 | 93 | 93 | 129 | 315 | 241 | 462 | 129 | 832 | 236 | 302 | 241 | 779 |
| 17:00 - 18:00 | 275 | 102 | 201 | 578 | 201 | 1485 | 135 | 1821 | 135 | 102 | 255 | 492 | 275 | 627 | 53 | 955 | 1485 | 53 | 279 | 1817 | 102 | 102 | 195 | 399 | 201 | 627 | 195 | 1023 | 279 | 255 | 201 | 735 |
| 18:00 - 19:00 | 257 | 123 | 175 | 555 | 174 | 1511 | 131 | 1816 | 131 | 123 | 237 | 491 | 257 | 747 | 27 | 1031 | 1511 | 27 | 265 | 1803 | 123 | 123 | 161 | 407 | 174 | 747 | 161 | 1082 | 265 | 237 | 175 | 677 |
| 19:00 - 20:00 | 173 | 90 | 171 | 434 | 171 | 1224 | 100 | 1495 | 100 | 90 | 257 | 447 | 173 | 679 | 53 | 905 | 1224 | 53 | 229 | 1506 | 90 | 90 | 142 | 322 | 171 | 679 | 142 | 992 | 229 | 257 | 171 | 657 |
| 20:00 - 21:00 | 136 | 55 | 99 | 290 | 99 | 155 | 68 | 322 | 68 | 55 | 176 | 299 | 136 | 283 | 33 | 452 | 155 | 33 | 122 | 310 | 55 | 55 | 75 | 185 | 99 | 283 | 75 | 457 | 122 | 176 | 99 | 397 |
| 21:00 - 22:00 | 94 | 51 | 78 | 223 | 78 | 391 | 46 | 515 | 46 | 51 | 148 | 245 | 94 | 213 | 30 | 337 | 391 | 30 | 92 | 513 | 51 | 51 | 70 | 172 | 78 | 213 | 70 | 361 | 92 | 148 | 78 | 318 |
| **Totals** | **3459** | **1569** | **2635** | **7663** | **2633** | **15827** | **2064** | **20524** | **2064** | **1569** | **4506** | **8139** | **3459** | **7162** | **542** | **11163** | **15827** | **542** | **3745** | **20114** | **1569** | **1569** | **1912** | **5050** | **2633** | **7162** | **1912** | **11707** | **3745** | **4506** | **2635** | **10886** |

| | |
|---|---|
| **Total Out Bound** | **47623** |
| **Total In Bound** | **47623** |

## Table 22 - hourly distribution of traffic movements by all approach links at junction No. 58




**Technical Assistance for ATMS in Colombo Metropolitan Region**

**Hourly Distribution of Traffic Movements By All Approach Links at Intersection No 58**

| | R A De Mel Mw (From Kollupitiya) | | | | | | | | Bauddhaloka Mw (From Thunmulla Jn) | | | | | | | | R A De Mel Mw (From Wellawatta ) | | | | | | | | Bauddhaloka Mw (From Bambalapitiya Jn) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Link "A" | | | | | | | | Link "B" | | | | | | | | Link "C" | | | | | | | | Link "D" | | | | | | | |
| | Out Bound | | | | In Bound | | | | Out Bound | | | | In Bound | | | | Out Bound | | | | In Bound | | | | Out Bound | | | | In Bound | | | |
| Time | 4 | 8 | 12 | Total | 1 | 2 | 3 | Total | 3 | 7 | 11 | Total | 4 | 5 | 6 | Total | 2 | 6 | 10 | Total | 7 | 8 | 9 | Total | 1 | 5 | 9 | Total | 10 | 11 | 12 | Total |
| 06:00 - 07:00 | 0 | 0 | 0 | 0 | 46 | 466 | 82 | 594 | 82 | 0 | 0 | 82 | 0 | 268 | 198 | 466 | 466 | 198 | 0 | 664 | 0 | 0 | 0 | 0 | 46 | 268 | 0 | 314 | 0 | 0 | 0 | 0 |
| 07:00 - 08:00 | 0 | 0 | 0 | 0 | 97 | 996 | 413 | 1506 | 413 | 0 | 0 | 413 | 0 | 772 | 247 | 1019 | 996 | 247 | 0 | 1243 | 0 | 0 | 0 | 0 | 97 | 772 | 0 | 869 | 0 | 0 | 0 | 0 |
| 08:00 - 09:00 | 0 | 0 | 0 | 0 | 98 | 1113 | 656 | 1867 | 656 | 0 | 0 | 656 | 0 | 803 | 282 | 1085 | 1113 | 282 | 0 | 1395 | 0 | 0 | 0 | 0 | 98 | 803 | 0 | 901 | 0 | 0 | 0 | 0 |
| 09:00 - 10:00 | 0 | 0 | 0 | 0 | 104 | 1252 | 497 | 1853 | 497 | 0 | 0 | 497 | 0 | 496 | 246 | 742 | 1252 | 246 | 0 | 1498 | 0 | 0 | 0 | 0 | 104 | 496 | 0 | 600 | 0 | 0 | 0 | 0 |
| 10:00 - 11:00 | 0 | 0 | 0 | 0 | 74 | 1002 | 494 | 1570 | 494 | 0 | 0 | 494 | 0 | 588 | 243 | 831 | 1002 | 243 | 0 | 1245 | 0 | 0 | 0 | 0 | 74 | 588 | 0 | 662 | 0 | 0 | 0 | 0 |
| 11:00 - 12:00 | 0 | 0 | 0 | 0 | 115 | 1028 | 233 | 1376 | 233 | 0 | 0 | 233 | 0 | 574 | 222 | 796 | 1028 | 222 | 0 | 1250 | 0 | 0 | 0 | 0 | 115 | 574 | 0 | 689 | 0 | 0 | 0 | 0 |
| 12:00 - 13:00 | 0 | 0 | 0 | 0 | 122 | 1098 | 823 | 2043 | 823 | 0 | 0 | 823 | 0 | 900 | 314 | 1214 | 1098 | 314 | 0 | 1412 | 0 | 0 | 0 | 0 | 122 | 900 | 0 | 1022 | 0 | 0 | 0 | 0 |
| 13:00 - 14:00 | 0 | 0 | 0 | 0 | 75 | 1092 | 807 | 1974 | 807 | 0 | 0 | 807 | 0 | 867 | 276 | 1143 | 1092 | 276 | 0 | 1368 | 0 | 0 | 0 | 0 | 75 | 867 | 0 | 942 | 0 | 0 | 0 | 0 |
| 14:00 - 15:00 | 0 | 0 | 0 | 0 | 94 | 812 | 629 | 1535 | 629 | 0 | 0 | 629 | 0 | 779 | 279 | 1058 | 812 | 279 | 0 | 1091 | 0 | 0 | 0 | 0 | 94 | 779 | 0 | 873 | 0 | 0 | 0 | 0 |
| 15:00 - 16:00 | 0 | 0 | 0 | 0 | 63 | 836 | 421 | 1320 | 421 | 0 | 0 | 421 | 0 | 508 | 211 | 719 | 836 | 211 | 0 | 1047 | 0 | 0 | 0 | 0 | 63 | 508 | 0 | 571 | 0 | 0 | 0 | 0 |
| 16:00 - 17:00 | 0 | 0 | 0 | 0 | 74 | 1334 | 760 | 2168 | 760 | 0 | 0 | 760 | 0 | 707 | 281 | 988 | 1334 | 281 | 0 | 1615 | 0 | 0 | 0 | 0 | 74 | 707 | 0 | 781 | 0 | 0 | 0 | 0 |
| 17:00 - 18:00 | 0 | 0 | 0 | 0 | 80 | 1370 | 903 | 2353 | 903 | 0 | 0 | 903 | 0 | 680 | 333 | 1013 | 1370 | 333 | 0 | 1703 | 0 | 0 | 0 | 0 | 80 | 680 | 0 | 760 | 0 | 0 | 0 | 0 |
| 18:00 - 19:00 | 0 | 0 | 0 | 0 | 50 | 1474 | 671 | 2195 | 671 | 0 | 0 | 671 | 0 | 566 | 335 | 901 | 1474 | 335 | 0 | 1809 | 0 | 0 | 0 | 0 | 50 | 566 | 0 | 616 | 0 | 0 | 0 | 0 |
| 19:00 - 20:00 | 0 | 0 | 0 | 0 | 27 | 1130 | 372 | 1529 | 372 | 0 | 0 | 372 | 0 | 732 | 228 | 960 | 1130 | 228 | 0 | 1358 | 0 | 0 | 0 | 0 | 27 | 732 | 0 | 759 | 0 | 0 | 0 | 0 |
| 20:00 - 21:00 | 0 | 0 | 0 | 0 | 48 | 690 | 218 | 956 | 218 | 0 | 0 | 218 | 0 | 321 | 185 | 506 | 690 | 185 | 0 | 875 | 0 | 0 | 0 | 0 | 48 | 321 | 0 | 369 | 0 | 0 | 0 | 0 |
| 21:00 - 22:00 | 0 | 0 | 0 | 0 | 21 | 616 | 145 | 782 | 145 | 0 | 0 | 145 | 0 | 207 | 160 | 367 | 616 | 160 | 0 | 776 | 0 | 0 | 0 | 0 | 21 | 207 | 0 | 228 | 0 | 0 | 0 | 0 |
| **Totals** | **0** | **0** | **0** | **0** | **1188** | **16309** | **8124** | **25621** | **8124** | **0** | **0** | **8124** | **0** | **9768** | **4040** | **13808** | **16309** | **4040** | **0** | **20349** | **0** | **0** | **0** | **0** | **1188** | **9768** | **0** | **10956** | **0** | **0** | **0** | **0** |

| | |
|---|---|
| **Total In Bound** | **39429** |
| **Total Out Bound** | **39429** |