University of Southern Queensland

Faculty of Engineering and Surveying

A Study and Evaluation on SMART Project, Malaysia

A dissertation submitted by

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Abstract

A tunnel is a passage way that carries people or vehicle to across a destination that have obstruction or to shorten the travelling time. Tunnels in the olden days are used for mainly mining works. In the recent years as technology evolve with time, tunnels construction had become more commonly used transport routes in places that alternative solution such as roads or bridges impossible to be built or the costing is higher since there are obstruction to be accounted for in order to built the necessary routes. Tunnels are also used as rails links, vehicles and also as canals for water diversion. Most tunnels are built through a hill or mountain and underground below cities, roads, ocean or rivers. The constructions of tunnels are very complex because it involves precise and accurate planning. Tunnel construction depends mainly on geological study of the sub-surface before determining the type of construction method and costing involves. This is because the type of soil formation will determine the structural needs, types of machineries, suitability for that particular location to construct the tunnel and also the environmental impact on the society and the natural surrounding especially the sub-surface of the soils (e.g. underground streams and the stability of the soil).

Tunnels are constructed all around in the world as the method of construction is getting more advances and this allows the tunnels that are impossible to build are now done. This thesis is mainly a study on the SMART Tunnel Project that is under construction in Malaysia. This tunnel is very unique because this is one of a kind tunnel in the world that combines the wet and dry system. The tunnel is used as a pathway to transport vehicle and also a channel for stormwater diversion from the city of Kuala Lumpur. The system is very unique as the tunnel is built using two Slurry Shield TBM machines that allows the drilling and tunnel lining work to be done continuously without setbacks. The machine also eliminates the hazard of tunnel stability during construction and also the ground water drawdown that cause sink holes. The entire thesis is about the tunnel construction method, technology used, tunnel design, purpose and efficiency of the tunnel.

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Certification

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The study undertaken on the SMART Project that is located in Malaysia is very beneficial especially in the development of the transportation system in urban areas such as Kuala Lumpur city. The study is complicated as this thesis is to evaluate and study the detail construction method, material used, technology adopted and also to evaluate the effectiveness of the tunnel. I would like to take this opportunity to express my gratitude to the SMART Tunnel Project Management Team, Department of Sanitation and Irrigation, Malaysian Highway Authority and also the Malaysian Meteorological Department for their support during the overall duration of this research project.

Lastly, I sincerely express my gratitude to my family and friends for their encouragement and support throughout this research project as their encouragement and support are my motivation throughout the years of my study.

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List of Abbreviations

SMART	Stormwater Management and Road Tunnel
TBM	Tunnel Boring Machine
Sg. Besi	Sungai Besi (Besi River)
Sg. Kerayong	Sungai Kerayong (Kerayong River)
Sg. Gombak	Sungai Gombak (Gombak River)
Sg. Klang	Sungai Klang (Klang River)
LLM	Lembaga Lebuhraya Malaysia (Malaysian Highway Authority)
MMC	Malaysian Mining Corporation

Chapter 1: Introduction

1.1 SMART Project

SMART is the acronym for "Stormwater Management and Road Tunnel Project. This project is located in Kuala Lumpur the capital metropolitan city of Malaysia. Malaysia is located in the South East Asia in the equatorial climate region. The project was initiated by the Former Prime Minister Tun Dr. Mahatir Mohammad under the Malaysian Development Plan. The project is undertaken as a joint venture projects the government and the private sector corporation.

The government department involved in this project are the Department of Irrigation and Drainage Malaysia and Malaysian Highway Authority. The private sectors are MMC Berhad and GAMUDA Berhad. This project is done under close supervision of the above government department includes local consultants Sepakat Perunding Sdn Bhd in association with Mott MacDonald from United Kingdom.

Source: SMART Management Team, 2005

Figure 1a: SMART System

1.2 SMART Project Objective

The two major criteria that influenced the project are;

- To solve the frequent flash flood in the Kula Lumpur City Centre
- To solve the traffic congestion at Sungai Besi, Kula Lumpur Southern Gateway

Source: The Star, 2005

Figure 1b: Flash Flood in Kuala Lumpur City

1.3 Research Project Objective

- To conduct a study on the construction of the SMART Project.
  ~This project is very different because it is one of the kinds in Malaysia and world. This project is designed to reduce flood and traffic situation in Kuala Lumpur using underground tunnel system

- To adopt the new technology used in this project.
  ~ The technology used in this project is something new to me and the Civil Engineering industry in Malaysia. Underground tunnelling projects are very rarely done in Malaysia and I wish to take this opportunity to study this project.

- To learn the new materials used and construction method in this project.
  ~ The construction method is new to the industry as it uses tunnel boring machines that reduces water draw drawn that normally creates sink holes above ground. This is very crucial to this project as most of the route of the tunnel is on existing roads and buildings. This can overcome and sink holes mishaps that can cause any tragedy.

- To identify and analyse the causes of frequent flooding in the city centre.

- Analyze the impact on the environment and the society surrounding this project

- Research the effectiveness and the purpose of this project in solving the major flooding problem during monsoon season (peak rainy season) and traffic congestion

- Identification of problems caused and factors contributing to the problem during and after constructing this tunnel.

1.4 Scope of Work

The Smart Project works consists of three major parts, there are:

- A Bypass tunnel of 9.7km in length are to be constructed underground from upstream of the Klang River in Kampung Berendam, Ampang reaching southward and will end at the ex-mining pond in Taman Desa.

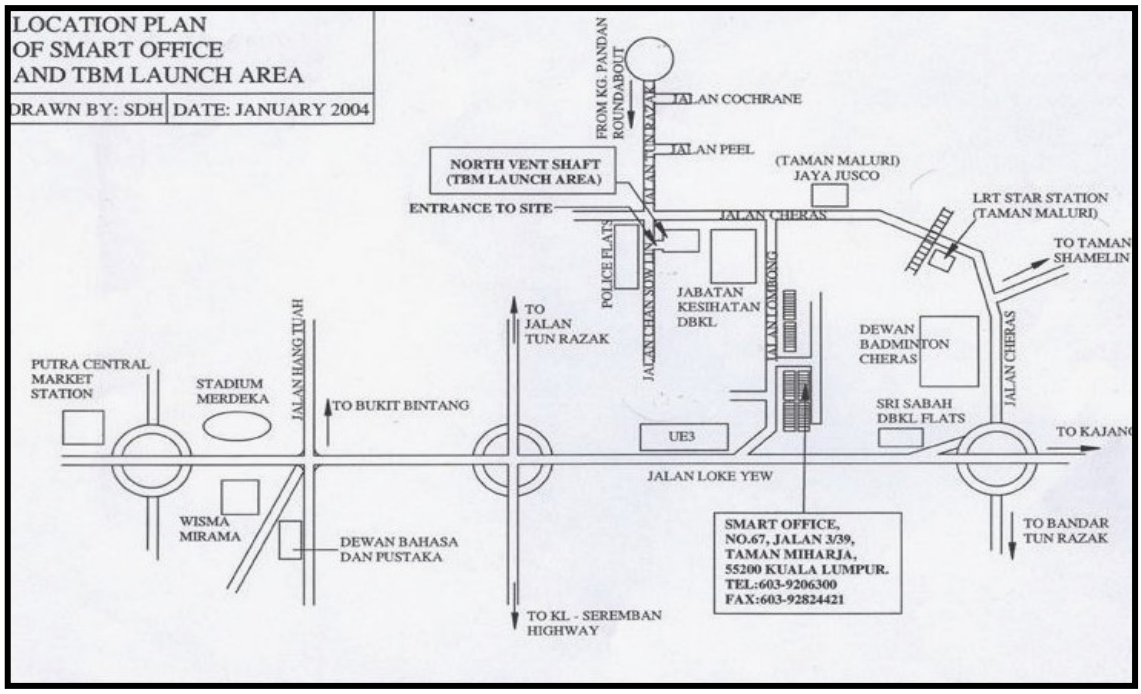
Figure 1c: SMART Tunnel boring works in progress

- Another aspect of the tunnel is the stormwater management part that consists of:
  - The construction of the holding basin in kampong Berendam
  - The upgrading of an ex-mining pond in Taman Desa as a storage reservoir
  - The construction of a twin box culvert outlet structure from the Taman Desa Pond to Kerayong River.
  - The construction of related control gates structures.

  After the project is completed, the pond and the bypass tunnel will have the capacity to store 1 million cubic metres of flood water. This number is more than 50% capacity of the current system.

- The tunnel will be divided into two categories that are the stormwater drainage system and the road tunnel for vehicles. The road tunnel will be of 3km in length will integrate both flood mitigation and motorway purposes. This dual usage portion begins from The Kampung Pandan roundabout and ended at the Kula Lumpur- Seremban Highway near Istana Road junction. The motorway consists of double decked carriageway in the tunnel. The ingress and egress to the existing roadway system are connected to Tun Razak Road(1.4km) an to the KL- Seremban Highway(1.6km)

- There is also a flood detection system will be integrated in the SMART system to manage traffic control operation and flood forecasting.



Source: SMART Management Team, 2005

Figure 1d: Route map of the SMART Project

1.5 Financial Status

The SMART Project is expected to be worth 2.5 billion Ringgit Malaysia. The Project is specially constructed to channel the excess flood water away from the city at a shortest period of time. The company involved in this project are GAMUDA Berhad with the joint venture of MMC Engineering Group with the supervision and Quality Control by the Department of Sanitation and Irrigation and Malaysian Highway Authority, Government of Malaysia. The project is started as part of the development project under 8th Malaysian Plan to ease to up rise of the frequent flooding in the heart of the city.

GAMUDA Berhad will design the tunnels, engineering works, procurement, construction, installation, testing and commissioning of this integrated bypass tunnel (KUKTEM Report, 2004).

Tunnel Boring Machine that will be used in the tunnel coring works will be delivered to Malaysia from Wayss & Freytagg and BAM NBM from the Netherlands had secured the procurement worth 83 million Ringgit Malaysia from the clients, contractors that are Malaysian Mining Corporation (MMC) for the 5.4 km of the section with of the project. The model of Tunnel Boring Machine is Herrenknecht Mixshield will be used and the specification is in (Table 1a, Pg 8).

The remaining 1.7km that is designated for the double function is part of the 4.3km north tunnel section that will be constructed by MMC and GAMUDA.

This part of the tunnel will be constructed using a second TBM machine that will be delivered by the Wayss & Freytagg and BAM NBM (KUKTEM Report, 2004).

Most of the tunnel concrete works will be done with the use of precast technology. ACP Industries has secured the supply of the precast concrete segmental lining from Wayss & Freytag worth 51.2 million Ringgit Malaysia. The junction box for the ventilation shafts at the end of 2.4.km dual-purpose stretch, where the concrete segments are supplied by Kecom Sdn Bhd, the Malaysian Branch of KEC Ltd of Korea (KUKTEM Report, 2004).

Description	**TBM No. 1(North Drive)**	**TBM No.2 (South Drive)**
TBM Fabrication	Feb 2003-Nov 2003	March 2003-Feb 2004
Factory Acceptance	Nov 2003	Feb 2004
Shipping to Malaysia	Dec 2003-Feb 2004	March 2004-May 2004
Assembly of TBM in Malaysia	Feb 2004-May 2004	May 2004-Aug 2004
Testing & Commissioning	May 2004-July 2004	Aug 2004-Oct 2004
Tunnel Boring	July 2004-June2006	Oct 2004-May 2006
TBM Originated	Germany	Germany

Source: SMART Management Team, 2005

Table 1a: TBM Arrival and Launch Schedule

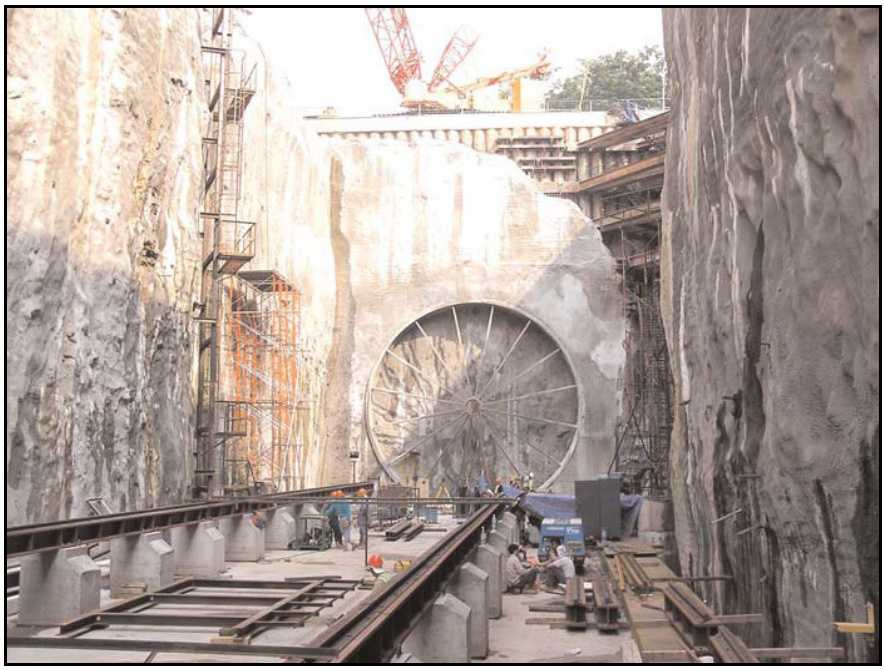


Figure 1e: TBM used in SMART Project at South Junction Box

1.6 Importance of the Project

The project was specifically started because of the frequent flooding in the metropolitan city because of the current drainage system could not cater the increment of the yearly rainwater in the city. The city is located in the valley there for drainage system is very important to channel the water out to the nearby stream. Currently the water is channelled into the Klang and Gombak River that is passing thru the city.

These are the two important rivers that brought up the city. Kuala Lumpur is the capital city of Malaysia that is developing into a major business, administration, education and living hub. The project mainly initiated after numerous studies conducted in Klang River that proves the confluence of the Klang River/Ampang River and also Klang River/ Gombak River is at the critical level and the river is prone the flash floods includes all the surrounding vicinity. This process is further worsened by the existing Tun Perak Bridge at the corner Masjid Jamek which causes the flash flood to happen almost frequently after heavy rain fall in the city.

To overcome this problem a new water channel is needed to overcome the frequent flash floods in the city. SMART Project was the solution to overcome the problem. This system will divert excess stormwater away from the existing water catchments area that is the Ampang/Klang River through a holding pond, a bypass tunnel and a storage reservoir before it will released back into the Klang River. This is one of the proper solutions to solve this problem because the existing rivers could not cater the large amount of water during heavy storm.

Another major task of the SMART Project is to reduce the traffic congestion at The Kuala Lumpur's southern gateway. A portion of the tunnel about 3km will be a dual-usage, which is the stormwater management and road tunnel. This portion of the tunnel starts from Kampung Pandan roundabout and ends at the Kuala Lumpur-Seremban Highway near the Istana Road junction.

1.7 Tunnel Construction Details (Overview)

The underground geology studies show that Kuala Lumpur city centre is actually located on the Karstic Limestone. This type of soil geology contains high water table content and within this formation lays cliffs, pinnacles, cavities, collapsed cavities and occurrences in the city. The TBM specifications are as follows:

Cover Length	10.245m
Cover Weight	1500 Tonnes
Overall Length	70m
Overall Weight	2500 Tonnes
Cutterhead Diameter	13.26m
Maximum Speed	30mm/min
Minimum Steering Diameter	200m
Total Power Supplied	8200kVa
Cutterhead's Electric Power	4000kW

Source: SMART Project Management Team, 2005

Table 1b: Tunnel Boring Machine (TBM) Details

Figure 1f: Reinforcement work at upper deck

Chapter 2: Literature Review

2.1 Tunnels

Underground tunnels in early days are used especially in mining. Tunnelling and mining are together since beginning of the industry. Before mining, tunnels in ancient history were used for water carriage in underground. In cities such as ancient Rome, tunnels were designed to carry water supply from aqueduct nearby. The technology of tunnelling advanced from ancient days until now. Sometimes tunnelling becomes most soluble solution, but constructing tunnels are still under major studies because we need to upgrade the design according to time and needs.

The development rock tunnelling is influenced by these major parts. There are rock drilling machine, drill bits, and explosives (Megaw & Bartlett, 1981). When the scientist from China invented the gun powder, it gave way to new methods for tunnelling work to presume. Gunpowder since that has advanced into more severe usage in the tunnelling industry. Gunpowder gave way to much more powerful nitro-glycerine, quickly followed by dynamite, introduced by Nobel in 1967(Megaw & Bartlett, 1981). In rock drilling, compressed air became the accepted motive power, although the usage of the hydraulic powered machines was preferred for a time period commonly in Europe.

The use of explosive in hard layer is common in order to blast through the hard surface. Blasting is one of the easiest methods in tunnel construction, but there are weakness such as the safety and problems of excessive caving in of the layer. There are different types of tunnels constructed from different soil layer or location, such as:

- Soft ground
- Hard Rock
- Underwater

Tunnels also are the major solution for the purpose of pedestrian crossing, general road traffic, for the usage of the vehicles, railway links and also for canals. Most of the tunnels are designed and constructed specifically for carrying water for daily consumption, for the purpose of generating electricity such as the hydroelectric or as sewers for major cities to ease the flooding problems and for telecommunication cables. Brunel's great Thames Tunnel is the first tunnel that was ever built to cross under a tidal river and the first shield driven tunnel (Labor Law Talk Encyclopedia, 2005).

Tunnels are usually constructed in different type of ground soil layers that varies from soft clay to hard rock layer. In soft clay layer the tunnel digging are done using New Austrian Tunnelling Method (NATM) and in hard layers Tunnel Boring Machine (TBM) are used widely ((Megaw & Bartlett, 1981).

2.2 History of Tunnels

a) The Atlantic Avenue Tunnel, Brooklyn, New York that was built in late 1844 by cut and covers method for the Long Island Rail Road. This is New York's oldest underground tunnel for rail link (Labor Law Talk Encyclopedia, 2005).

b) The Channel Tunnel between France and England under the English Channel is the second longest tunnel in the world with a total length of 50km, out of which 39km are under the sea (Labor Law Talk Encyclopedia, 2005)

c) The Thames Tunnel was built by Marc Isambard Brunnel together with his son Isambard Kingdom Brunnel which was completed and inaugurated in 1843. This is the first underwater tunnel and also the first tunnel using the tunnelling shield (Wikipedia, 2005).

Source: Wikipedia, 2005

Figure 2a: Interior of the Thames Tunnel, London, 1943

c) The North Cape Tunnel in Norway that was opened in 1999 is one of the world longest undersea road tunnels. It connects the island of Mageroya with the main land that spans around 7km and reaches the depth of 212m below sea level. The construction period was around 4years from 1995 to 1999(Labor Law Talk Encyclopedia, 2005).

2.3 Tunneling Technologies

2.3.1 Tunnel Design

In the real world, as we know tunnelling is one of the common solution to solve the design problems in are such as existing cities with a lot of obstruction or heritage path, in nature such as mountain areas, cross the channel or ocean ant other basic obstructions. All this had an influence on the development of tunnelling technologies in the recent years. Tunnelling can be back dated to the early days such as discussed in section 2.2 above.

There are some common characteristic that had to be considered when considering in the area of tunnelling. The entire factor below will finally decide the suitable construction method in that area to complete the tunnel project (O.Kusakabe, K.Fujita, & Y. Miyaki, 1999). The key factors are:

- The environmental condition, geotechnical and hydrogeological characteristics of the soil layers.
- The impact of the construction of tunnels to the underground utilities and on the surface such as streets and buildings.
- Availability of possible surface traffic for all vehicles or traffic control.
- The cost of tunnel, the technical aspect, and the construction time schedule of the tunnel.

2.3.2 Cut and Cover Tunnel

In constructing tunnel using the cut and cover method, the shape of tunnel will usually be rectangular and stations and the followings are the basic technologies been used:

- Reinforced concrete walls with steel struts, pre-stressed tie-backs or self supported.
- The ground water in the soil is lowered by introducing the water well systems.

The diaphragm of the tunnel installed using machineries and the bottom depth ranges from 20-30m below ground surface. Then the well is to eliminate water, it will be placed inside or outside the excavation (O.Kusakabe, K.Fujita, & Y. Miyaki, 1999).

2.3.3 TBM Technologies

The Tunnel Boring Machine (TBM) was introduced in 1975. The transport and evacuation of the excavated mucks and the mounting the reinforced concrete lining was done using this machine. Since then the technology has developed widely. For instance for 1m tunnel, the technology comprises;

- The excavation phase and the TBM advance.
- The pre-casted concrete segmental lining is erected.
- Soil grouting and water proofing works outside the lining ring.

The TBM is launched in larger tunnels that later were used as the water pumping station or ventilation shafts (O.Kusakabe, K.Fujita, & Y. Miyaki, 1999)

2.4 Underground Road Tunnels

Development of countries had brought new technologies particularly on engineering design. Innovation in engineering also plays a major role in upgrading existing services and invention of infrastructures such as long bridges. tunnels, skyscrapers and etc. Road tunnels development are actually very famous in Europe compare to Asia. But currently it is getting more attention in Asia as there are numerous advantages from this type of development. There are different types of road tunnels development in the world such as:

The following are some of the tunnels in the world

Country	Tunnel Name	Length (m)
Norway	Laerdal	24510
China	Zhongnanshan	18040
Switzerland	St. Gotthard / San Gottardo	16918
Austria	Arlberg	13972
France-Italy	Frejus	12895
Norway	Gudvanga	11428
France	Le Tunnel Est	10000

Source: The World's Longest Tunnel, 2002

Source: The World's Longest Tunnel, 2002

Figure 2b: Laerdal Tunnel, Norway

In Malaysia, the use of road tunnels are very less compare to other European countries. There are numerous tunnels such as The North-South Expressway Tunnels (Jelapang) and currently SMART Tunnel. Penchala Tunnel is the first breakthrough in tunneling technologies in Malaysia, when the government joint ventured with GAMUDA Berhad to construct the 710m long tunnel

Source: LLM, 2005

Figure 2c: Penchala Tunnel, Malaysia

2.5 Tunnels as Stormwater Sewers

Stormwater sewers are defined as storm drains. Most major cities around the world are using sewer system to transport rainwater to nearby outlet such as stream or rivers. Storm sewers are large structure or pipes that transport water runoff from streets to natural water source such as stream and rivers. Commonly catch basins are provided in order to store the water before gradually releasing it into natural source. The catch basin also functions as the trap for water floating debris such as rubbish, sands and other unwanted materials that not suppose to be in the natural rivers.

Some storm sewers are treated and some are not treated. This depends on area and jurisdiction. Treatment of water helps to clean and purify the water in order to release in the natural rivers. This is very important as every engineering structures or planning have to consider the environmental issues as one of the priority status.

2.5.1 History of Storm Sewers

The earliest sewer that was found was in the Indus Valley civilization. In ancient Rome, the Cloaca Maxima was considered a marvelous engineering design and construction. In the medieval European cities, small natural waterways are built to channel wastewater and as time passes this were upgraded to covered channel that is known today as sewer systems (Labor Law Talk Encyclopedia, 2005).

2.6 Tunnels vs. Bridges

The advance in construction technologies have resulted in development of major structure such as skyscrapers, roads, highways, airports, ports, tunnels bridges and etc. The main reason bridges are more preferable because of the cost and the simplicity of the design and construction. Simplicity doesn't mean that bridges are easy to build that tunnel, but in certain circumstances it does look easier. There are advantages and disadvantages of using bridges compare to tunnels.

The advantages are it is cheaper compare to tunnel that needs expensive budgets. The disadvantages are navigational consideration may limit the use of high bridges or draw bridges spans when intersecting with shipping channels such as the Penang Bridge that intersects the Penang Straits from the island to the mainland Butterworth with length at 13.5km

Source: LLM, 2005

Figure 2d: Penang Bridge, Malaysia

Where as the tunnel construction are more expansive compare to the bridges but the advantages are for navigational crossing it will be easier and more convenient to build as it doesn't interrupt the movement of busy channel Such tunnels are constructed around the world such as the Lincoln Tunnel (Between New Jersey and Manhattan Island in New York City . There are also combination of bridge and tunnels such as the Hampton Road Bridge-Tunnel that connects City of Norfolk and Hampton.

Source: Lincoln Tunnel, 2005

Figure 2c: Lincoln Tunnel, New York

Source: Scott N. Kozel, 2003

Figure 2d: Hampton Road Bridge-Tunnel, Norfolk

Chapter 3: Site Investigations

3.1 Overview

The investigations of the suitability and characteristics of any construction site before beginning any construction and development is necessary to any engineering industry. Main priorities had to be given to the safety of the society, affect to the design, construction works and the environment have to be given deeper thought to avoid any discrimination or unjustified incidents to occur. There are several ways to explore and investigate a new site such as:

1) Preliminary investigations using existing data and resources.
2) A detailed geological survey of the new site to understand the surface are of the site
3) Application of the geophysical survey to learn about the sub-surface of that area.
4) Site testing such as boring, drilling and excavation to provide confirmation about the surface and sub-surface geology.
5) Soil Testing and rocks to assess their suitability, particularly their mechanical properties.
6) To identify all obstruction and potential hazard including risk assessment for the preliminary works in this site.
7) Main priority have to be given for the sub-surface investigation as this is a tunneling project that concerns underground works mostly.

8) Understanding the ground water properties including soil classification as this will lead to utilizing type of machineries and type of construction methods to be applied in this tunneling works.
9) Undertake detailed Environment Impact Assessment (EIA) to eliminate any potential environmental disaster in the before, during and after the construction of the tunnel.

In most engineering project either small or large most of this criteria are undertaken by professional consultant that been hired by the project administrator or the government to understand more thoroughly about the project and the location of this project. Most of this people are specialized in the field of surveying, geology, geophysics or engineering will prepare a compressive report.

In this project particular emphases have to be given to the geophysical study of the sub-surface of the construction site. This is because this a tunneling project. SMART Tunnel particularly are one of the kind in the world that combines the wet and dry tunnel together as one tunnel in order to solve stormwater crisis and traffic congestion in Kuala Lumpur, Malaysia. This is the first time that such a massive scale project involve underground tunneling work have been carried out in Malaysia making it very unique.

The exploration of a new site such as this to assess the feasibility of a project, to plan and design accordingly to the foundations and to estimate the costing of the project according to the study done to eliminate any problems during and after the construction is undertaken. In this case geophysical study should be emphasizing on some of the following criterion:

- Nature of rocks and soil present at this area including the sequence of the soil strata and the thickness of the deposits and the presence of igneous intrusions.
- Distribution of the rocks over the entire project area.
- The frequency and the orientation of joints in the different rocks and location.
- The presence of any weathering of the rocks and particularly of any soluble rocks such as limestone.

- Economic deposits which may be extracted by miming or quarrying to leave concealed voids at this ground.
- Groundwater conditions which may contain noxious material such as sulphates which may affect the cement.
- Suitability of rocks and soils especially those to be excavated as construction materials.

3.2 Surface Investigations

In any engineering investigations should proceed from the genera to the specific. In the preliminary investigation undertaken for SMART Tunnel there is certain steps that normally been undertaken in there engineering field. Surface investigations are very important because it determines the proper study before any construction process can begin. The most famous and commonly used methods are Geological Reconnaissance

3.2.1 Geological Reconnaissance

It is normally impossible to thoroughly investigate the whole area of the construction site during the preliminary investigations. Careful study and considerations will result into less design errors, wastage in materials, costing of the project and also the management of overall project. The final geologic condition incorporated into the design assumptions are usually based on the information regarding the area of construction where the tunnel going to be built.

Geologic reconnaissance includes literature studies, study using the aerial photography and surface geological mapping. The construction of SMART Tunnel needs serious consideration as the tunnel is built beneath the metropolitan city, Kuala Lumpur. The locations selected for this tunnel are in the alignment of a numerous obstruction such as residential township, business areas, highways and etc.

There are also existing underground utilities to be considered such as electrical cables, drainage, foundation of existing buildings and ground water resources. In this project before the commencement all the studies conducted such as;

I. *Literature Studies* ~ There where review on publishes information regarding the geology, soils, groundwater, seismic history and performance of structures in the project area. Knowledge regarding the history of the site is also very important as it leads to identification of old landfills or alteration to the drainage pattern.

II. *Aerial Photograph* ~ If we view the whole site from the ground we only will get limited view regarding the area of the project. For large scale project such as the SMART Tunnel, view from the ground could not accommodate this large scale project. Aerial view is more preferable as all the necessity features of the project will be identified from a distance and necessity steps can be taken to avoid any obstruction and planning for the design works can be done smoothly

III. *Geophysics* ~ This is a tool which can be used for geologic studies for tunnels. This type of study usually depends on the skills to interpret the data that have been collected from the field study and testing. The advantage of using this study, where they are relatively fast and applies low cost. The precision is usually low and the restraints must be used in order to provide accurate results Geophysical methods are such as seismic refraction and reflection survey, electrical resistivity soundings, gravity surveys, and magnetic surveys.

(John O.Brickel and TR Kussel, 1982)

IV. *Site Investigations* ~ This is the most common form of land study by incorporating land surveying to identity all the construction aerial features. Mostly with the advance of technology land mapping using the satellite will be easier as it saves time but costing will be very high. So it is practical for big project such as the SMART Tunnel as is can resolve the land issues. In certain areas where the use of technology are limited is better to use the manual method in order to record all the data. In this project since the project area is beneath the Kuala Lumpur city centre, the management decided to use the satellite mapping and also manual land surveying in order to collect all data with precision and accurately.

3.3 Geophysical Investigation

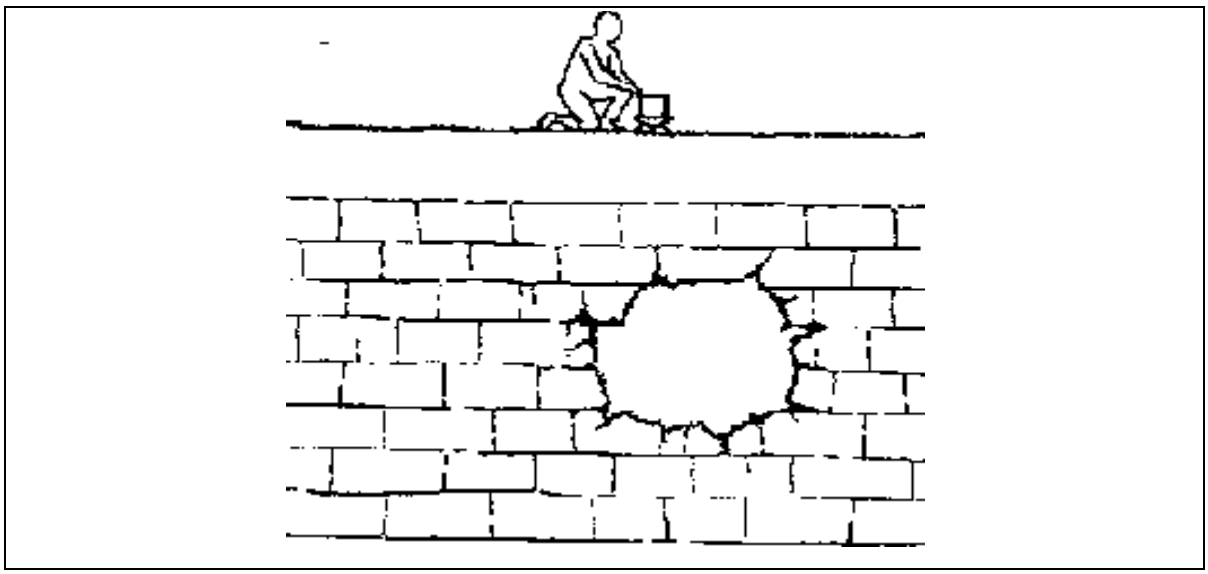
Geophysics study is very important in tunnel construction as it identifies the geological structure beneath the surface area. In SMART Tunnel Project major emphasis was given in this area because the tunnel is under the city. This is a tool that depends mainly on the data interpretation from the surface and preliminary investigation. Special consultants are hired mainly to study the data and results and recommendation are made on the construction, design and the costing of this project.

The most important thing in geological studies is the location of the anomalous that required more detailed study and research. In the beginning, geophysical work are done before the soil testing by boring works begins. This is because by geophysical studies identification on the areas that should be bored because of the soil condition will save time and cost of the preliminary investigations works. Geophysical methods that are very common that are used are the seismic refraction and reflection surveys, electrical resistivity soundings, gravity surveys and magnetic surveys.

3.3.1 Micro-Gravity Method

Microgravity method is one of the kinds that will give very accurate results in the field. This is a passive technique where the accuracy is 1 to 109 (1 mgl) measurements of relative changes in the earth gravitational field. There will be changes in the gravitational fields as a result from variations in the density of sub-surface materials or the presence of buried engineering structures. This method is very useful to locate voids in the ground to determine whether further treatment to be done in order to avoid soil collapse in the event of tunnel works being pursuit.

It also very useful any used widely in the SMART Tunnel, because it can locate existing engineering structures beneath the surface in order to avoid any damages to the existing structure. There are a lot of factor that influence the gravitational field that is measured at a particular location and time. There should be careful interpretation of the raw data as it has to be corrected.



Source: Geophysical Consulting Services, 2004

Figure 3a: Micro-gravity Method

There fill be some effects on the equipment such as the instrument drift and earth tides. These can be overcome by taking multiple readings at a fixed point throughout the survey in order to build up a drift curve. Drift correction are the calculated based on the closure error between the first and last base reading in each loop. In order to reduce the tidal effect, it can be calculated by using compute based programme or previous publishes tidal gravity data in order to make the corrections.

After the field work, the results can be categorized either as scaled single profiles or color coded maps and contour plots of the reduced data. There will be three level of correction or reduction that are:

I. Bouger ~ Includes all reduction processes except the local terrain correction
II. Complete Bouger ~ This will include local terrain correction
III. Residual Bouger ~ In this case it includes removal of regional gravity trend through spatial filtering of the Bouger and Complete Bouger corrected data.

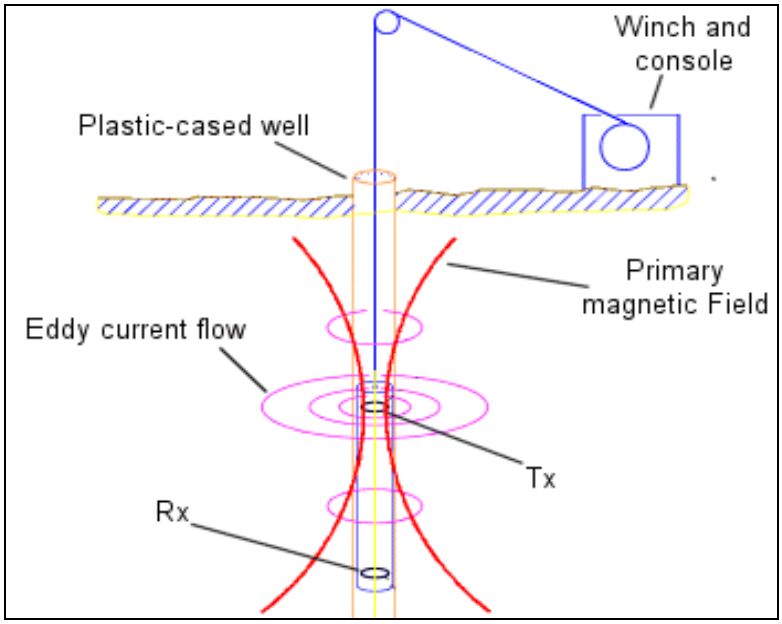
(A.C Mc Lean and C.D Gribble, 1985)

3.3.2 Borehole Logging Method

Borehole logging method is also very common in the geophysical industry. This method is done by lowering down a probe into the borehole that had been bored using the soil boring machine. This probe will measure the physical properties of the surrounding rock or soil. When the probes measure the physical properties of the soil and rock surrounding it will be used to map the underground surface to use for the construction works.

The principles of the borehole logging methods are when the probe is lowered down the hole it will send an electromagnetic oscillating magnetic field. This magnetic field will induce an electric field surrounding all the material in the soil which will turn into current flow within the soils. The strength and the power of the electricity flow depend on the conductivity of the soil.

The eddy current in return will create a magnetic field, which will be detected and measured by the receiver on the probes that had been lowered down in the hole.



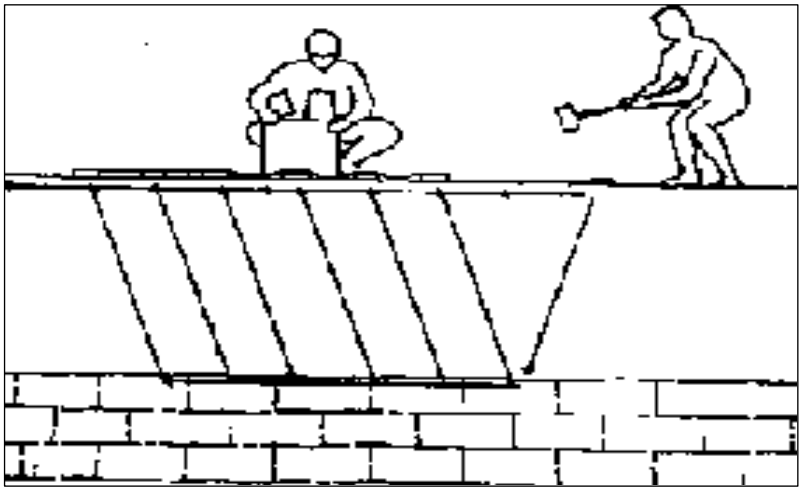
Source: Geophysical Consulting Services, 2004

Figure 3b: Borehole Logging Method

3.3.3 Seismic Refraction Method

The Seismic Refraction Method is normally used in the large scale underground construction project such as SMART Tunnel Project. It is done based on the velocity of a wave passing through a material is a function of the material's function of the material's physical structure (John O.Brickel and TR Kussel, 1982). The travel time of seismic waves refracted at the interfaces between subsurface layers of different velocity. In order to make the wave, seismic energy is provided at the surface of the soil layer.

This energy will radiates out from the shot point, and it will travel either upwards or downwards and also laterally along higher velocity layers before returning to the source. This will enable geophones that are placed on the surface to detect the energy that returns back when the travel-time of the refracted signals will provide information on the depth of the profile.



Source: GEO Services International, 1999

Figure 3c: Seismic Refraction Method

The geophysical properties that are measured using this method will produce the seismic velocity. There will be two kinds of wave that will be produced here that is the P-

WAVE (a compresional, longitudinal wave) and also the S-WAVE (a shear, transverse wave).

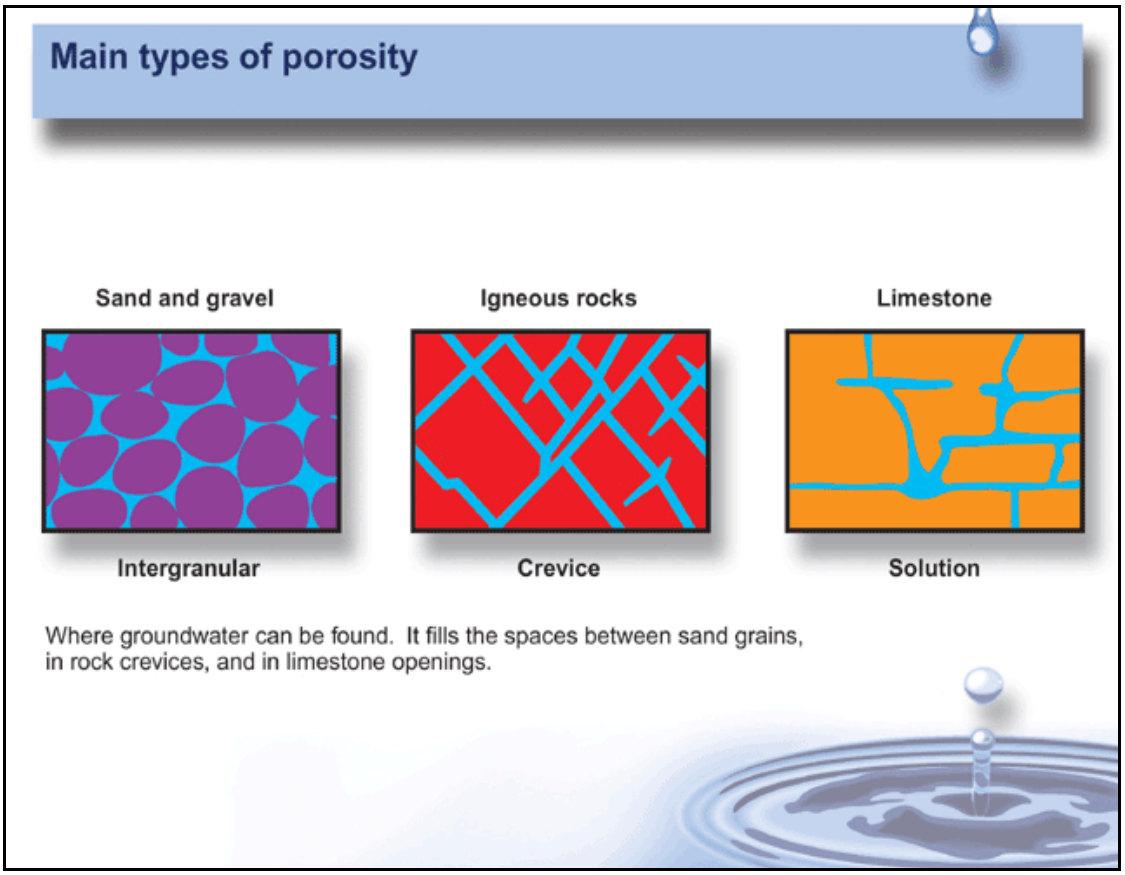
P-WAVE will move in high velocity of any seismic wave and usually will be used to choose the first breaks of seismic waves that propagate through earth materials (John O.Brickel and TR Kussel, 1982). Where travel time equation can be derived as a function of the velocity, depth to a refractor such as bedrock will be determined in this survey. The main uses of the Seismic Refraction Method are:

- Mapping bedrock topography
- Determination of seismic velocities to find out rock rippability

3.4 Groundwater Investigation

3.4.1 Groundwater

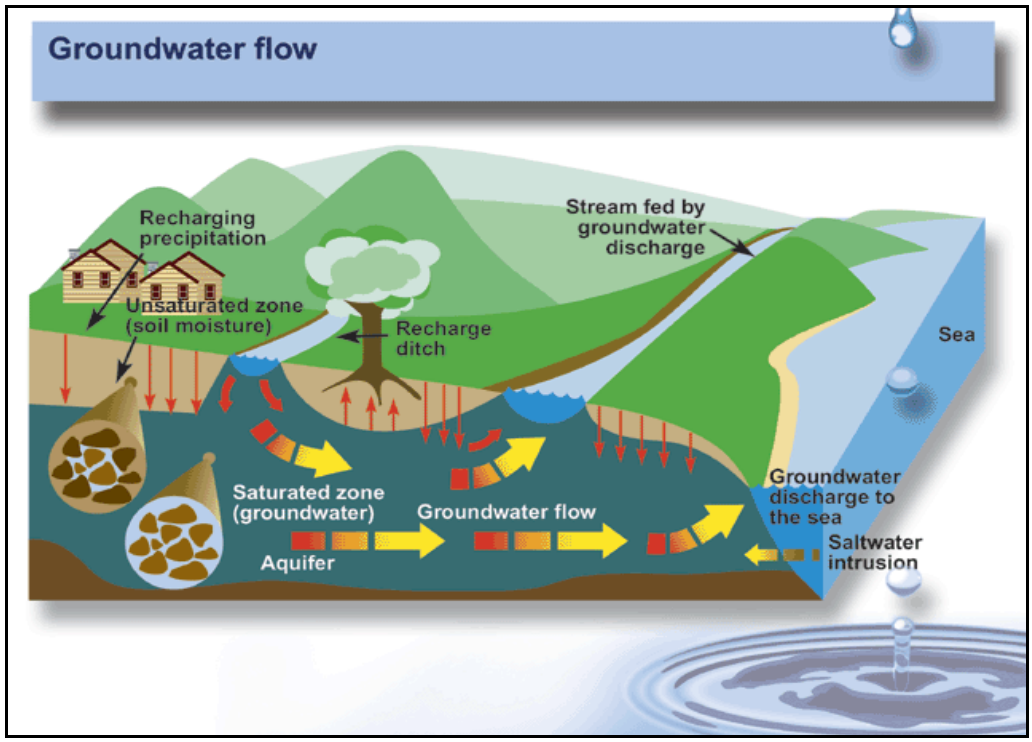
Groundwater is not confined to only a few channels and depression in the same way that surface water is concentrated in streams and lakes .Groundwater flow almost exist anywhere in the ground. It runs through particles of rock and soils or in crevices and cracks in rock. The water fills these openings are usually within 100metres of the surface. Most of the earth's fresh water is found in the ground layer of the sub-soil surface. When the layer of the rocks gets deeper, the gaps between these rocks reduces, thus reduces the containment of water in the areas. Below are the types of porosity can be found in the soil layer especially in limestone vicinity;



Source: Department of Environment, 2005

Figure 3d: Types of porosity

The levels of the water containment in the sub-soil area are classified into different categories. The level where all the spaces or gaps are filled with water is called the water table. Then, comes the unsaturated zone, where the spaces in the rock and soil contain both air and water. The water in this level is defined as soil moisture. The region below the water table is called the saturated zone. The location of the SMART Project is mostly in the limestone areas.



Source: Department of Environment, 2005

Figure 3e: Groundwater Flow

3.4.2 Investigation Purpose

Geophysical methods are very effective to determine to ground water resources. This is one of the key underground researches that should be taken into consideration during the geophysical exploration for tunneling works. When investigating the groundwater properties, some of the following should be taken into consideration:

- Water levels(Piezometric Level, Variation over time)
- Water Chemistry
- Water Temperatures
- Groundwater Inflow(Expected)

The main purpose to investigate the groundwater in this SMART Project or any other project because this investigation plays the major role in the tunneling works. In previous chapter, it was found that in SMART Project Kuala Lumpur most of the soil layers are limestone with groundwater content. Tunnel drilling and blasting works mostly will affect the groundwater flow. This directly will cause sink holes and probably will cause damage in property or major incidents on the surface of the project location.

3.4.3 Karst Limestone

Limestone is a sedimentary rock consisting mainly mineral calcite which is calcium carbonate ($CaCo_3$). Limestone's character is very unique because it is a soluble mineral and reacts with acidic water. The end result of the reaction with acidic water will cause cavities, caves, solution slots, pinnacled bedrock, stalactites/stalagmites, basal notches and overhangs in limestone cliffs. The earth's movement over years will cause limestone to convert into marbles. In Malaysia the formation of marble are very widely in Klang Valley and Kinta Valley. Klang Valley is the location of the SMART Project. Due to the earth's metamorphosis process the marble will be fine to coarse grained recrystallised calcite and dolomite. This process will increase the density and strength of the rock. Most formation in Malaysia are actually already been formed into marble form. This gives an advantage to the location of the SMART Tunnel because the form of the rock will give adequate strength to construction of the tunne4l in Klang Valley (B.K.Tan, n.d.)

The properties of Limestone are very interesting and unique. This is because the formations are usually very complex near the earth's crust. The layer of limestone is very poor in farming or vegetation and usually not suitable for agricultural cultivation. This is because the soils are usually dry because of the maximum possible drainage of the sub-soil. Limestone contains numerous cavities such as hidden deep holes will drain out the water from the surface. These cavities may collapse without prior warning, and will cause major damages to whatever infrastructure that is above Karst limestone are categorized into three different layers such as:

High Karst	These is the layer which discharges water which drained out from the top surface to the base of the formation
Middle Karst	The layers contributes water which will travel by the influence of hydrostatic pressure ate greater depths.
Deep Karst	Same as the middle layer where the water will continue to flow downwards under hydrostatic pressure to the base.

(G.L Seymour, 2003)

Source: Department of Environment, 2005

Figure 3f: Surface of Karst Limestone

Generally, in karst limestones the formation of water from precipitation directly travel downwards due to the gravity system in the form of channels towards the point of discharge .Solution of wall rock often upsets the static equilibrium of rock mass causing the expansion of cavities by the fragmentation of rocks. Cavities in limestone should be seriously investigated because this will cause structural failures in urban areas. The formation of cavities in the bedrock is actually caused by the flow of the groundwater in the sub-surface. Settlement and sinkhole incidents are very common in Malaysia, especially in Kuala Lumpur.

3.5 Tunneling Methods

Tunnels are constructed according to types of soil formation. This is a major criterion for choosing tunneling methods. Tunneling project depends also on schedule, cost allocation and location. There are several methods or ways in selecting proper tunneling method, such as:

- Selection of proper tunneling system.
- Cost and Risk Analysis
- Tunnel designs

(A.Z. Eisenstein, 1992)

In urban tunneling such as the SMART Tunnel, the design, selection, cost and safety of the tunnel will be very important. This because the tunnel is built in busy metropolitan city such as Kuala Lumpur fill with high rise structures and dense with high population. Proper care must be taken in order to avoid disaster or accidents from happening. In SMART Tunnel project the usage of Tunnel Boring Machine was used because of the efficiency and the simplicity of construction process. There are several types of TBM that are available in the market that are designed for special construction purposes. In this project the Slurry Shield TBM was chosen because of the existing groundwater condition that is a major setback to the construction. The further study on TBM will be in Chapter 4.

Figure 3g: Slurry Shield TBM at SMART Project

3.5.1 Selection of Tunnelling Methods

In most tunnel construction works, the most important criterion is the tunneling method. This is because proper tunneling method will make the construction process to run smoothly without any delays and problems. In SMART Tunneling project, the usage of Tunnel Boring Machine was chosen because this is the new method that has numerous advantages. There are different TBM that are used currently in most tunnel projects world wide. Different country with different soil and ground properties has different aspects to tackle in order to complete the tunnels. Tunnel Boring Machine or TBM are used to excavate or deep tunneling works in urban or remote areas.

The TBM is usually circular with a rotary cutter in front of the machine. The machine is jacked using hydraulic jacks side ways and a force is applied to push the machine forward in the cutting location. The machine moves on a track and tunneling and lining works can commence immediately after drilling. Horizontal directional drilling will be used to core tunnel that are less than one metre rather than using the TBM. Tunnel boring machine is new inventive machine that will solve the problems that are caused by normal drilling and blasting.

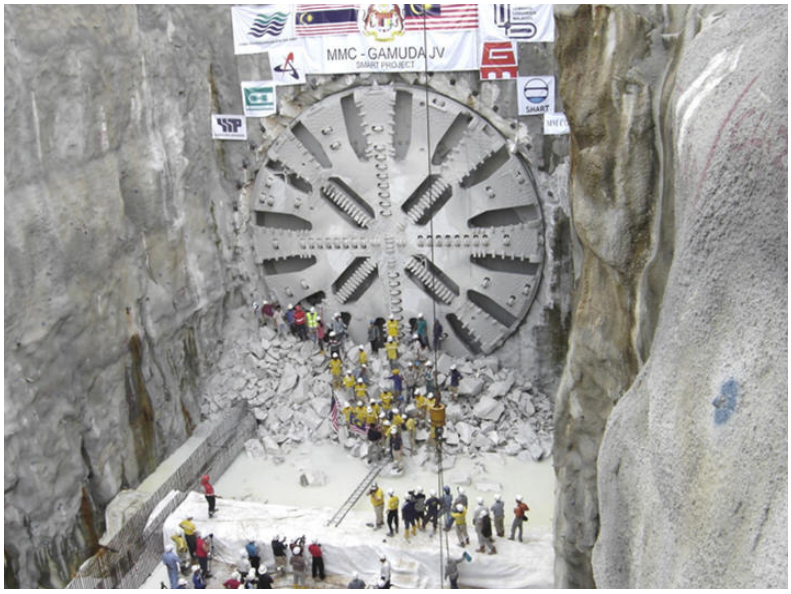


Figure 3h: TBM break through at South Junction Box

Road header machine is also one form of tunneling machine that is commonly used currently. Road header machine are limited in the operation of cutting hard rock surfaces. It is limited by the system stiffness, the inability of radial and point attached cutting tools to withstand high normal forces and premature carbide insert failure. Road headers are traditionally used in rocks with unconfined compressive strength. Road headers are widely used in tunneling where the formation of soft to medium strength rock formation.

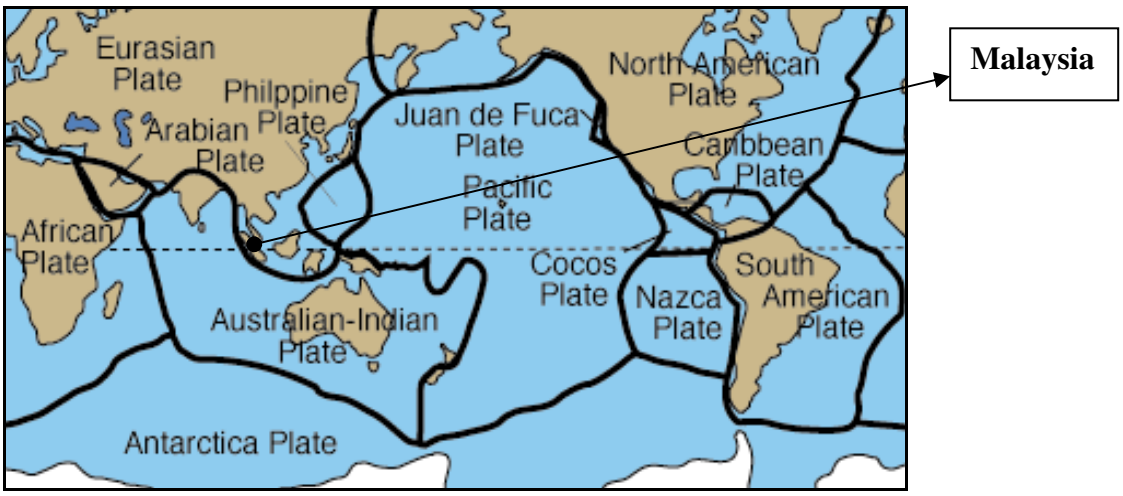
The advantages of road header are the high mobility, versatility and low capital cost of system operation. Road header was not used in the SMART Tunnel Project because of the size and formation of the tunnel and rock.

Source: Mining Techonology.Com, 2005

Figure 3i: Road Header Machine and continuous miner

3.6 Natural Disaster Investigation

Natural disaster investigation is very important in order to gather all the information regarding the location of the project in order to eliminate the risk factors. The types of disaster that are very common in Malaysia are such as flooding and earthquake. Flooding is very common in Malaysia because of the tropical weather that will cause rain most of the days in a year. Earthquake is very unlikely as Malaysia is actually outside the South-East Asia's earthquake plate.

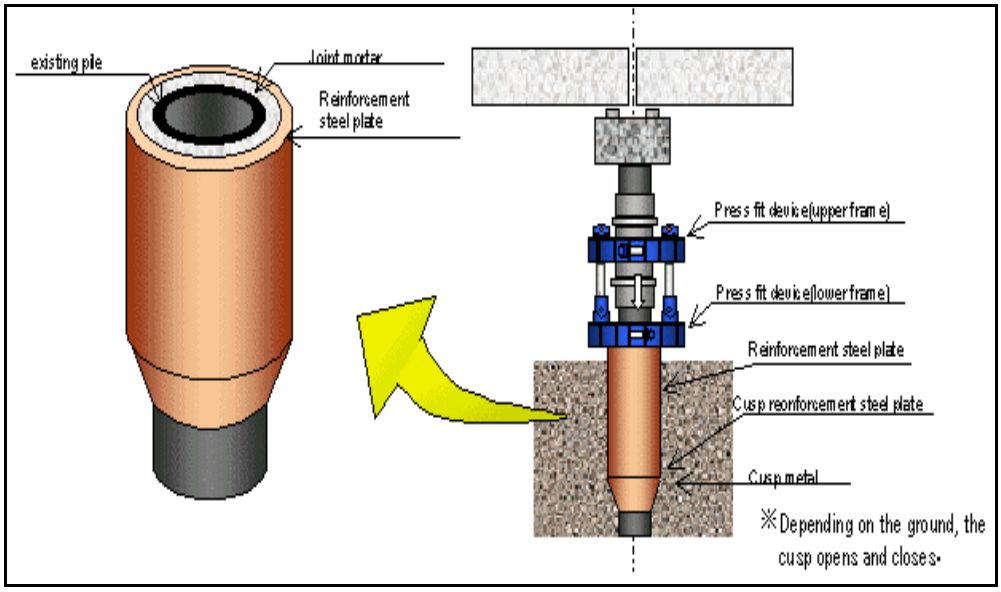


Source: Shirashi Corporation, 2001

Figure 3j: Major Tectonic Plate around the world

Even though Malaysia is outside the region, studies are been conducted to avoid structural damages in all major project such as the SMART Project. The Indonesian region of Acheh that is very close to East Malaysia is one of the critical epic-region. This can be seen during the Tsunami that was caused by the tectonic plate in Acheh. This caused an earthquake with a magnitude of 9.0 Richter scale that caused major devastation until to coastal of Africa. This was an awakening call to Malaysia that was very certain that we are safe from this natural disaster.

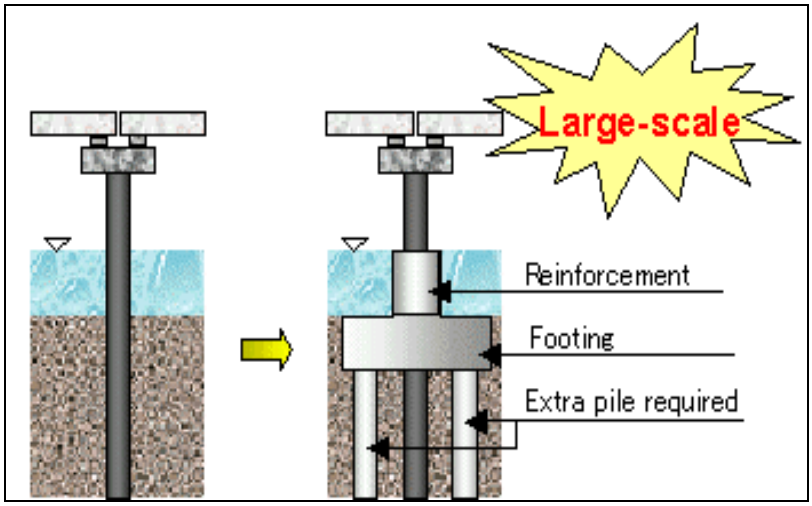
The government of Malaysia enforced laws that all skyscrapers and major infrastructure should be built with earthquake resistance capabilities. One of the methods that are currently incorporated into tunnelling works is to earth-quake proof the piles. The method is by rolling steel plate around the piles by pressure fit. These methods is very cost effective ant the strength is very high. (Refer to Figure 3k)



Source: Shirashi Corporation, 2001

Figure 3k: Method protect the piles

Other methods to structurally protect the tunnel is where the footing of the structure is also been protected. The footing method follows the ultimate lateral strength earthquake resistance design that required large scale of reinforcement at footing area. These are done after the pile of the foundation is rolled by the pressure fit plates. Then the footing will be heavily reinforced in order to reduce the vibration of the earthquake.



Source: Shirashi Corporation, 2001

Figure 3l: Footing Protection

Earthquake can be classified into three categories that is:

- *Major Earthquake* ~ This is considered as severe that is considered having 10% probabilities over the time period exceeded of 50years and the impact will be devastating and cause severe loss of lives and damages to properties.
- *Moderate Earthquake* ~ In this part the probabilities are 50% over the time period exceeded 50 years
- *Minor Earthquake* ~ This will produce light or moderate ground shaking over short duration time.

(Dan Putnam, 1997)

3.7 Site Investigation Conclusion

Basically this chapter gave the in depth idea and knowledge regarding the guidelines used for site investigation. The chapter covers method used to conduct site investigation, the soil profile in Kula Lumpur, natural disaster and the tunneling method. The site investigation study for the SMART Tunnel Project was very beneficial as it gave the wide ideas of the site investigation undertaken in Malaysia. The site investigation not only covers the geophysical investigation but also the surface layers.

The study on the karstic limestone formation that is found surrounding the project site and also this is the main soil formation in Kuala Lumpur other than clay layers. The geophysical and surface studies are conducted in order to build the tunnel in a proper design. In order to plan for the construction and the design of the tunnel, first we have to conduct the site investigation to determine the type of structural design, financial aspect, type of construction machineries and also any particular concern that have to be highlighted during the construction period. Therefore the site investigation study is one of the most important criterion that have to be implemented in a construction process in order to built in a safe and ethical manner.

Chapter 4: Tunnel Boring Machine (TBM)

4.1 Synopsis of TBM

As discussed in Chapter 3 previously, Tunnel Boring Machine (TBM) is inventive machine that upgraded the quality of construction industry especially tunneling infrastructures. TBM is a machine that has a rotary cutting head mounted on the front and the operation deck that is shielded behind. The machine operates on a rail track that uses hydraulic jacks that is mounted at the site to stabilize the machine. The machine pushed forward by forces that will directly breakthrough the rock surface that will cause the tunnel to be drilled.

This machine is designed to handle any type of ground compare to continuous and road header machine. This technology is very suitable for urban tunneling especially in a busy city centre like Kuala Lumpur. There are three types of TBM currently such as the earth pressure balance, slurry shield, and compressed air. All this are positive face control. Usually the earth pressure balance and Slurry shield are more preferred compare to the compressed air machine. Both this types are preferred over open face TBMs and non-shield methods such as the New Austrian Tunneling Method. Most tunneling work around the world is using the NATM includes SMART in Malaysia

4.1.1 New Austrian Tunnelling Method

This method was developed between 1957 and 1965 in Austria. The main contributors to develop this method were by Ladislaus von Raeewicz, Leopold Muller and Franz Pacher. The NATM is a method that uses the approach integrating the principles of the behavior of rock masses under load and also to monitor the performance of underground construction during construction. There are several criterions that has to betaken into consideration in this methods as the method is not a set of specific excavation and support techniques.
There are seven most important principles have to be taken into consideration in NATM. There are:

- Mobilizations of the strength of rock mass
    - These where the method depend on the inherent strength of the surrounding rock formation in the sub-surface area. The rock formation is used as the main support of the tunnel.
- Shotcrete protection
    - When drilling the tunnel, loosening and excessive rock deformation must be minimized. This can be done by adopting thin layers of shotcrete as soon as the drilling is done by the TBM.
- Measurements
    - When using the NATM, it requires installation of monitoring equipment that is embedded in lining, ground and boreholes.
- Flexible support
    - Flexible supports are done by not only depending on the lining but also rockbolts, wire mesh and steel ribs are used to achieve a good strength of wall support.
- Closing of invert
    - The most important part of this method is the closing of the invert and create load-bearing ring. This is very important when tunneling in soft ground where the wall integrity is not well structured.

- Contractual arrangements
    - The contractual arrangements is needed because the NATM method is mainly based on the monitoring measurements and changes in support and construction method is frequently altered to suit according to the tunnel.
- Rock mass classification determines support measures.
    - There are main rock classes for tunnels and their supports. It also serves as the guideline for the tunnel structural reinforcement.

4.2 Types of TBM

4.2.1 The EPB Shield TBM

This type of TBM is only used in the dense and non-cohesive ground condition. These types of soils range from liquid to soil. When using this machine, secondary support such as compressed air is not used. The operation of the machine is similar to TBM as discussed previously but the machine is supported by the loosening soil (Herrenknecht, 2005).

Source: Herrenknecht, 2005

Figure 4a: EPB Shield used at Botlekspoor, Netherlands

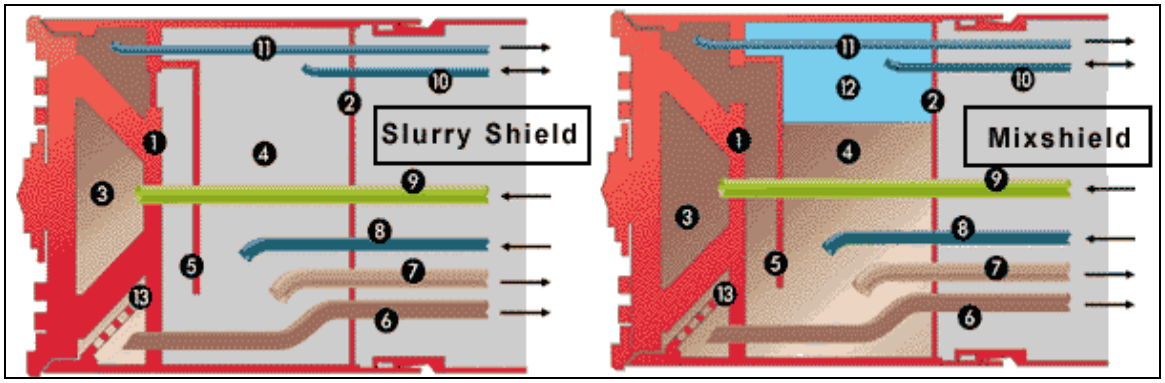
4.2.2 TBM with Shield

The TBM with shield is commonly used in most of the tunnel works around the world. This type of machine can be used in most rock formation such as brittle rock, soft rock and different tunnel formation. The tunnel can be drilled, excavated and also instantly lined during the drilling period as the machine acts as moving construction factory. The construction of large diameters tunnel with great length is very suitable to use this machine

Source: Herrenknecht, 2005

Figure 4b: TBM with shield Sorenberg, Switzerland

4.3 Slurry Shield & Mix Shield TBM



1. Submerged Wall	6. Slurry conduction line	11. Extraction chamber ventilation
2. Pressure Wall	7. Pressure Chamber Conveyor Pipe	12. Compressed air buffer
3. Extraction Chamber	8. Pressure chamber supply pipe	13. Suction screen
4. Pressure Chamber	9. Extraction chamber Supply pipe	
5. Communicating Pipes	10. Compressed air supply and outlet	

Source: Herrenknecht, 2005

Figure 4c: Model showing slurry shield and mix shield

4.3.1 Slurry Shield TBM

Slurry shield are commonly used in stable condition such as hard rock or cohesive. The difference between slurry shield and mix shield is the slurry shield is used without the compressed air support. In the other hand mix shield uses compressed air. Slurry shield operates when required specific gravity and viscosity is pressure-fed into the cutter chamber at the front end of the TBM. This is done to support the tunnel face by using the pressure exerted of the slurry and the viscosity of the slurry permeated into the tunnel face against the earth pressure and groundwater pressure. The slurry shield is very useful in areas with very high amount of groundwater flows.

This is because the slurry shield is designed to eliminate the arising sinkhole problems that can cause very devastating impact on the surface above the project area. The excavated soil is mixed with slurry and pumped out through the slurry circulation equipment to the slurry treatment plant at the surface of the ground. The slurry shield tunneling machine is very useful and has numerous advantages such as:

- When the machine is operating and drilling the tunnel face is supported by the slurry pressure and this will directly reduce the risk of ground settlement to occur.
- The groundwater pressure to the tunnel face is counter balanced with the usage of the slurry pressure. This is very effective in areas where the groundwater flow is extremely high such as the SMART Tunnel location.
- The working area is kept clean when the drilled and excavated material is taken out together with the slurry. So, this will give a dust free working condition and the soil with slurry will be treated in the treatment plant above ground.
- The slurry shield is flexible because the cutterhead can be suited according to the rock strata.

Slurry Shield TBM was for the tunneling work in SMART Project. This is because its efficiency of reducing groundwater drawdown eliminates the settlement of ground in the construction location. Most TBM are selected according to certain needs in the project such as:

- Length of shield
- Required face support pressure
- External loads on the shield
- Required strength of the push cylinder
- Required cutting wheel torque
- Calculation of air consumption
- Danger of blow outs
- Amount of settlements
- Necessity of stone crusher
- Type of lining needed
- Amount of excavated soil

(R. P.Van Der Putten, 1997)

4.4 SMART Project Tunnelling Method

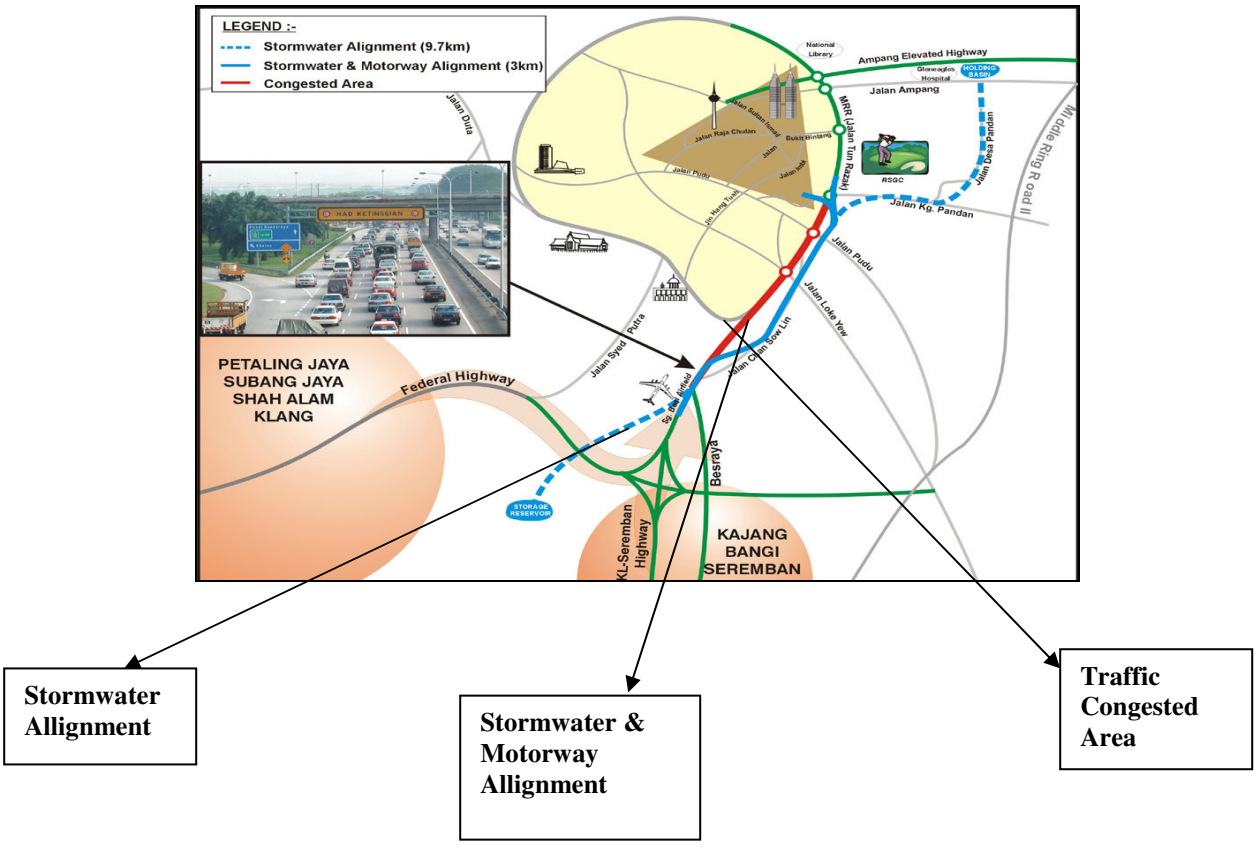
The SMART Tunnel uses the Slurry Shield TBM for the boring of the tunnel. The tunnel length is approximately 9.7km in length and diameter is around11.83m (inner diameter. The purpose of this tunnel as mention earlier is to channel and store excess flood water from Kuala Lumpur city centre. There are two TBM used in this project that was nicknamed as:

- TUAH TBM
- GEMILANG TBM

Figure 4d: TUAH TBM

TUAH TBM was the first one delivered to Malaysia from the manufacture in Germany that is Herrenknecht AG. This Machine was delivered on 4th June, 2004 and will be used towards the north of the tunnel alignment. The second machine GEMILANG that was delivered later was used for tunneling towards the south bond. Both this TBM will be completing 95% of the tunneling work and remaining 5% will done by using cut and cover method.

Figure 4e: GEMILANG TBM



Source: SMART Management Team, 2005

Figure 4f: SMART Tunnel alignments

4.4.1 Tunneling Process

The slurry shield TBM that was used in the SMART Project consists of four parts in the machine that produces proper and good alignment tunnel. The four parts are:

- *Rotary cutter head* ~ The cutter head is made of tungsten discs and the main purpose of the cutter head is for the excavation of rocks. This is the part where the hard surface of the rock is penetrated through.
- *Bulkhead* ~ The portion of the machine where the pressured bentonite slurry shield is formed. This is the main part where the stability of the TBM and the surrounding soil formation from collapsing due to the groundwater drawdown that will cause sinkholes.
- *Hydraulic rams* ~ The forward movement of the machine is controlled by the hydraulic rams. The rams is also used to set the alignment of machine straight so that deviation doesn't happen during impact of the boring works.
- *Tunnel lining erectors* ~ The installation of the tunnel lining is controlled here. The part of the machine allows the installation of the pre-cast concrete lining continuously after the drilling of the tunnel.

Other parts of the two boogies that are on the rail that accommodates the electrical, slurry pumping, ventilation equipment includes cable and pipes. After the tunnel boring works are completed the pre-cast linings are transported continuously to the erectors by boogies on rails. These linings are then hoisted by machinery and placed in the position in the tunnel before being bolted to joint. The void between the excavated ground surface and the linings is immediately filled with cement mortar grout under pressurized conditions to ensure all the voids are fully filled and completely closed without any holes. In SMART Project, there will be two tunneling machine used that is the Tuah TBM and Gemilang TBM. Tuah TBM will head north under Tun Razak Road and Desa Pandan Road. The Gemilang TBM will head south under Chan Sow Lin Road and KL-Seremban Highway.

4.5 Comparison between TBM and Cut & Cover Method

4.5.1 Cut and Cover Method

The SMART Tunneling Project consists of 95% using the TBM and 5% using Cut & Cover Method. Cut and cover method was the early stages of tunneling method that was used around the world. This method was very effective until the invention of the TBM machine that changes the tunneling industry. The main principle of these methods is excavating the ground along the route of the tunnel, construct the tunnel and bury the tunnel by backfill the route with earth and compaction material such as sand or quarry dust.

Strong supporting beams have to be placed in order to support the trench from collapsing. The construction method is relatively inexpensive and usually used for subway construction. But every good method has the bad sides of the process. In cut and cover method, which is the disturbance of the ground traffics. These methods cannot be used in urban areas where the city is dense with high skyscrapers. The cut and cover methods are very suitable for shallow trenches only. Any deep trenches or submerged tunnels will be bored using the tunneling shield methods.

Figure 4g: SMART Tunnel using Cut & Cover Method

4.5.2 Tunnel Boring Machine

Comparing the Cut & Cover Method to TBM**,** TBM is very widely used currently because there are different type of boring machines for soil formation and tunnel types. These machines have more advantages compare to the cut and cover methods. The advantages such as the TBM can be used in urban or remote areas. Even city with dense structure will not be an obstruction for these machines. The impact on the soil formation on the surrounding tunneling area will be minimized. The efficiency in tunneling works is increased as the tunneling work will run continuously including the lining works without any interference.

The safety and the environmental impact is also one of the main reasons the choosing of TBM is more preferred. The TBM tunneling method avoids caving in as the machine itself acts as the support to the soil. Some machine are even equip with slurry shield to avoid the drawdown of groundwater. The disadvantages of TBM are the methods are very expensive and the machine is less efficient in excavating rock formation which is extremely hard and lacks flexibility towards rapidly changing ground condition. Other than this the installation and dismantling of the machine takes quite a time and the availability of the cross sectional tunnel shape is limited.

4.6 Tunnel Boring Machine Overall Review

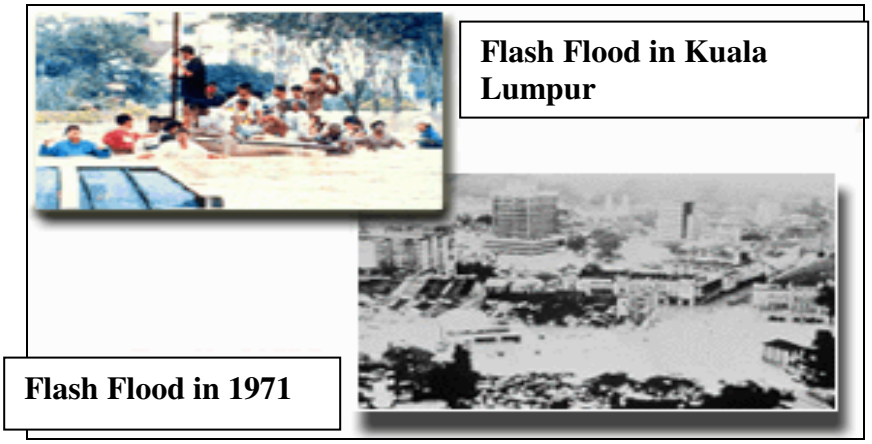
Tunnel Boring Machine or TBM are very useful for tunneling activities compare to other machineries. This is because the machine has numerous advantages than disadvantages compare to other machine such as the Road Header This inventive machine ranges in different types according to the suitability of the ground condition in a particular site. From this chapter, we can see most of the machine types, the functions and the efficiency of the TBM in the tunneling industry. In SMART Tunnel Project, the Slurry shield TBM provides better efficiency in ground condition of Karstic Limestone. This machine is suitable as Kula Lumpur city is located in the Karstic Limestone region with high capacity of ground water that will cause difficulties when doing underground works

Chapter 5: Study on the Flash Flood

5.1 Synopsis

Flash floods are defined as a rapid flooding in low lying areas, rivers streams usually caused by the intense rainfall cause by thunderstorms. Most flash flood s occur because the intense rainfall cause the ground location where the thunderstorm takes place becomes saturated and could not absorb or accommodate the heavy downpour. The rainfall runoffs are collected in the low level areas and will flow down to the downhill areas. Other than the intense downpour, flash flood also can be caused by cloaked drainage system, shallow river and also bad sewer design.

Flash floods are dangerous because it can happen in a split of time and nobody will notice it. The water level especially in urban areas can rise into critical levels as there will be no warning. This is dangerous as the water can be a good conductivity for electrical cables, damages to property and lives. Flash flood water has the capacity or force to move boulders, bring down trees and properties and obliterate bridges.



Source: Department of Sanitation and Irrigation, Malaysia

Figure 5a: Flash Flood in Malaysia

5.1.1 Definition of Floods

Flood water is one of the common natural disasters that happens almost every conner of the world. The global warming that is melting the ice in the artic region worsens the situation. This directly causes the sea water level rise gradually. Most floods have enough capacity to change the direction of the river and also damage the properties and cause lost of thousands of lives yearly. Flash floods are one of the most dangerous flooding scenarios because this happens without warning.

A flash flood can be defined as a fastest moving flood that cause severe destructive along the pathway. Heavy downpour that is collected in a stream or gully turns the scene from calm to instant rushing force. This is the main cause of lost of lives and damage in properties as the flood will catch the people off guard.

Source: Department of Sanitation and Irrigation, Malaysia

Figure 5b: Flash Flood in Klang Valley

5.2 Interaction between Flood and Weather in Malaysia

Flash flood Malaysia is becoming very common as more development and urbanization are taking place in a great velocity. Malaysia is one of the country in Asia that having flood problems. This is caused by the tropical weather that causes high rainfall intensity in the region. Most floods or flash flood occurs during the monsoon season from November till January (Flood Commission, 2005).The worst flood situation in Malaysia happen 1926 and followed by 1931, 1947, 1954, 1957, 1967, 1971 and 1992 (Flood Commission, 2005). It was estimated that almost 9% of the location in Malaysia (26000kmsq) are flood prone during monsoon season.

Malaysia is one of the countries in South- East Asia that have very high rainfall intensity. The main states that have flood problems are Penang, Kula Lumpur, Terengganu, Kedah and Kelantan. The highest rainfalls in Malaysia are during the monsoon season from mid November to March. In this season the east coast of peninsular Malaysia, east coast of Sabah and coastal area of Sarawak will experience heavy downpour (The Weather, 2005). In November and early December, the monsoon weather will reach the west coast of peninsular Malaysia.

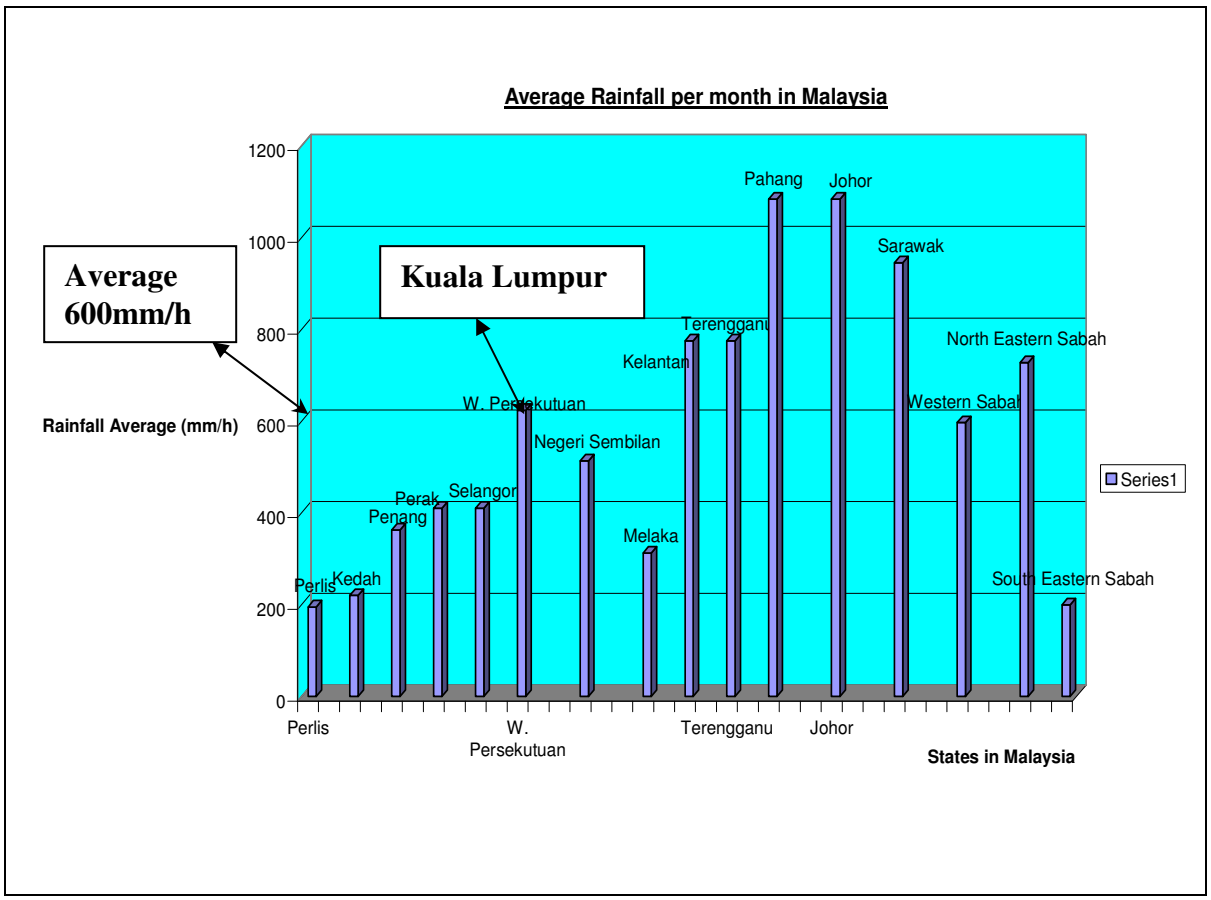
This will result heavy thunderstorm in major parts of west peninsular Malaysia. The monsoon season will begin in the coastal of Kelantan and Terengganu in November. This will spread to Pahang and east of Johor. The rainfall forecasts for the entire states in Malaysia are shown in Table 5a. The weather in Malaysia especially in peninsular Malaysia is monitored by the Meteorological Department. There are 18 numbers of stations scattered around all the potential rainfall areas in west Malaysia (Refer to Figure 5e

Table 5a: Rainfall Forecast in Malaysia

State	Month	Rainfall Forecast (mm) per month	Average	Average on monsoon season
Perlis	**Nov – Dec** **Jan – Mac**	**100 – 200** **80 – 100**	**150** **90**	**195**
Kedah	**Nov – Dec** **Jan – Mac**	**150 – 200** **80 – 100**	**175** **90**	**220**
Penang	**Nov** **Dec – Mac**	**250 – 300** **150 – 200**	**275** **175**	**362.5**
Perak	**Nov – Dec** **Jan – Mac**	**280 – 330** **180 – 240**	**305** **210**	**410**
Selangor	**Nov – Dec** **Jan – Mac**	**280 – 330** **180 – 240**	**305** **210**	**410**
W. Persekutuan Kuala Lumpur	**Nov – Dec** **Jan – Feb** **Mac**	**300 – 350** **180 – 250** **200 – 300**	**325** **215** **250**	**623**
Negeri Sembilan	**Nov – Dec** **Jan – Feb** **Mac**	**300 – 330** **100 – 180** **150 – 200**	**315** **140** **175**	**513**
Melaka	**Nov – Dec** **Jan – Mac**	**200 – 250** **100 – 150**	**225** **175**	**313**
Kelantan	**Nov – Dec** **Jan – Mac**	**600 – 800** **100 – 200**	**700** **150**	**775**
Terengganu	**Nov – Dec** **Jan – Mac**	**600 – 800** **100 – 200**	**700** **150**	**775**
Pahang	**Nov – Dec** **Jan** **Feb – Mac**	**600 – 700** **300 – 400** **200 – 300**	**650** **350** **250**	**1083**
Johor	**Nov – Dec** **Jan** **Feb – Mac**	**600 – 700** **300 – 400** **200 – 300**	**650** **350** **250**	**1083**
Sarawak	**Nov** **Dec – Jan**	**280 – 340** **400 – 650**	**310** **525**	**945**

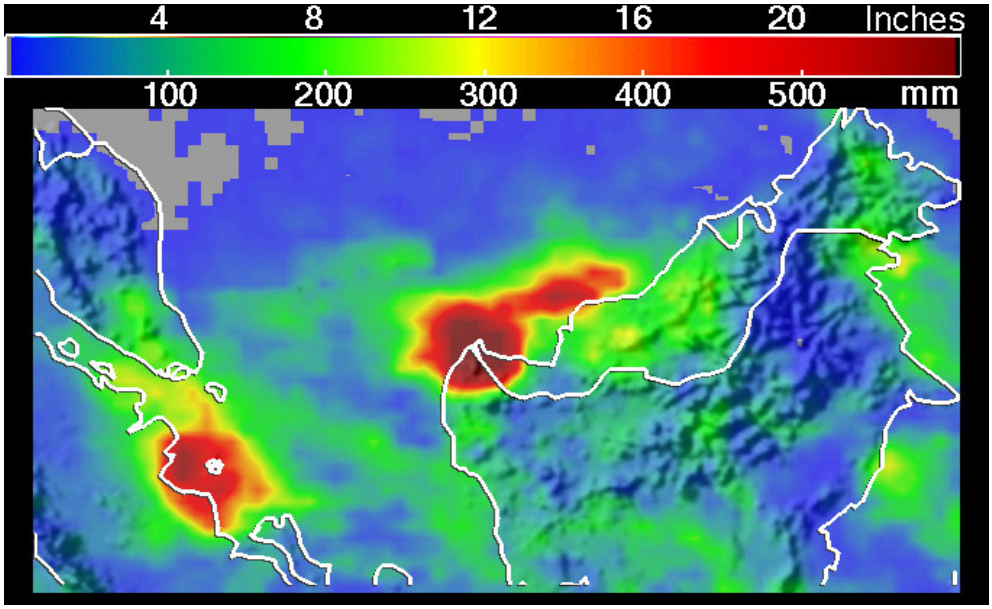
	Feb – Mac	**300 – 360**	**330**	
	Nov	**260 – 340**	**300**	**597**
	Dec – Jan	**220 – 280**	**250**	
Western Sabah	**Feb – Mac**	**100 – 180**	**140**	
North Eastern Sabah	**Nov – Jan**	**270 – 360**	**630**	**728**
	Feb – Mac	**150 – 240**	**195**	
South Eastern Sabah	**Nov – Mac**	**150 – 250**	**200**	**200**

(Source: Malaysian Meteorological Department, 2005)



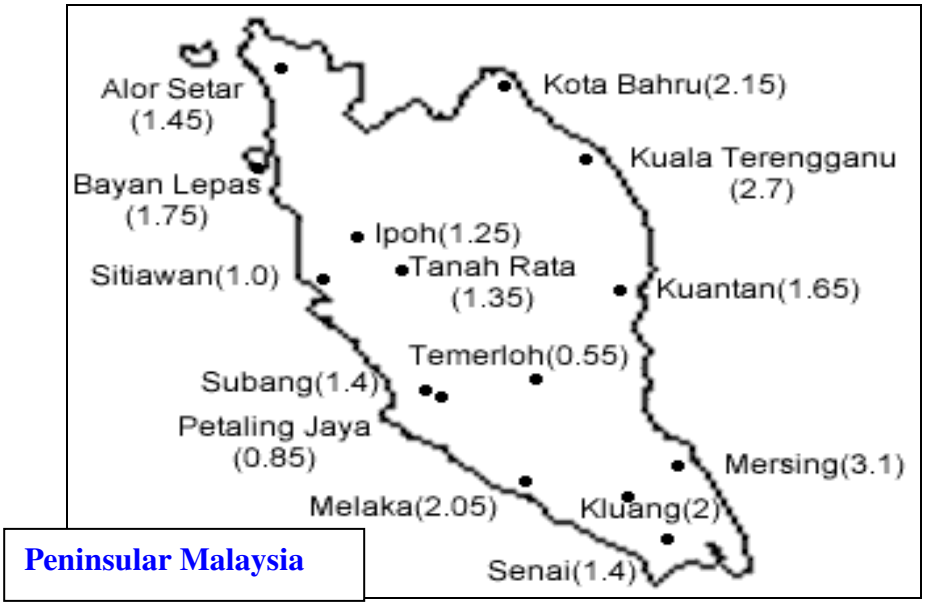
Source: Malaysian Meteorological Department, 2005

Figure 5c: Rainfall in Malaysia (Refer to Table 5a)



Source: Malaysian Meteorological Department, 2005

Figure 5d: Average Rainfall Data



Source: Malaysian Meteorological Department, 2005

Figure 5e: Meteorological Station in Peninsular Malaysia

5.3 Flash Flood in Klang Valley (Kuala Lumpur)

Klang Valley or better known as Kuala Lumpur is the capital city of Malaysia. The cities population is estimated at 1.8 million people. Kuala Lumpur is a major hub foe financial, education, work, living and tourism. Previously Kuala Lumpur was the administrative capital of Malaysia, but recently have move to Putrajaya. Malaysia is one of the countries in the world that have high rainfall intensity with average of 3000mm annually and this makes the country rich in water resources. The amount of water in Malaysia especially the rainfall is seasonal. This because there are in some month of the year there will be high rainfall sometimes there are no rainfall at all. Flooding and drought are the results of this situation. Flood is the most common problem in Malaysia. Excess rainfall cause frequent flash flood especially in cities like Kuala Lumpur.

There several other factors that may contribute in flash flood. This particular section of the study mainly involves the flash flood in Kuala Lumpur city. As we know flood usually are not manmade but it is cause by natural phenomena. This can be over ruled as currently most flash flood is caused because of the over development of the particular place. The main reason will be studied in section 5.4. Kuala Lumpur is one of the cities that have the common problem. Even the metropolitan city with proper drainage system has the same common problem. This is because new developments and sky scrappers cause the total impervious area to rise and the drainage of water into ground are reduced.

Most development are done with most impervious areas are estimated around ten percent. Most developers usually go for maximum development or in other words make as much money as possible in that particular area. Concerns on this type of minor matters are usually are disregarded. In previous years before urbanization takes place, the rainwater runoff will usually will be intercepted by the vegetation, infiltrate into ground and then runoff to the rovers by underground stream line.

Modern urbanization had interrupted this process as now the rainfall are collected from the roofs and other paved ground such as roads and channelled into the sewer line that will be diverted into the nearby natural rivers.

This causes over flooding of water in that particular river when the river takes natural rainfall and also the water intake from the nearby township that channels the water to the river by drainage system. In Malaysia it is found that there are estimated 29,000km^2 of average nine percent of the total land area in this country are flood prone and affecting 4.9 million people (Keizul & Azuhan, 2005). There are modern solution to this situation especially the frequent flash flood in Kuala Lumpur that is cause the country to loose RM 1 billion(estimated AUD 0.3 billion) to reinstate the situation every time flood happen.

Source: Department of Sanitation and Irrigation, Malaysia

Figure 5f: Flooding in the heart of Kuala Lumpur city centre

5.4 Main Causes of the Flash Flood

As we discuss in the previous section flooding is one of the major problem that cause devastation around the world. Devastation from flood is very critical as each year there are lives and damage in properties due to this natural phenomena. We cannot stop the rain but we can reduce or eradicate the possibility of flooding from occurring. In Kuala Lumpur, the main cause of flooding are the heavy down pour with storm that pours on the same area for hours.

The definition that states the main cause of the flood is usually from heavy downpour. These downpour will cause the water level existing rives and streams to rise significantly. These will cause the natural form channels such as rivers unable to cater the incoming water from the near by city drainage system.

In Malaysia, especially the peninsular part of the country, there wide dense networks of rivers and streams. The total numbers of rivers that flows through this part of the country is estimated at 150 rivers. Most of the rivers in Malaysia drain to South China Sea and Straits of Malacca. According to the FAO Land and Water Division (1999), the annual rainfall volume is 990km^3. Out of this the total surface runoff is estimated around 566km^3. This is about seven percent of the total annual rainfall and estimated that about eighty percent will flow back to rivers and back to sea.

Figure 5g: Map of Malaysia

The annual flood discharge in Kuala Lumpur have increased from 148m^3/s to 440m^3/s. This is due to the rapid development and urbanization of the city causes the water draw back to nature reduces as most of the pervious area had been turned into impervious. This directly contributes to the frequent flash flood in the city. The several causes that had been identifies throughout the study regarding the main causes of the flash flood occurrence in Kuala Lumpur. There are such as;

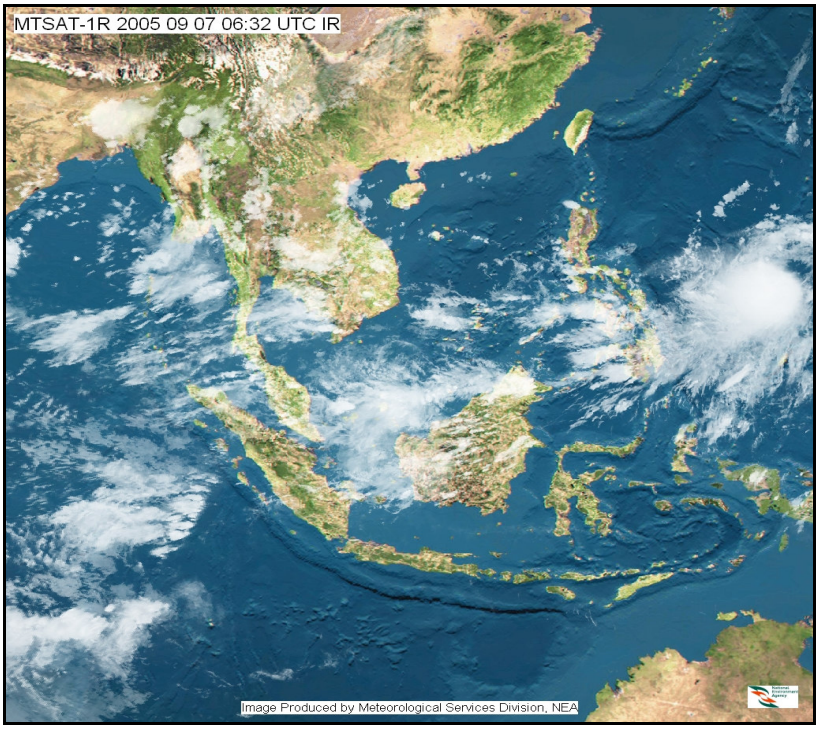
The main causes are;

- Rapid development especially near the Klang River, Gombak River and Kerayong River where approximately 3.6 million people resides beside the rivers.(Figure 5f and 5i shows the three major river flowing across Kuala Lumpur)

Figure 5h: Kerayong River

Figure 5i: Klang and Gombak River in Kuala Lumpur

- The drainage system in city is directly linked to the rivers causing the river capacity could cater the during thunder storm.
- Improper solid waste management that causes rubbish to be dumped into the rivers (estimated 50 tonnes daily cleanup collection of rubbish).
- The rivers becoming shallow because of the silt sedimentation at the bottom of the rivers due to soil erosion from the land development which practices poor soil conservation practice (average 10million tones of silt from these rivers.).
- The current rivers are not wide and deep enough to cater the increment of rainfall compare to twenty years ago.
- Climatic change that causes the storm to downpour at the same area for a long period of time.



Source: Malaysian Meteorological Department, 2005

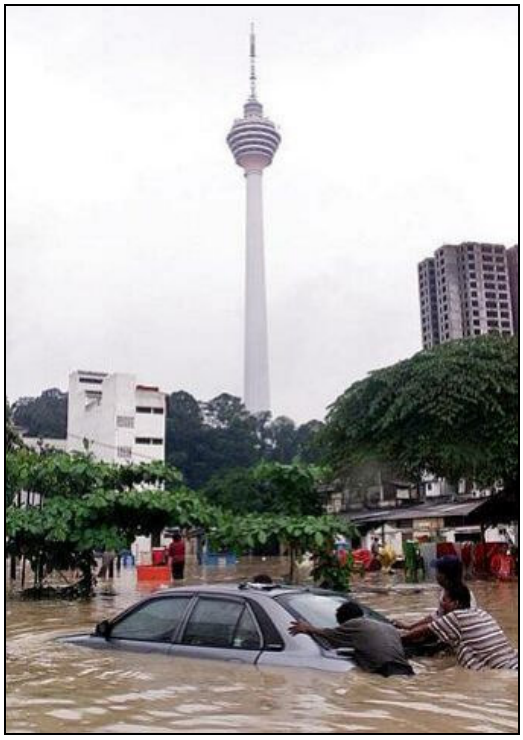
Figure 5j: Satellite view of storm formation in Malaysia

- Improper river management causes unbalance in the flow of the natural river.
- Infiltration of water to ground reduces as the pervious area in the city reduces and all the rainwater is flown to the drains and rivers.
- The presence of squatters nearby these rivers with improper sewer system causes the sewage discharge from these squatters are channelled directly to the rivers (estimated squatters in nearby these rivers are 20,000 to 40,000 squatters).
- Sullage discharge from industrial sectors and commercial sources that are establishes near by these rivers cause further deterioration to the rivers.

The devastation due the frequent flash flood causes the government to consider various ways to solve the situation as soon as possible. The pictures below are taken during the flash flood that happen in recent time during the monsoon season

Source: Department of Sanitation and Irrigation, Malaysia

Figure 5k: Flash Flood near the Masjid Jamek LRT Station



Source: Department of Sanitation and Irrigation, Malaysia

Figure 5l: Flash Flood near the KL Tower

5.5 Principles and Solution to solve the situation

In order to solve the situation that has been discussed in section 5.4, a study has been formulated to incorporate in this thesis. The study undertaken to enhance ways to solve the frequent flooding that is causing the people and the government billions of dollars in recovery attempt. Studies are based on several characteristics as below and major key area will be discussed further in later section;

- River channel improvement
- Floodway
- Retarding basin and Control Basin
- Protection against storm surges(usually coastal area only)
- High standard embankments (usually for dams)
- Efficient Flood control measures
- Flood warning system
- Erosion control to reduce silt sediment in the river bed

- Solid waste management
- River management

5.5.1 River Channel Improvement

The main scope of river channel improvements is widening the existing river channels to cater future flood water surge. The river beds are dredged to that the discharge of the flood water will not erode the sides of the rivers that cause sedimentation on the river base.

5.5.2 Floodway

Floodway are designed to carry the flood water from the city without discharging using normal drainage system that usually discharge directly to the rivers causing the water level in the river to rise significantly causing flash flood. The flood ways are usually designed to carry the flood water away from the city before discharging back to the river. (E.g. SMART Project)

5.5.3 Retarding Basin and Control Basin

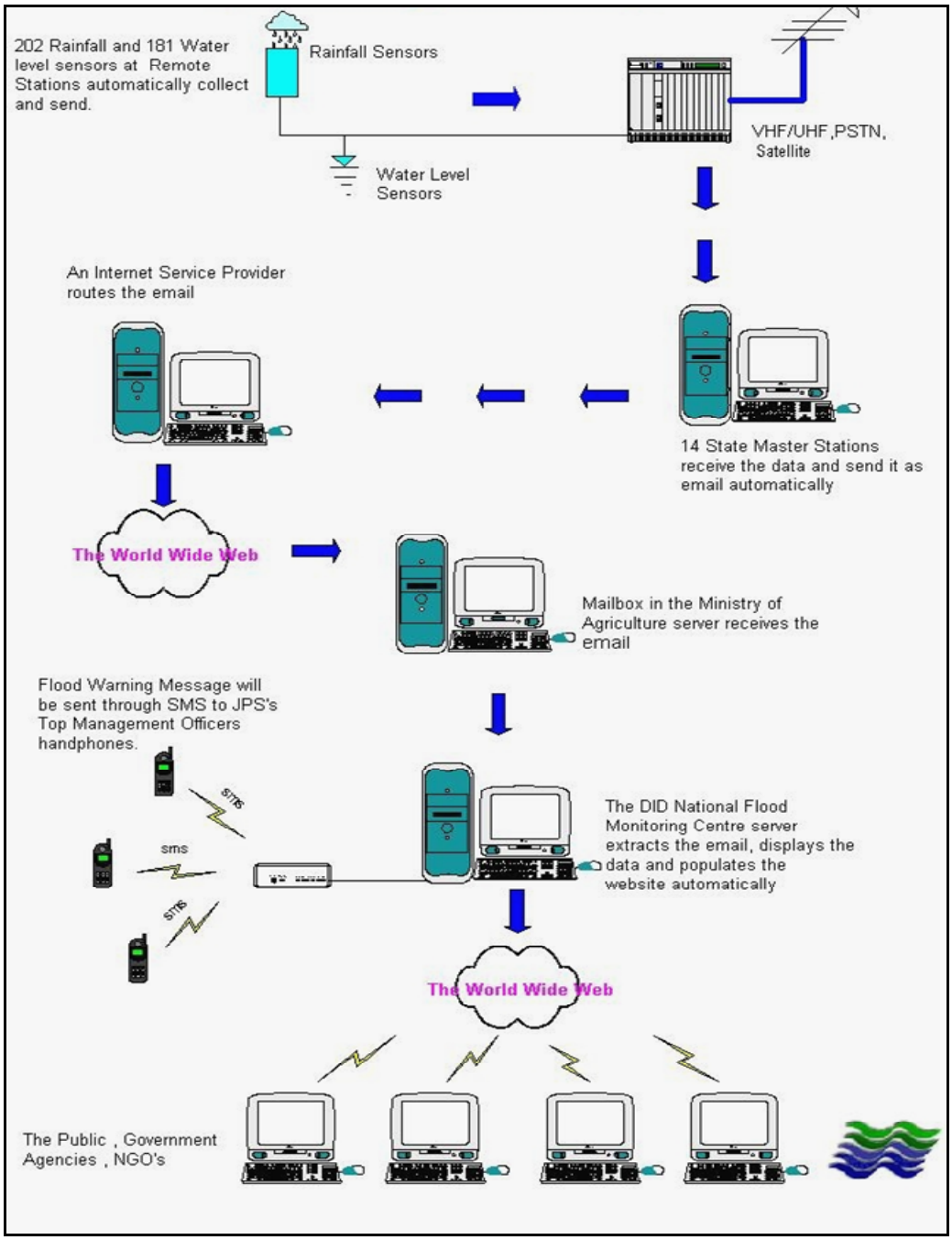
Retarding basin is built to store the water from floodway during heavy storm. The flood water will be channelled through the floodway to a retarding and control basin. In here the water will be stored and gradually released back to river downstream. Usually retarding basin is built in big capacity and additional basin are built beside so that future capacity and excess water that surge higher than the normal storm can be stored here. The retarding and control basin can act as water source (K.Ramadasan, M.N.A Salam, S.Kumaran & B. Perumal, 2000).

5.5.4 Efficient Flood Control Measure

Flood control measures are very important because this is the key step in controlling flood fluctuation in urban or rural areas. In current year urbanization controls the environment as there are no balance or precaution step been taken in order to control any natural disaster. River basins are being targeted as the key areas of development and this causes the basin to loose their natural water containment and retarding functions.

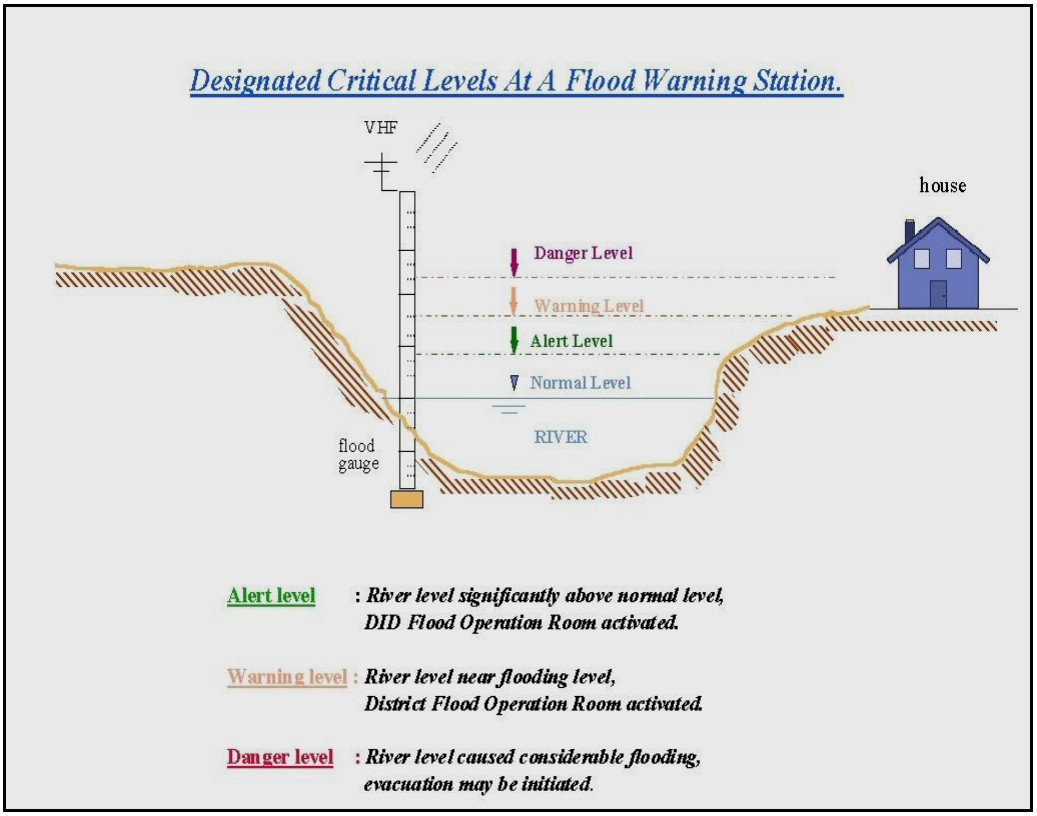
When urbanization or development takes place nearby river basin, the dense population that concentrates in this particular place causes more damage or what we called "damage potential". This can be overcomes by proper development coordination through the formulation of basin development that will includes flood warning system and efficient systematically evacuation system. This plan also formulates a comprehensive plan to reduce the damage to the environment during and after the development (K.Ramadasan, M.N.A Salam, S.Kumaran & B. Perumal, 2000).

5.5.5 Flood Warning System



Source: Department of Sanitation and Irrigation, Malaysia

Figure 5m: Flood Warning and Information Network



Source: Department of Sanitation and Irrigation, Malaysia

Figure 5n: River Warning Network in Malaysia

The flood warning system is very important as this is the only early warning system that can detect the rise of the river level during heavy thunderstorm. The system was designed by the Department of Sanitation and Irrigation of Malaysia, to minor all the rivers throughout the country. The main focus in this section was given to the design for rivers surrounding Klang Valley. The warning and detecting system can be seen in (Figure 5h and 5i). The information system plays the major role the get the information from all the station situated along the river side, process the information and channel the information to the authority further immediate response. Telecommunication system such as the "short messaging service" are now used as to spread out the flood warning as this services are very handy in the 21st century.

5.5.6 Control to reduce silt sediment in river bed

Sedimentation of silt in the river bed also causes flash flood as the silt reduces the depth of the river and causes the river to overflow when there are normal rainfalls. The silt causes the river to loose the original capacity to channel the water during the rain storm. Rivers in Kuala Lumpur are having the same problem as most of the river beds are filled with eroded silt from the river banks and also from the soil erosion due to heavy development along the riverside (K.Ramadasan, M.N.A Salam, S.Kumaran & B. Perumal, 2000). To overcome this problem the government spent millions of dollars to clean up the river beds frequently by using and excavator the scoop out the silt from the river beds. Embankment wall are built on the sides of the river to reduce the soil erosion that happened during heavy thunderstorm (Refer to Figure 5i).

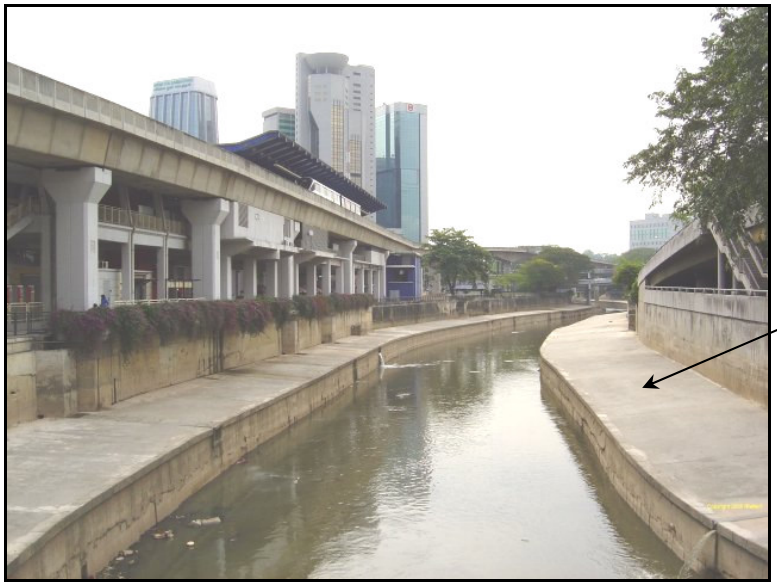


Figure 5o: Concrete wall to reduce soil erosion in Klang River

5.5.7 Solid Waste Management

Solid waste management for rivers is very important as more and more river pollution based on solid waste especially rubbish. These are a common problem for Kula Lumpur city as most of the rivers are polluted with garbage that are clocking and reducing the size of the river. These are one of the main causes of flooding as the flow of the river is being disrupted. In monsoon season these will cause bad odor as the rubbish degrades in the river and causes the diseases to spread (e.g. Denggi Fever). Illegal squatter that are very common site in Kuala Lumpur city uses the rivers as the main way to channel all the solid waste including the houses sewerage system.

Figure 5p: Squatters near rivers in Kuala Lumpur

Most of the squatters are not equipped with the proper centralized sewage system. Decayed solid waste in waster causes deterioration in water quality. It is estimated that around 4.5million liters/day of sullage water from the squatters are channelled into the rivers. The government has spent millions of dollars to clean up the rivers weekly and also install filtration chambers to filter out the rubbish from the rivers. The squatter's problem is still under the government consideration as there are political issues involved here.

5.5.8 River Management

River management is one of the main things that can control all the issues discuss before. Implementing regulation and to promote the importance of rivers is also the key characteristics to reduce the river polluters. Proper river management is also important because rivers channel the storm water during monsoon season. Currently river management basically involve managing the natural resources of river basin, control of soil erosion and flood, land management nearby rivers and managing the water resources.

Most of our rivers are from the highly dense forest in highland areas and it is estimated around ninety percent of the rivers found in Malaysia are from natural forest areas (K.Ramadasan, M.N.A Salam, S.Kumaran & B. Perumal, 2000). The main concept of river management involves the management of the land usage near the river banks, along the river or up at the source of the river (upstream). Focus also should be given in conservation efforts so that rivers will be there for the future generation. There is awareness programmes such as 'One country one river' campaign been undertaken to educate all the people regarding the important of keeping the rivers as natural as possible.

5.6 Comparison between SMART & alternative solution

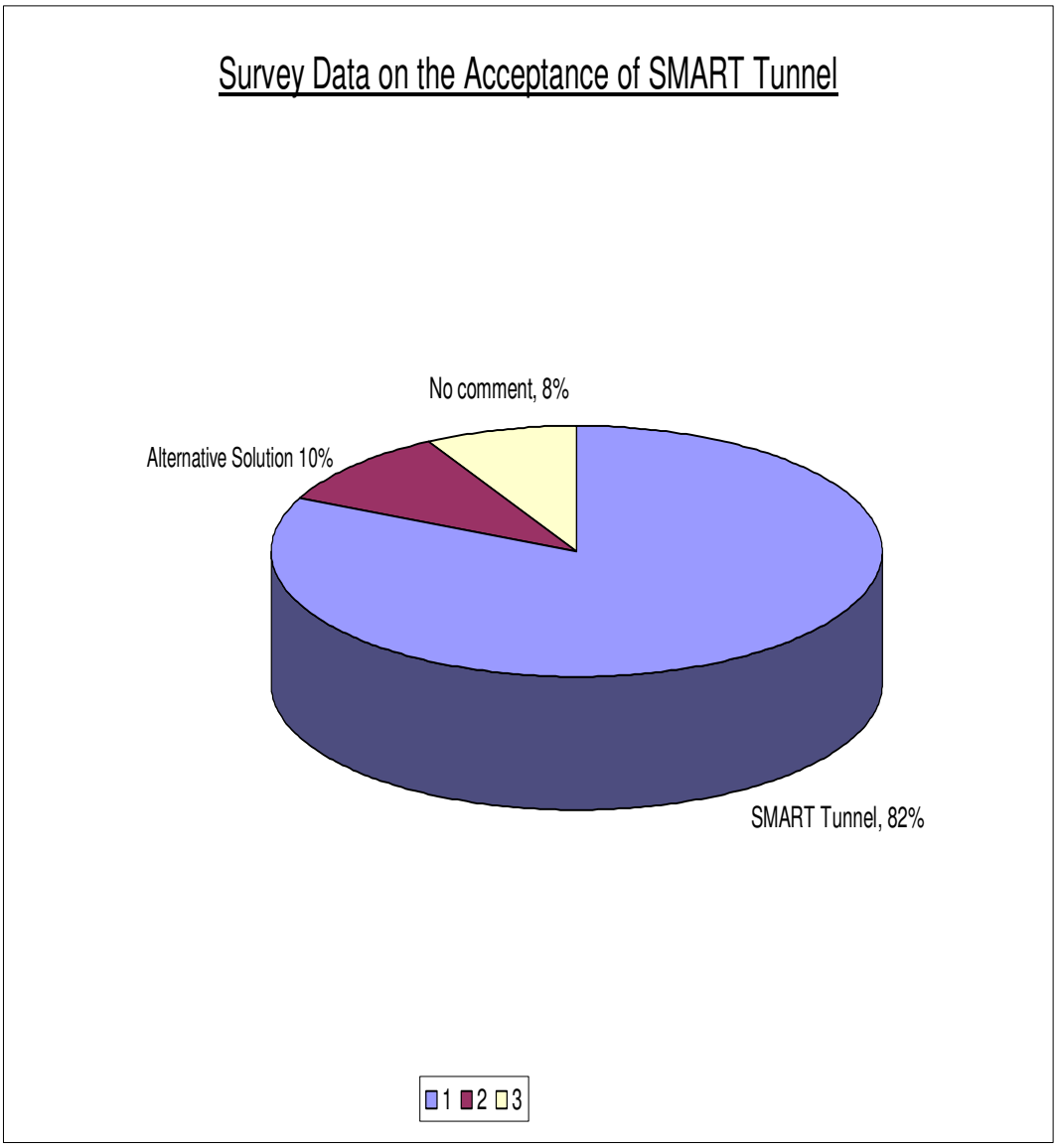
One of the main objectives of this research project is to see whether the necessity of SMART Tunnel project compare to alternative solution (if any). This section is not to undermine to The Government of Malaysia the expenditure of all the tax payer money to construct this tunnel. In the earlier sections, the original costing of this project is estimated RM 2.5 billion (AUD 0.83 billion). This is evaluating the necessity of this tunnel for the Klang Valley city.

Alternative solutions to solve flooding In Kula Lumpur due to heavy stormwater;

- Widening existing Klang, Gombak and Kerayong River that flows through Kuala Lumpur
- Using existing PUTRA LRT Tunnel as the stormwater diversion tunnel (Project scrapped)
- Kuala Lumpur Flood Mitigation Project

- Use concrete embankment to reduce the soil erosion that been reducing the river depth as silt are accumulating in the river bed.
- Controlling the urban development along the river banks in order to save the natural flow of the river.
- Implementing Stormwater Management

This above solution is also been undertaken together with the construction of the SMART Tunnel. This tunnel is the part of the "Storm water Management "process in order to solve the situation. Most of the solution are already been discussed in section 5.5. There is a issue regarding the usage of the existing PUTRA LRT Tunnel as stormwater channel, but the project was scraped as the solution will cause the existing usage of the tunnel as underground rail link to be interrupted. This will cripple the rail link at the city centre as this rail link is very important for Kuala Lumpur. There was a basic study carried out find out whether the tunnel project is accepted by the society. The results are shown in Figure 5Q



Source: Random Interviews conducted in Kuala Lumpur city

Figure 5q: Survey Data on the acceptance of SMART Tunnel

The above survey data are random interviews conducted on the streets of Kuala Lumpur regarding the society's view of the project. From the chart above we can say that eighty percent of the community welcomes the project as the best solution to solve the frequent flash floods in the city centre. The rest of the community are either against on the project because of the expenditure or have no basic idea regarding the SMART Tunnel Project

The Kuala Lumpur Flood Mitigation Project is also one of the solution proposed and been carried off. The project is estimated around RM 530 million (estimated AUD177 million). This is part of the Department of Sanitation and Irrigation's effort to relieve the flooding in Kuala Lumpur. This is part of the mitigation project for Gombak and Keroh River. The main scope of works that involved in this project is;

- Upgrading the present Gombak river diversion where the diversion is to channel more flood water from Gombak River to Batu Pond and from Keroh River to Jinjang Pond
- Along this diversion the construction of new barrage, a diversion channel to divert any additional incoming flow and enlargement of Batu Pond and Jinjang Pond (To store the capacity of 4.5 million and 2.5 million cubic metres of stormwater).

New connection Channel at Kampung Changkat under construction

Existing Channel at Kampung Changkat Diversion Channel

Source: Department of Sanitation and Irrigation, 2005

Figure 5s: Part of the work for the Flood Mitigation Project

5.7 Overall Conclusion

In this study of flash flood in Klang Valley, it was found that even though the alternative methods are cheaper but it is not for long term condition. This because alternative such as river widening project are proven cheaper but the results are temporarily and the government have to spend more money to overcome the problem in the future. The Kula Lumpur Flood Mitigation Project is the best solution as the flood water that are carried out from the city bypassing are estimated around 3,000,000 cubic metres.

This is more than current capacity of less than 1,000,000 cubic metres. There are other advantages in the progressing SMART Tunnel Project as this project is not only for floods mitigation but also for traffic diversion at the Southern Gate entry point to the city. As we know from previous section, the tunnel is dual purpose as it caters for the traffic congestion and also the flood water during heavy storm

The alternative method such as the river widening is short term improvements. This has to be done frequently has the silt sedimentation from the soil erosion at the river banks will keep on surfacing as more and more development are carried out along the rivers.

Chapter 6: Study on the Traffic Congestion

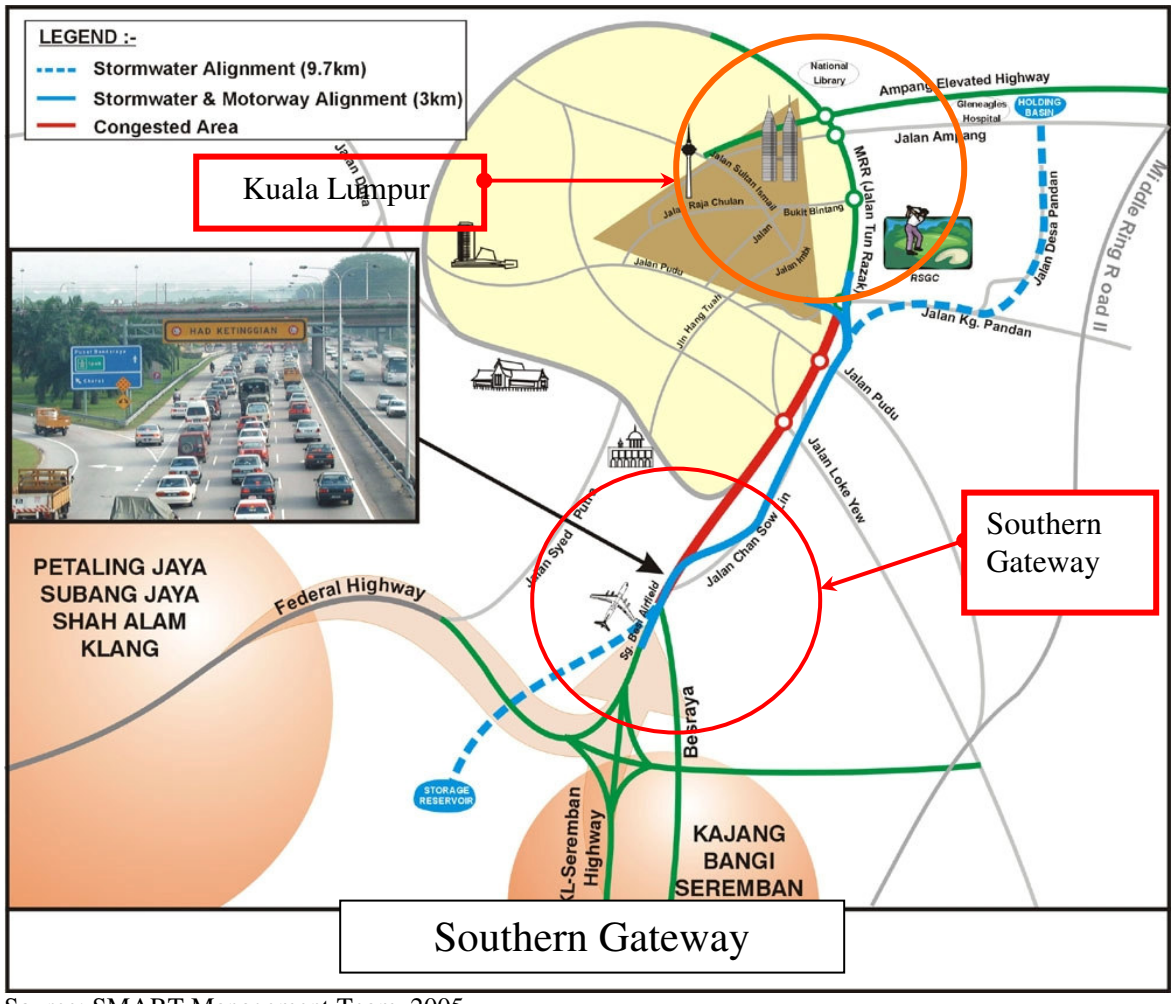
6.1 Synopsis

One of the major parts of this research study is the find out the main cause of the traffic congestion at southern gateway and the recommendation and solution to solve the cause of the traffic congestion. In Kuala Lumpur city traffic congestion is one of the major factors that cause problems to the traffic and highways built each year. Even though there are numbers of highway built to solve this problem but there will be traffic congestion especially during peak hours. One of the solutions that the government came out is the SMART Tunnel Project. This project is mainly as we know is to solve the stormwater problems and also the traffic congestion at the Southern Gateway.

Southern Gateway is one of the key entry points to the city from the south of Kuala Lumpur. This one of the most congested part of the highway as the highway interlinks the city with the residential areas in the south. There are approximately 1.04 million people resides in this area. Most of the people are working in the city, and usually travel using their own transport to work. The highways that are located in the southern gateway are KL-Seremban Highway, Besraya Highway and Sg. Besi Highway. This are the three highways that are passing through this area and most of the people heading towards the city are keen to use this part of the route as the entry point to city. The route connects direct to city centre as there is no detour involved in this route. This is one of the major points; high numbers of vehicles occupies this route daily.

This is one of the major parts of this research project as stated in the objectives and aims of this study. The study is essential to show whether SMART Tunnel is built to solve all the problems stated in the previous chapter. In this part of the study the causes and alternative recommendation will also be given in order to make this study more efficient.

6.2 Location of Southern Gateway



Source: SMART Management Team, 2005

Figure 6a: Location of Southern Gateway

The location of the Southern Gateway is shown in Figure 6a above. The red line in the tunnel alignment indicates the traffic congestion areas in that particular route. The blue lies indicate the tunnel alignment that passes through from the north to the south of the city.

6.3 Main causes of traffic Congestion in Southern Gateway

The traffic congestion is one of the key criteria in this research study. This is because SMART Tunnel is actually built to cater and solve the traffic congestion in Southern Gateway. This is one of the main principles of the tunnel other than to solve the flooding in Kuala Lumpur city centre. As we know from previous chapters, Kuala Lumpur is capital city of Malaysia. The population on Kuala Lumpur is approximately 1.42 million people (DBKL, n.d.). The population is still growing and making the city overcrowded. The city is dense with high population because this is the key state of education, economic and living.

Figure 6b: Traffic Congestion in Southern Gateway

In this research project the methodology to find out the main causes of the traffic congestion in the Southern Gateway are basically by;

- Site visits to the affected areas
- Interview with
  - Malaysian Highway Authority
  - SMART Management Team

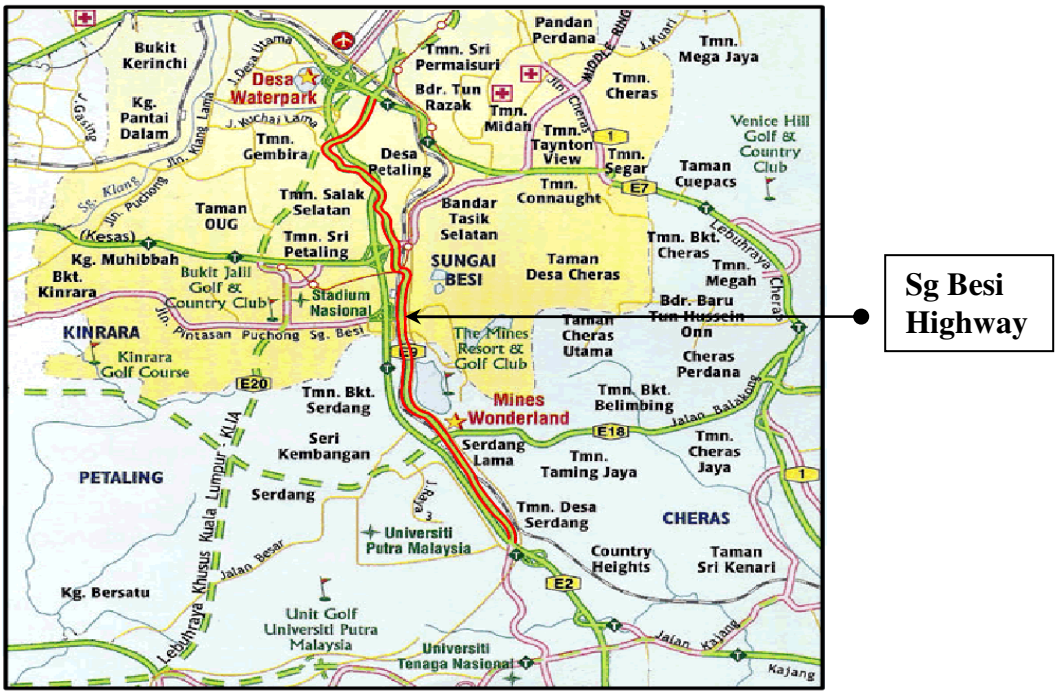
From the interview there are several causes have been identified as the main contributors to the traffic congestion in Southern Gateway such as;

- Several Intersection joining to single highways
- Numbers of cars have drastically increased
- High traffic from the South heading towards the city using the same highway

These are the main causes that are identified throughout the investigation that causes the traffic congestion in the Southern Gateway entry to city. Further discussion will be done in the following section that breaks up to individual causes.

6.3.1 Several Intersection causes

The intersection is one of the probable cause of traffic congestion in Southern Gateway. The Southern Gateway is connected by two intersections that are adjoining to the Sg Besi Highway. This is the main road that connects the Southern Gateway to the city centre currently.



Source: Lembaga Lebuhraya Malaysia, 2005

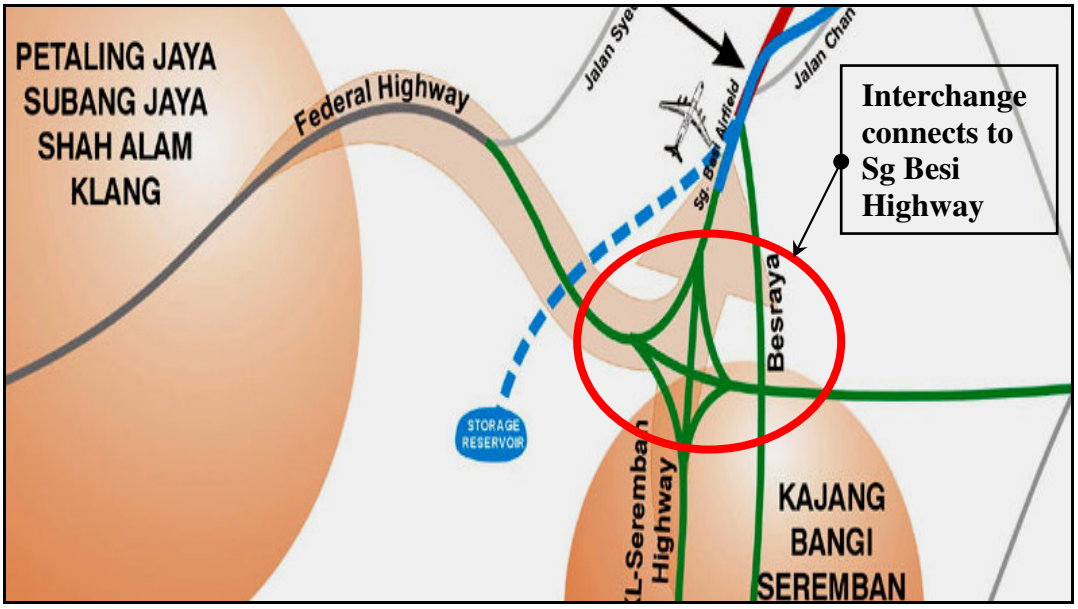
Figure 6c: Road Network at Southern Gateway

As we can see in Figure 6a the SMART Tunnel alignment are actually designed to run with Sg Besi Highway alignment in order to divert the car in the tunnel to solve the traffic congestion in this particular area. In this are one of the main cause of the traffic congestion is, there are two intersections cutting through the Sg. Besi Highway. The Two highways are;

- Besraya Highway
- KL-Seremban Highway

The intersection causes major traffic congestion because the two intersections of highways links to this road, the Sg Besi highway could not cater the intense increment of cars during peak hours. Most of the people that live in the Southern Gateway are working in Kuala Lumpur city. This is the shortest and cheapest route for them in order to get into the city. The maximum toll rate here is at RM 2.00 (AUD 0.70) (LLM, 2005). Current government planning could not re-locate the two interchange that connect to this highway.

When the Besraya and KL- Seremban Highway were built there was no consideration that this location will be overcrowded in the future. So to overcome this problem the government came out with SMART Project that have dual purpose. This tunnel is to cater and channel the stormwater from the city centre to downstream of the river and also to disperse the traffic congestion that is currently happening frequently in Sg. Besi Highway.



Source: SMART Management Team, 2005

Figure 6d: Intersection Links

The tunnel alignment was set to follow as in Figure 6a as in previous pages. This is to reduce the numbers of cars taking the Sg. Besi route to the city by giving the road users alternative to use the tunnel as the passageway to get into the city by not using the current highway. This will directly reduce the traffic in that particular highway and eventually the traffic flow will be smooth with any interference in the near future. This dual purpose tunnel will help the people of Southern Gateway to get into the city fast and cheap.

6.3.2 Increment of vehicle statistics

The population in Kuala Lumpur had increased significantly since the establishment of Kuala Lumpur as capital city of Malaysia. The current population that resides in Kuala Lumpur is estimated at 1.5 million people (Kuala Lumpur Information, 2005).

It is estimated the numbers of cars have increased drastically since 1981 in Kuala Lumpur. There were 61, 752 numbers of cars in 1981 and increased to 247, 677 numbers in 1990.In 200 it was estimated the numbers of cars will reach 263 per.1000 population. Averagely it will be 1 car to every 3.8 people that resides in the city. The car tolls still increasingly at the rate of 25% to 34% (Abdul AB. Rahman, n.d.).

In this case the solution is quite difficult as there are more and more people buying cars in Malaysia. There are government efforts to reduce the umbers of cars entering the city by implementing different strategy plans. Plans such as;

- Vehicle zoning
- Increase the road tax
- Public transport projects
- Car pooling systems

All this plans were developed after through study have been conducted tom find the probable cause after significance increase of vehicle in the city. The plans did not worked out as planned as there numbers of setbacks that had been identified. They are such as;

- Protest from road users regarding the road tax increment
- Implementation of vehicle zoning to allow vehicles with different colour plates to enter the city in different days still under study
- Unreliable and overcrowded condition cause people to use own vehicle
- High cost imposed for public transport causes people to compare in usage of own vehicle
- Car pooling system failed because lack of interest from government and society.

6.3.3 High Traffic Flow

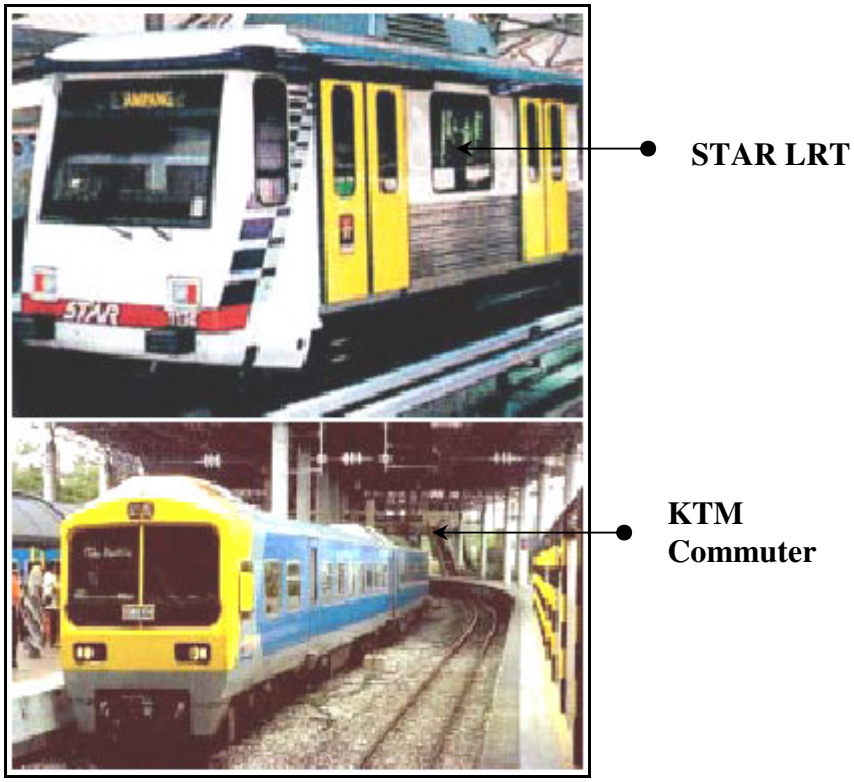
High traffic flow from the south heading towards the city is one of the probable cause of the traffic congestion in the Southern Gateway. The traffic flow from south of Kuala Lumpur are mainly due to the residential areas that are located in this part of Kuala Lumpur. Most people that are working in Kuala Lumpur are living in the southern part of the city. As discussed in section 6.3.2, increase in the population in the city in recent years had caused the increase in vehicle ownership in the city. Most people like to stay away from the city centre and travel to work everyday in their own vehicle. Southern Gateway is one of the residential areas the have been occupied by the busy city people. The usual traffic congestion will occur during peak hours in weekdays, public holidays and also commonly during rainy season.

In order to overcome the traffic congestion in this particular area, the government had proposed some solutions to overcome this issue. Some of the solutions are;

- SMART Tunnel Project
- Enlarging the current highway lanes
- Proposing alternative route to the city centre
- Increase the efficiency of the public transport in this particular area.
- Sponsoring campaigns to reduce the numbers of vehicle by carpooling

Some of the above solutions are already been undertaken. One of the efficient solutions is the SMART Tunnel. This tunnel not only will overcome the flooding in the city centre bit also to disperse the traffic in Sg. Besi Highway and giving the road users alternative route to head to the city. It is estimated that 8.3 million person trips are made daily from Klang Valley (DBKL, n.d.).

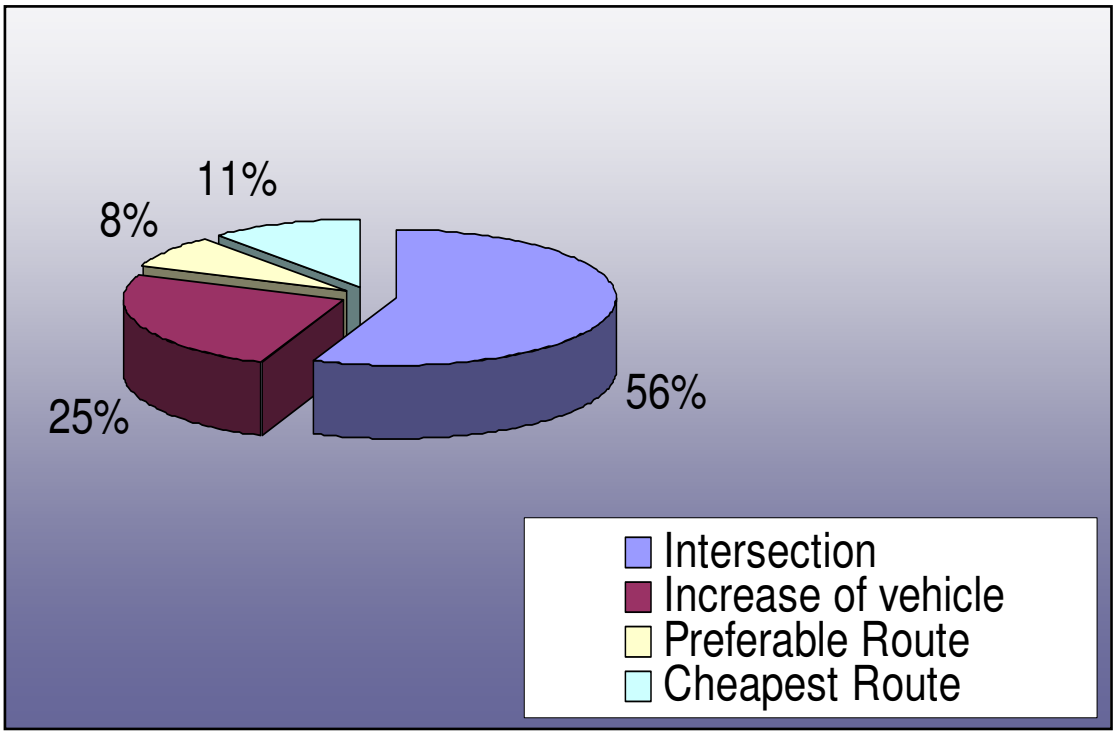
Alternative routes such as the new Middle Ring Road are one of the solutions proposed in order to reduce the traffic flow into and out of the city during the peak hours. Rail networks such as the KTMB Commuter and the STAR Light Rail Transit the outcome of the improvement of public transport outside the city. This rail link connects the people daily from the city to outer part of Kuala Lumpur such as Southern Gateway.



Source: DBKL, n.d...

Figure 6e: Rail Transportation System in Kuala Lumpur

6.4 Public Survey on the Traffic Congestion



Source: Random Survey conducted at Southern Gateway, 2005

Figure 6f: Public Survey on Traffic Congestion

In order to find out the main reason of the traffic congestion in Sg. Besi Highway, a public survey was conducted randomly to support the reasons given in the previous section of this chapter. This survey was done randomly as it is difficult to get the information from the road users of the Sg. Besi. In order to make the survey as simple as possible only one question was given to the road user that is;

What is the main course of the traffic congestion in Sg. Besi Highway?

- *Cause by two intersections adjoining to this road*
- *Increase in numbers of vehicle in this road*
- *Sg. Besi Highway is the preferred route to the city*
- *Sg. Besi Highway is the cheapest and shortest route to the city*

The questions was given to approximately 100 road users using the Sg. Besi highway and the results are seen in the pie chart in Figure 6d above.

6.5 Overall Conclusion

In this part of the research project it can be seen that the main cause of the traffic congestion in the Southern Gateway are manly because of the intersection problems. The intersection such as the Besraya Highway and the KL-Seremban Highway are the routes that are adjoining the Sg. Besi Highway. The intersections are very closely apart that cause the traffic to be diverted into this route. The Sg. Besi Highway could not cater the increase in traffic mainly during peak hours and rainy season. Other probable causes are the increase in the vehicle ownership in Kuala Lumpur because the numbers of cars in the city had significantly increased in recent years.

As a conclusion there are several project been undertaken in order to reduce the traffic congestion in Southern Gateway and also other parts of Kuala Lumpur. SMART Tunnel is one of the project as this project is the most efficient to solve the traffic congestion as the alignment of the tunnel is set from the south heading towards the city centre. The only disadvantages of this tunnel as the tunnel will be closed to public and re-open back after 48hours of major storm. This will cause the traffic congestion problems remains unsolved during the major stormwater discharge by the tunnel. In other way, this research project had pin point one of the main areas that the government have to look into in order to solve issues arise regarding the flooding and traffic congestion in Kuala Lumpur.

Chapter 7: Review on SMART Tunnel Design

7.1 Design Overview

Every project that had been around the world went through a lot of designing processes before the structure can be seen visually. SMART Tunnel project is a very unique design. This is because this is a one of the kind project that combines the wet and dry tunnel in one structural element. This tunnel comprises three decks. Two of the top decks are for the vehicles and the bottom deck is for the stormwater channel. This tunnel was proposed because of the increasing traffic jam in Kuala Lumpur and also to flooding in the metropolitan city. The main purpose of this tunnel is to:

- Stormwater Tunnel
  - To divert the floodwater away from the city centre by using a bypass
  - To regulate and control the water level in the existing Klang River throughout the year
  - To improve the efficiency of the hinterland drainage within the city
- Motorway Tunnel
  - To provide reduce the traffic congestion on the main Southern gateway to the city centre(KL – Seremban Highway) and West(Federal Highway)
  - To provide road users alternative traffic dispersal system for that particular area.
  - To reduce road users travelling time into the city centre.

The stormwater tunnel will be built with the length of 9.7km and the diameter is 13.2m. The motorway decks will be a dual deck with traffic flow through on one deck and opposite direction on the deck below with a length of 3km. The tunnel located in vicinity of the urban metropolitan city, Kula Lumpur. Special care is taken not to disturb the soil formation that will cause structural imbalance to existing structure surrounding the tunnel. The main care was using tunnel boring machine as part of the construction process. The tunnel is made up with pre-cast concrete linings

7.2 Tunnel Designing Method

Design and construction of tunnels are very unique and some designers considered it as an art. There are different types of tunnels available currently around the worlds that are operating smoothly without any difficulties. Careful planning has to be done in order to produce durable, longer lasting and safe tunnel. Tunnels are designed according to several criteria such as;

- Cost of the tunnel
- Mechanized or Hand-held machine
- Length and size of the tunnel
- Ground formation at the location of the site
- Fastest and safest method
- Labour
- Location (Urban, remote, mountain areas, under sea)

Most tunnels around the world are designed foe special purposes. The main purpose is to transport or move from one point to another designated point without any interferences that previously been caused. These interferences are such as sea, mountain and congested area such as cities. Tunnels today are used vehicles such as cars, subway rail, stormwater channel, water supply and etc. In tunnel design the safety factor to the users plays significant important role planning and constructing a particular tunnel.

7.2.1 Characteristic of Tunnel Design

There are some characteristics in the design process that will result in efficient tunnel construction. There are such as:

- Interactive
  - This is the part where the communication between the designer and the builder is accurate and efficient to pass all the necessary information for proper interpretation.
- Integrative
  - These where the designers plays the major role when he/she applies all the knowledge to design a satisfying tunnel
- Iterative
  - Different method of approach should be taken in order to produce a good and high safety featured tunnel. This may include trial solutions that will improve the tunnel designing sector.
- Gross-Disciplinary
  - The important individual that is given the task of designing particular tunnel should combine in depth knowledge of their specialties together with moral awareness.
- Creative
  - Requires the designers imagination that is commonly used in alternative sequence of work in order to design effectively
- Holistic
  - This is all the aspects of evolving solution are taken into consideration.
- Ethically grounded
  - Design and built with the interest of all the stakeholders and also the need to respect the social and environment issues and also taking responsibility to all the actions taken.

(A.M Wood, 2000)

7.2.2 Design Process

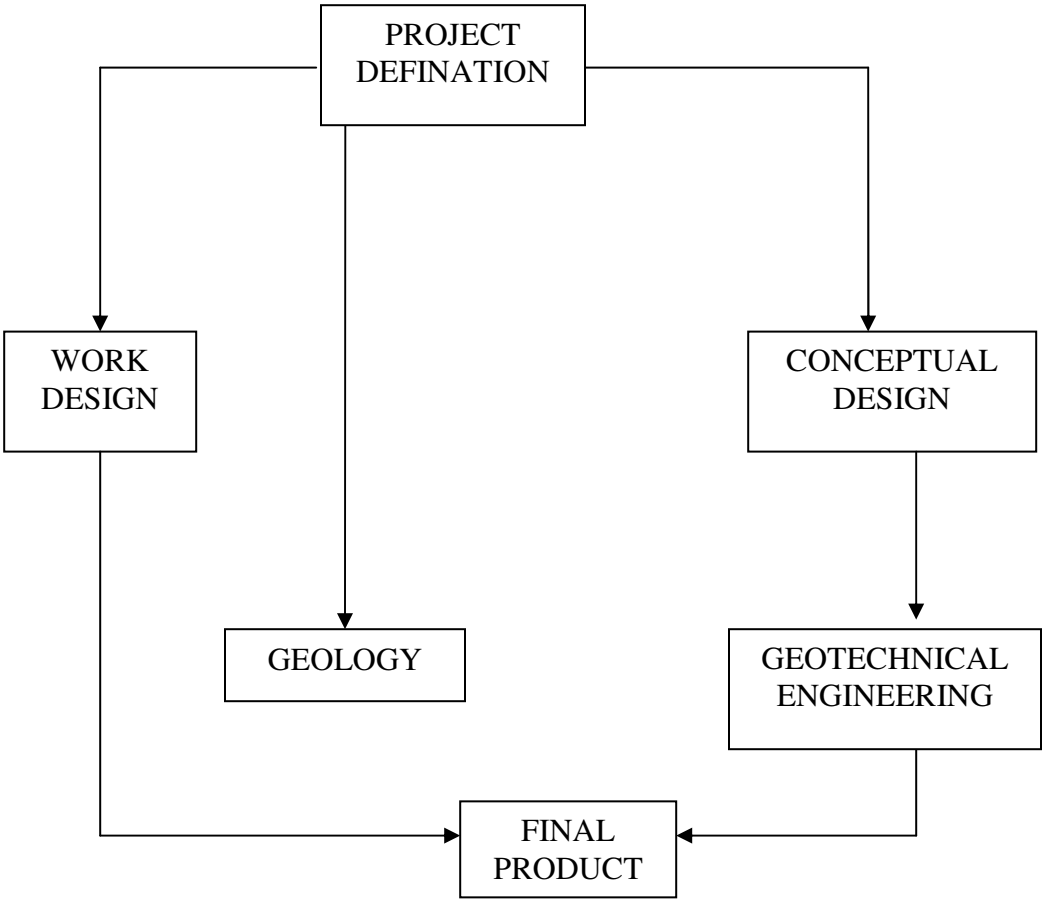
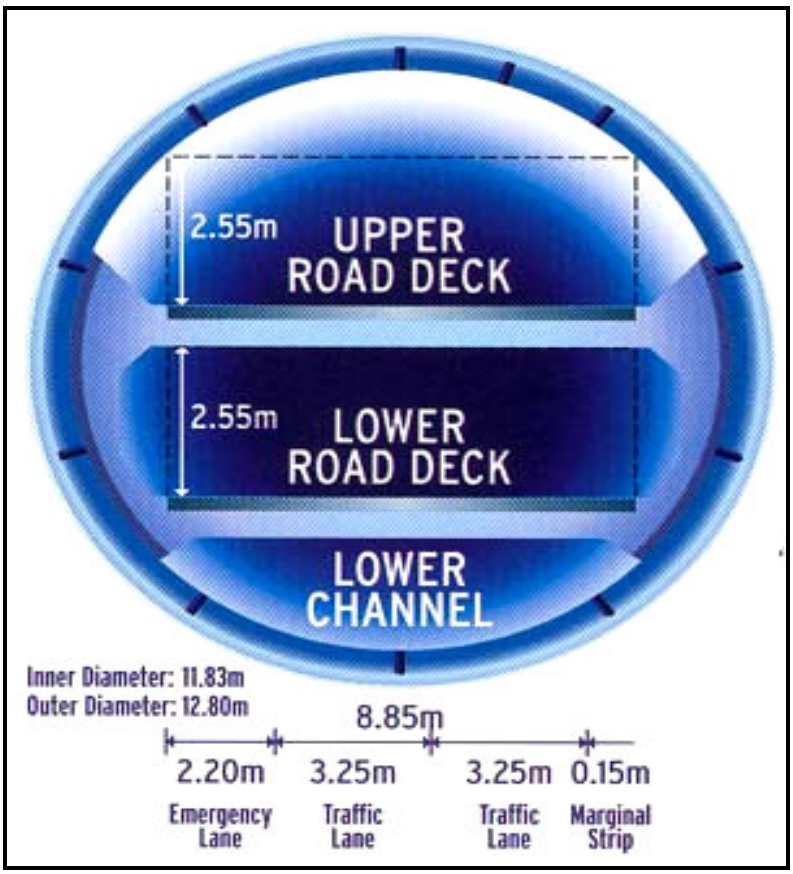


Figure 7a: Basic Work Principle Structures

The design or work principles for most construction work and design are very complex. The complexity is the understanding of the client's requirement, financing, available resources and the technology adopted in the design and built concept. The basic chart above describes the inter-relationship between all the personnel involve in the design and built stage. The geology and geotechnical issues are the main criteria that have to be concern in any tunnel design such as SMART Tunnel. This is because any tunnel design is based on the soil formation surrounding the built tunnel. So, the geology and geotechnical engineering have to be in alignment in order to produce a good design.

7.3 Choice of Design

The SMART Tunnel was designed to cater the frequent flooding in the Kuala Lumpur city centre. The tunnel also acts as the road diversion to ease the traffic congestion in the Southern Gateway. This is a most frequent congested area as the current road caters for traffic that comes into and out of the city especially peak hours. This gets worst during rainy season. This project comprises the built, operate and transfer (BOT) that will efficiently control the operation of the tunnel when it commences to operate. The tunnel comprises three decks that is upper, lower and lower channel as shown below.



Source: SMART Management Team, 2005

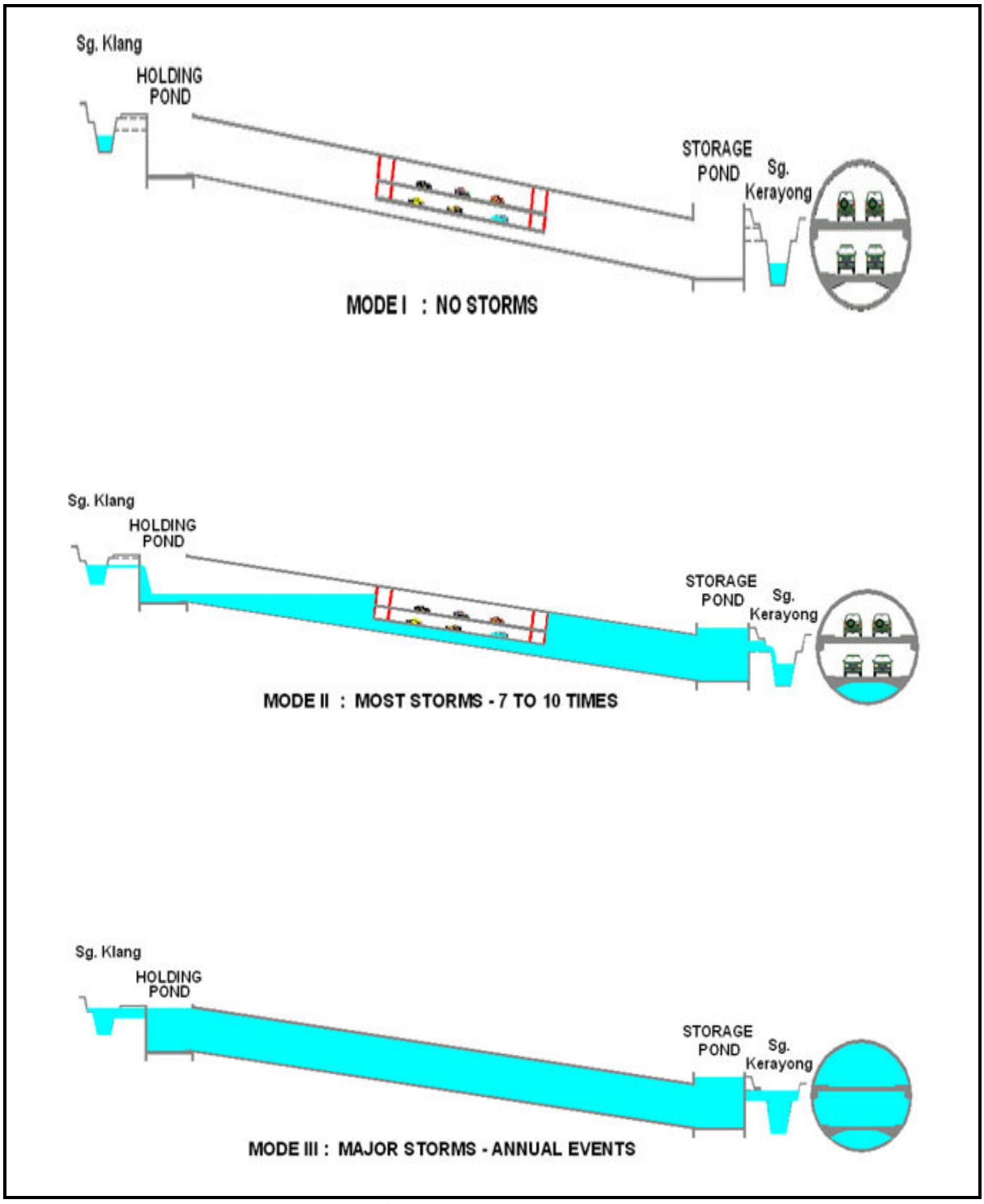
Figure 7b: SMART Tunnel Sectional view

7.3.1 Principle of SMART Operation System

The Stormwater management and Road Tunnel have a unique feature that distinguishes the tunnel to other tunnels in the world. This is because the tunnel is the one of the kind project in the world that combines the concept of wet and dry tunnel system. The tunnel caters for vehicle passage way and also channels to divert the stormwater from Kula Lumpur city centre. The design view can be seen in Figure 5b. The main operation of the SMART Tunnel mainly evolves on three principles based on the flood discharge at the Klang River and Ampang River confluence includes the operation of the traffic diversion motorway.

The first principle will be under normal condition. This is where, there are no flood situation arises in the city centre or low rainfall. In this case the overall upper deck and lower deck will be used fully has the traffic motorway. The computerized operation system will monitor the situation in order to run the tunnel smoothly (Refer to Figure 7c). The second mode is when there is flood water is diverted into the bypass tunnel by using the third deck (lower channel) .This happen when the rainfall is moderate and can be channelled thru only one deck. When this happen, the tunnel is still open foe vehicle to pass through as the bypass road. The two upper deck will be kept open include the lower channel section as the water is diverted (Refer to Figure 7c).

The third principle is when heavy storm hits the city. When this happens the system will close down the upper deck and lower deck to vehicle. The tunnel will be fully inspected before it is closed down to be fully used as a channel to diver the water. After these decks are closed the tunnel will be used only as stormwater divert system. The flood water tight gates will open to allow the flood water to be channelled into the tunnel. The three decks will be used to channel the excess water from the city to a holding pond (Refer to Figure 7c). After the storm is over the tunnel will be cleaned from rainwater sludge before vehicle is permitted to enter. The holding basin at the end of the channel is equipped to cater more than the allowable water in order operates the system more efficiently.



Source: SMART Management Team, 2005

Figure 7c: SMART Tunnel Operation Modes

7.4 Location of the Tunnel

In most countries the tunnels are built underground and some the choices to built structure above ground. There will be always debate whether a particular infrastructure should be built underground if the alternative are there that the tunnel can be discarded and a suitable road diversion or other structure can be replace the tunnels. This is same for SMART Tunnel project. There always choices or questions raised whether above ground or below ground. In this matter the influence criteria, design features, the difficulties, the costing and most important the political monopoly in this business. Mostly it is influenced by the particular project location and the feasibility to build the tunnel.

As we understand from Chapter 3 the location where this tunnel is build is in the formation of limestone. Most sub-soil profile in the Klang Valley is on the karstic limestone and clay formation. This allows the construction of the tunnel to be feasible as the formation reduces soil collapsing. There are challenges in constructing the tunnel on this soil formation as karstic limestone's have the properties of pinnacles and cavities. Urban transportation system expands in order to cater the increasing population in the areas. In order to develop proper transportation for particular urban areas, careful study had to be conducted in order to reduce the inefficiencies in the system and also the most important thing is the consideration of environmental problems or impact.

Underground tunnels are usually preferred as it gives allowance on space as the whole tunnel for the urban transportation system is constructed below ground. This is an advantage for the tunnelling works as there are less obstruction such as buildings in line with the tunnel alignment, traffic and safety of the public. Even though there are good to built tunnel below ground, there are also negative impacts from this consideration. As, we know after going through this thesis report construction of a tunnel is not as simple as it looks. It needs careful planning as the location of the tunnel whether above or below ground plays a major role in the development of urban transportation system.

7.5 Effectiveness of Design

The design of underground tunnels depends on the basic handling and the capacity of the tunnel to complete the main purpose the tunnel was built. Most tunnels around the world are built with engineering efficiency. SMART Tunnel is also one of them as the tunnel construction was planned and re-planned so that every aspect of the tunnel utility and safety are achieved in order to provide better transport system to the society. In this part of the research study, we will look on the basic requirements of the tunnel that will serve the society in the best manner.

7.5.1 Tunnel lining

In the design of the tunnel lining, SMART Tunnel uses pre-cast tunnel lining segments. The lining installation is simultaneously as the drilling work. This is one of the major advantages of using the Slurry Shield TBM machine as the drilling tool. After the TBM machine progresses with the drilling work, the installation of the tunnel lining work are done using the same rails used by the TBM machine as the movement rail. The rail provides easy access for the tunnel lining to be brought into the tunnel and the installation works progresses as the drilling continues. A single ring- shaped steel reinforced lining segments are used as the mould to support one segment to the other segments as the joining of the segments took place. A crane that are controlled using remote will be used to lift up and place the lining at the location to be installed

Source: Herrenknecht, 2005

Figure 7d: Tunnel lining works in progress

The TBM machine will drill the tunnel with the help of the side jacks as the stabilizers. The shield of the TBM machine provides 15cm gap between the tunnel lining and ground soil that will be injected with special cement grout. This is very important as when the TBM advances there are no support between the TBM and the ground soil. This gap allows the tunnel to be reinforced with the cement grout while the tunnel lining work progresses. The cement grout is very important as it seals off the seepage of water into the tunnel construction works. If the water seep through the tunnel works it will cause major cave in as the water pressure from ground water flow will push through into the seepage fissures and finally will break through into the open area of the tunnel construction.

After the surrounding soil is improved with the spray of the cement material, the tunnel lining is installed in place. Ring joints and parallel joints are used as the support when the tunnel lining work progresses (Refer to Figure 7g). The tunnel lining are sealed with neoprene band which circulates into groove during the manufacturing and installation of the linings. The sealing of tunnel lining takes place by placing two segments and pressing the seal profiles together. The necessary force is applied to the ring joints by the tunnelling jacks of the shield and it is estimated that approximately 5600 tonnes of force is applied.

Source: Herrenknecht, 2005

Figure 7e: Tunnel Lining Products

Source: Herrenknecht, 2005

Figure 7f: Reinforced Steel Ring

Source: SMART Management Team, 2005

Figure 7g: SMART Tunnel Lining Work in Progress

7.5.2 Surrounding Soil Geology

In this part a brief explanation will be done as most of the soil geology studied had been covered in Chapter 3 of this research project. As we know from previous chapters the surrounding soil geology of this particular tunnel is mainly Karstic Limestone. SMART Tunnel is built on the formation of limestone and clay soil. This is the main soil formation in Klang Valley. This sometimes can be considers disadvantages to the tunnel builder as the formation in Kuala Lumpur mainly contains pinnacles, cavities and sinkholes. The main purpose to study the soil formation is to determine the suitable construction method that can be used in particular soil formation such as this project. The slurry shield Tunnel Boring Machine is used to solve the caving problems.

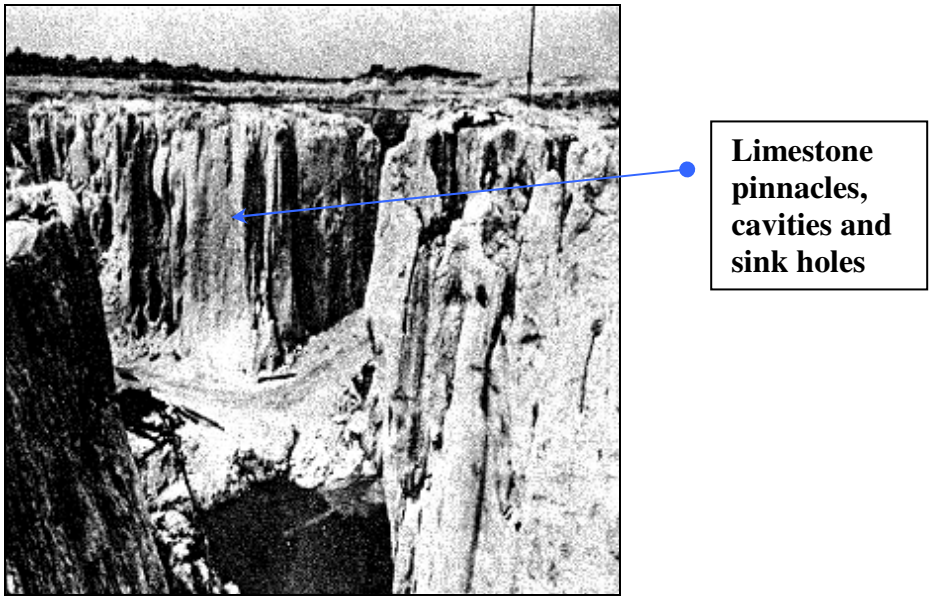
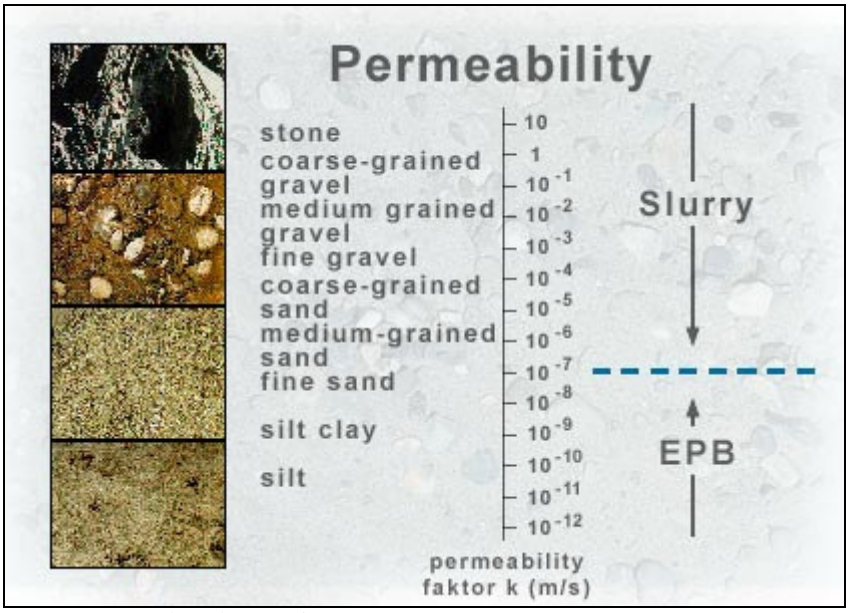


Figure7h: Karstic Limestone Formation



Source: Herrenknecht, 2005

Figure 7i: Soil Analysis for Tunnelling Works

In the data above is the method used to choose the machine and the construction method for the tunnel project. The usual applications are the liquid support (slurry) and the earth pressure balance method (EPB). These are the common method used after the analysis of the soil formation. The main characteristics that have to be taken into considerations for tunnels are;

- Water permeability
- Grading curve
- Mineralogy
- Ground quality
- Consistency limits
- Rock strength

(Herrenknecht AG, 2005)

7.6 Safety Features of SMART Tunnel

Safety is one of the key aspects that every engineering field has to consider. Every single thing that are built or designed is for the sake of the people's use. So safety is one of the main considerations a designer has to put into the design. Safety can be in different form such as for civil engineering any building or infrastructure has to be safe for every individual to use. In mechanical engineering the designer have to make sure every mechanical part in machinery have to be in proper order in order for people to use.

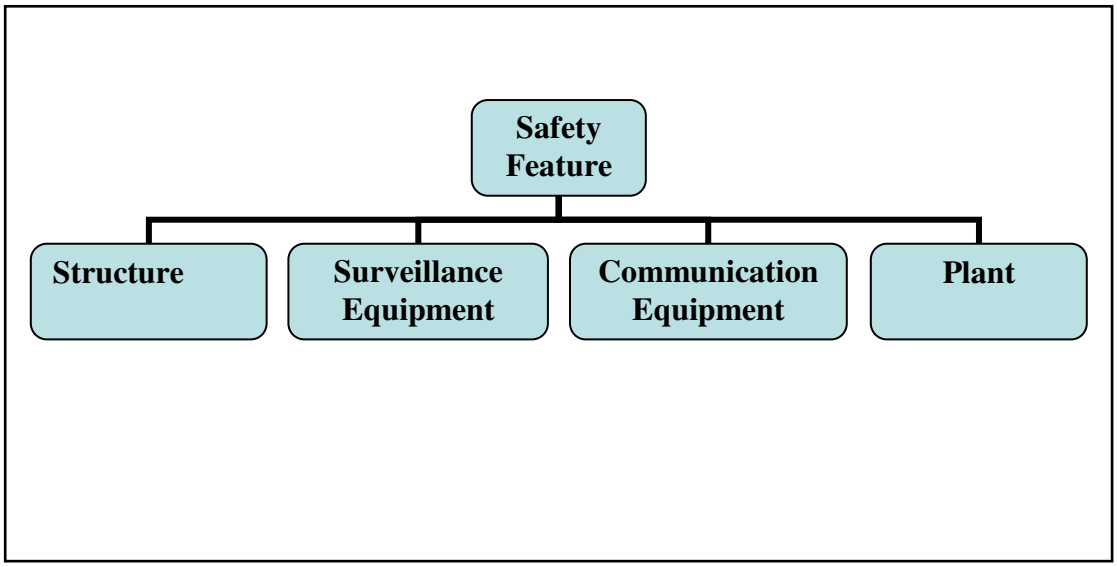
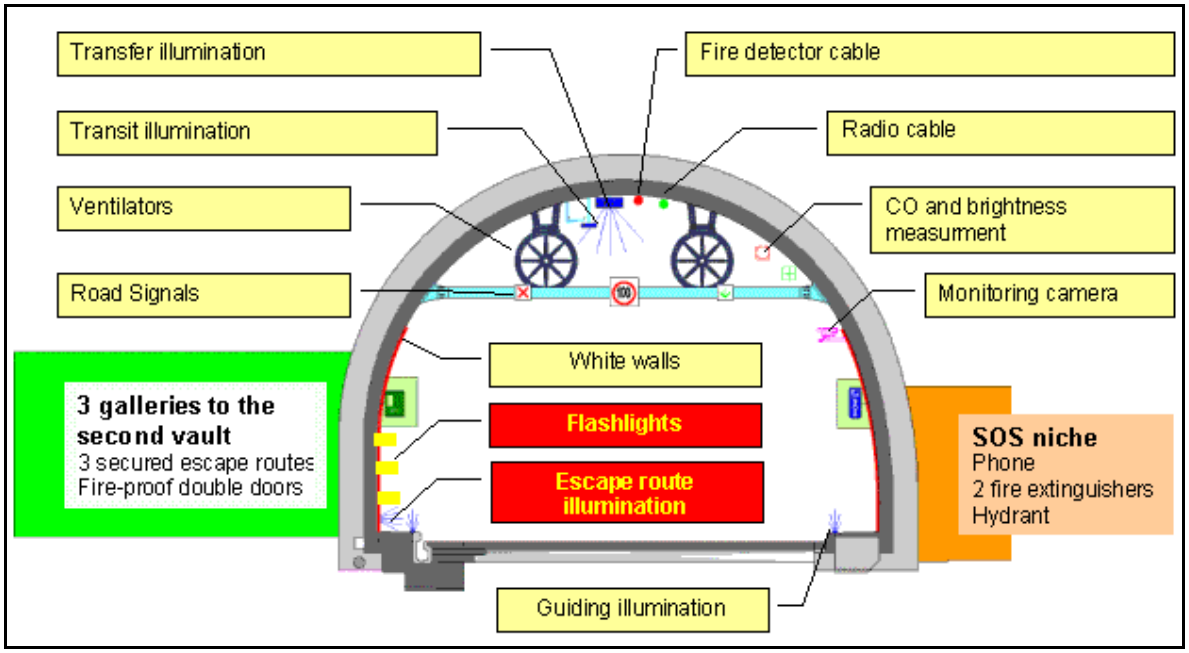


Figure 7j: Safety Features for tunnels

Most tunnels are designed with the all the above safety features. This safety features are equipped in all tunnels in order to safe guard the tunnel users from any dangerous mishaps. The structural aspect of the tunnel is one of the main elements that kept the underground tunnel safe. Engineers and designers have to check and re-check all the calculations in the design process in order to avoid any catastrophe. Surveillance equipment is placed in almost every corner to monitor the tunnel activities daily. This is important as if there are any accidents or fire in the tunnel than it can be detected using the surveillance equipment.

Communication equipment is paced in every interval in order for the road users to use to contact the tunnel authority in case of emergency. Finally plants can be classified in different classes as below;

- Telephone
- Power Supply
- Tunnel Lighting System
- Water supply
- Emergency Equipment (E.g. Fire hydrant. Fire sensors, Flood Sensors)



Source: Glion Tunnel- France, 2003

Figure 7k: Example of tunnel safety features

7.6 Safety Features of SMART Tunnel

Escape Route

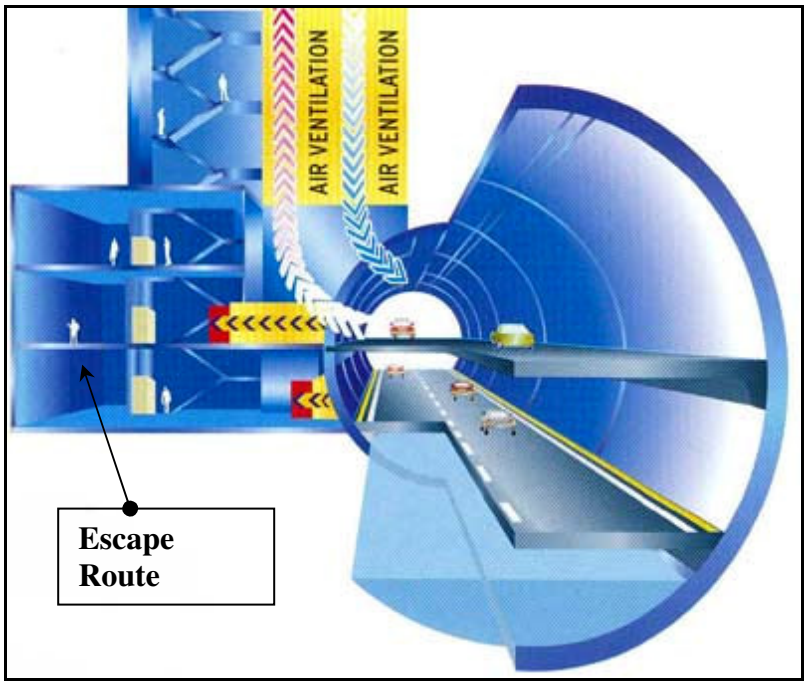
The tunnel is fitted with escape route every 250m of the tunnel. This passageway connects not only from the decks to external of the tunnel but also it acts as the crossway from one deck to another deck of the tunnel. This facilitates people to escape from the lower deck of the tunnel to upper deck in case of emergency at the lower deck. The entire passageway is fitted with smoke doors and also fire resistant wall in order to facilitate the evacuation of the tunnel in case of fire.

Fire Fighting System

The tunnel is fitted with automated sprinkler system the reacts when the fire sensors and smoke sensors activated. This sensor does not react with the vehicle smoke but only the smoke from real fire fighting equipments such as hose reels, fire hydrants and fire extinguishers are located at every intervals of the tunnel.

Ventilation System

There are four ventilation shafts that split the tunnel into three major divisions. There are located approximately 1km intervals. The powerful ventilation suction fans will constantly renew the air and maintain the air quality within the motorway. The lowest channel where the stormwater are diverted during normal storm does not equipped with any electrical devices. In case of the major storm where the three decks of the tunnel are closed the mechanical ventilation will automatically shut down in order to make way for the flooding of the tunnel.



Source: SMART Management Team, 2005

Figure 7l: SMART Tunnel's Ventilation System

Emergency Warning System

There are proper ingress and egress planned at the entrance and exit of the tunnel. The tunnel automated warning system will kick in as soon as the rivers bypassing the Kuala Lumpur City water level pass the critical limit. The tunnel closure is done by the warning system that activates during the tunnel closure to inform road user that the tunnel will be closed for full water discharge. The tunnel will be monitor using surveillance equipment and there will be tunnel operators that will inspect the tunnel manually to make sure all the cars exits the tunnel before the automated twin water tight flood control gates closes.

7.7 Environmental Impact Study (EIS)

In engineering field EIS is very important as this have very significant impact on the society, surrounding and environment we live in. As everything that we built are for the simplicity and usability of humans. EIS plays a very important role as engineer's have to be environmental cautious when building or designing certain structure or any kind of mechanical or electrical devices. In civil engineering field deterioration of environment has been a major issue. Malaysia is one of the countries that are taking the environmental issues very seriously since there are number of cases of found. The Ministry of Environment enforces strict laws especially on the field of construction industry. Every large scale project has to undertake EIS done by the appointed personal by the government.

The report has to be submitted to the Ministry of Environment. In tunnelling projects such as the SMART Tunnel in Malaysia, issues such as the vibration, noise, air pollution and underground soil geology disturbance are the main issues are to be concern with. There are not much environmental issues present for SMART Tunnel as the tunnel is actually constructed beneath Kuala Lumpur city. The city is already been developed to the maximum scale. This section will be brief as there are not many issues to be discussed here,

Noise Pollution

Noises from the vehicles that passing thru busy highways are actually one of the main sources of noise pollution in the city. In recent years there is more road and highways built in Malaysia as the part of the new transportation plan. Increment in the vehicle ownership also is the main contributors to noise pollution. Development of underground tunnels is one of the ways to solve the noise pollution problems as the noise from the vehicle s are confined into a space rather than open area. As for SMART Tunnel project there are numbers of complaint made regarding the noise from the busy construction site especially where cut and fill method are used (Refer to Figure 7m).

As the alignment of the tunnel is actually away from the city and not confined to residential are, this gives an advantage to the tunnel construction as there are no complaints made regarding the noise pollution. The SMART Management Team is looking into all the possibilities by reducing the working hours so that there only limited activity during night time.

Source: SMART Management Team, 2005

Figure 7m: Cut and fill works for SMART ventilation shaft

Vibration & Underground Soil Disturbance

Vibration from the construction and drilling of the tunnel are common contributors. This is one of the main issues as tunnelling below the city will cause some vibration to existing buildings. In the case of SMART Tunnel Project, the alignment of the tunnel is made so that minimum vibration is felt by the surroundings. There are measures taken to reduce the vibration especially by adopting the Slurry Shield Tunnel Boring Machine as the main tool for drilling works. Technology such as the TBM machine is very useful as it have minimum impact on the soil geology and groundwater source.

7.8 Overall Conclusion

In this section of the research project the explanation are done regarding the tunnel construction. SMART Tunnel is one of the kind projects the have more benefits to the people. The main reason the tunnel was proposed is to solve the flooding and the traffic congestion. This is the only tunnel in the world that combines the stormwater channel and also traffic diversion roads in one tunnel system. The transportation system in Kuala Lumpur needs this tunnel as the tunnel is the best solution for the best issue.

Finally the tunnel have some advantage and disadvantages, but mainly the advantages has overcomes the disadvantages. One of the main disadvantages of the tunnel as discussed in Chapter 6 is that the tunnel will only be opened to the traffic after 48hours after major storm. This is when the tunnel is running at “Mode 3” where the three decks are utilized for channelling stormwater bypassing the city. The solution to overcome this problem is to enlarge and re-locate the current two intersections that are adjoining the Sg. Besi Highway. If this is done then the road users have an alternative during the full closure of the tunnel.

Chapter 8: Project Conclusion

Tunnels are very essential to our way of life as it is the new innovation method in urban transportation system. Even though tunnelling works can be back dated to the eighteen century, the technology and the construction method had evolved with time. The current technologies used in the construction of tunnels around the world are becoming very advanced and very efficient. In recent years technology has introduced new sets of tunnelling technologies such as the tunnel boring machine. In this research project, SMART Tunnel in Malaysia had shown the new steps taken by the Malaysian Government to upgrade the national's urban transportation system in the capital city of Kuala Lumpur. This tunnel is the only kind in the world that introduces the wet and dry system. This tunnel is used to drain out the flood water from the Kuala Lumpur city centre and also to reduce the traffic congestion in the Southern Gateway (Sg. Besi Highway).

The main outcomes of the research study are to evaluate the efficiency, to understand the technology and machinery used in this project. Tunnelling is still new to Malaysia as there very few project that involves underground tunnel works. Understanding tunnelling works is very essential as will be the new transportation system for urban and remote areas in the future. As space is the main concern in most metropolitan city where living and working dominates most of the area. Construction of underground tunnels may significantly increase the safety, speed and capacity of goods and human transport in metropolitan cities such as Kuala Lumpur. Underground automated tunnels promise some great benefits to us.

It can minimize traffic delays, eliminating visual blight and also noise pollution. Other than this we can minimize the construction of roads and highways at the surface and maximize greenery effort in order to conserve the environment for the future generation. The impact on environment should be the main focus as most engineering designs such as highways and flyovers are built with consequences to the environment. Study on tunnels is very essential as the understanding will give us better understanding on the development of the future transportation system in the world. SMART Tunnel will help to solve the traffic congestion and the flooding in Kuala Lumpur city centre as it can take a maximum capacity of three million cubic metres of water in case of major flooding in the city.

The tunnel is actually designed for future water capacity in case of high volume of rain intensity in the future. Current usage will be less than one million cubic metres of discharge. The tunnel is actually linked with automated flood warning system that will start discharging the water from the river after certain level through the lowest channel only. The tunnel will be closed after this system detects that major stormwater discharge have to take place in order to clear the water from the city. Other than that the tunnel will be in full use by vehicles and also the stormwater channel. The tunnel is predicted to discharge in full capacity (full closure of the tunnel) twice a year only.

Most countries around the world are developing tunnels as the rail link, canals to carry drinking and irrigation water, roads and also for pedestrian crossing. The benefits of tunnels and the advantages are overwhelming then the disadvantages cause's tunnels to be the choice of design for engineers. Finally as a conclusion, the development of tunnels as a transportation system is very crucial to the engineering industry. In Malaysia, the development of tunnels is still low compare to other European countries that uses tunnels as the main transportation hubs. This research project is very beneficial as the understanding of tunnelling industry is very useful for the future transportation system.

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Appendixes

Appendix A: Project Specification

UNIVERSITY OF SOUTHERN QUEENSLAND

Faculty of Engineering and Surveying
ENG4111/4112 Research Project

PROJECT SPECIFICATION

For: Ram Kumar M. Kannapiran
USQ No: 0050027404
Topic: Case Study and Evaluation on the new SMART Project
Stormwater Management and Road Tunnel (SMART)
Kuala Lumpur, Malaysia

Supervisor: Dr. David Ross (USQ)
Enrolment: ENG4111- S1, 28th February, 2005.
ENG4112- S2, 18th July, 2005.

Project Aim: This case study is undertaken to study the construction method, the purpose and the technology used in this project and efficiency of the SMART project to solve the flooding and traffic congestion problem

Programme: Issue A , 13th March, 2005

1. Research the background information regarding the history the company involved and the flooding in Kuala Lumpur City.
2. To conduct literature review on the technology used in this project and the construction method in this project.
3. Analyze the impact on the environment and the society surrounding this project.
4. Research the effectiveness and the purpose of this project in solving the major flooding problem during monsoon season (peak rainy season) and traffic congestion.
5. Identification of problems caused and factors contributing to the problem when constructing this tunnel.
6. Further recommendation to solve the flooding and traffic congestion in Kuala Lumpur City Centre.

AGREED:

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(Ram Kumar M. KANNAPIRAN)	**(Dr. David Ross)**
(___/ ___/ ___)	**(___/ ___/ ___)**

Appendix B: Project Methodology

1. Synopsis

The research project on the SMART Tunnel will be conducted with the understanding of numerous aspects. The aspects are such as the research methods, the dimension or depth of the research and the final outcome of this research project In this section, to conduct this research project successfully this are the outlines that will be followed to produce adequate thesis.

2. Outlines of the research project

In this research analysis, to cover the important dimension of the projects, these are the steps that will be followed:

- Information Gathering
  - Visit to the SMART Project Management office to request and submit the official letter to conduct the research project.
  - After approval, conduct an interview with the office personnel to get the basic view on this project.
  - Preparation of the project proposal and specification to generally form a guideline of the project.
  - Frequent communication with USQ Supervisor- Dr. David Ross.
  - Second visit to the site office and conduct interview with the Project Manager. Gather the project information and analyse thru.
  - Visit to the actual project site for pictures on the progress and gather in depth of the project aspects.
  - Information gathering from government department and private bodies that involve in this project.
  - Research analysis thru the internet for more information
  - Visit to the local university library to gather research material

- Preparation of project dimension
  - Outline the table of content of the research project

- Preparation of the project timeline and schedule

- Project dissertation type out according to the content outline
  - Project type out using Microsoft Word, Microsoft Project and Microsoft Excel programmes.

- Final Analysis thru out the dissertation before submission.

Appendix C: Research Project Timeline

Weekly schedule for the Research Project, 2005

Month	Week	Time Schedule
March	**1**	Pre-planning for Research Project
	2	Submission of Topic Allocation
	3	Analyzing for Project Specification
	4	Submission of Project Specification
April	**1**	Gathering Information on Research Project
	2	Gathering Information on Research Project
	3	Gathering Information on Research Project
	4	Preparation for Project Appreciation
May	**1**	Documentation for Project Appreciation
	2	Documentation for Project Appreciation
	3	Submission of Project Appreciation
	4	Documentation of the Research Project Topics
June	**1**	Documentation of the Research Project Topics
	2	Documentation of the Research Project Topics
	3	Submission of Progress Assessment
	4	Interval for Semester Examination (S1,2005)
July	**1**	Research, gathering information and documentation
	2	Research, gathering information and documentation
	3	Research, gathering information and documentation
	4	Research, gathering information and documentation
August	**1**	Research, gathering information and documentation
	2	Research, gathering information and documentation
	3	Research, gathering information and documentation
	4	Research, gathering information and documentation
September	**1**	Research, gathering information and documentation
	2	Research, gathering information and documentation
	3	Final Presentation in USQ
	4	Research, gathering information and documentation
October	**1**	Conclusion of the final Section
	2	Conclusion of the final Section
	3	Conclusion of the final Section
	4	Submission of Report
November	**1**	Nil
	2	Nil
	3	Nil
	4	Nil

Note: General Guideline & Subject to Change

Appendix D: Risk Assessment

Risk Analysis

The process of Risk Analysis involves the following procedures;

- Identification of Risk Analysis
- Risk Evaluation
- **Risk Control**

Risk Assessment

1. The SMART Tunnel Project

No.	Hazard Classification	Risk Analysis	Probability of Occurrence	Control Measures
1.	Tunnel Flooded due to rain fall	**1**	**A**	Proper temporary drainage system includes high powered water pumps are placed in the tunnel
2.	Safety issue in the working area	**5**	**E**	All site personnel will undergo safety training and briefing every day before commence of work
4.	Delay in the Schedule	**4**	**D**	Daily, weekly and monthly site progress planning are conducted to overcome any possibility in the delay of the works
5.	Financial Status of the project	**2**	**A**	The project have strong back up from the government and the private sector to complete the project without any financial issue

6.	Environmental Issue	**6**	**C**	This project is closely monitored by the Department of Environment to reduce the possibility the treat to the environment
7.	Public Safety Issue	**2**	**B**	The project area and the method of the tunnelling work will not harm in any form to the public
8.	Climatic Condition	**3**	**C**	In this issue the tunnel is in frequent hit by heavy rain storm but have significant protection aspect from any form of risk
9.	Traffic Control	**3**	**C**	The project have some traffic control issue in the certain areas but have adequate detours and signage to overcome the issue
10.	Problems in the Contracts(Clause Errors)	**5**	**D**	This clauses that creates problems have been identified and in the process of negotiation to overcome the issue.
11.	The risk if SMART Tunnel Project not initiated	**6**	**E**	There will be frequent flooding in the city centre that causes lost of lives and damages to property and also traffic congestion.
12.	The risk if SMART Tunnel Project is initiated	**2**	**A**	There will be no flooding problem and traffic congestion problem in the city
13.	Risk of the project to the community	**1**	**B**	There will be more advantages then disadvantages and risk to the community if the project is carried out.

Note: Class rate please refer the Rating Classification

2. The Research Project

No.	Hazard Classification	Risk Analysis	Probability Occurrence	Control Measures
1.	Safety Issue during site visit to gather resources	**6**	**E**	Join the site safety training briefing before entering the site with proper PPE
2.	Travelling during site visit and visit to the local library using own transport	**6**	**C**	Try to use more of public transport that own vehicle
3.	Injury during preparing the thesis project	**1**	**A**	There is less risk during project preparation except when using computer.
4.	Financial status during the project duration	**1**	**A**	The will be no problem regarding the financial issue during the preparation of this thesis
5.	Health related issue	**1**	**A**	Nil

Note: Class rate please refer the Rating Classification

Risk Classification Rating

- Risk Analysis
  - Very Rarely - **1**
  - Rarely -2
  - Occasionally - **3**
  - Regularly - **4**
  - Frequently - **5**
  - Continuously - **6**

- Probability of Occurrence
  - Extremely Slight – **A**
  - Very Slight – **B**
  - Slight - **C**
  - Significant – **D**
  - Substantial – **E**