FLOOD OCCURRENCE, SMART TUNNEL OPERATING SYSTEM AND TRAFFIC FLOW: A CASE OF KUALA LUMPUR SMART TUNNEL MALAYSIA

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A Thesis Submitted in Fulfillment of the Requirement for the Award of the Degree of Masters of Science in Technology Management

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March, 2016
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DEDICATION

I dedicated this thesis to my dear father and my loving mother for their unwavering support, advice, encouragement and prayers which guided me towards this achievement, I am very proud of them.
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Alhamdulillah, praise be to Allah, the Omnipotent, the Omniscient, Lord of all worlds, the Sustainer, the Shaper and the Capacity to take Master in the Day of Judgment, and praise is upon to His messenger Mohammad (SAW) and those that follow him until the end of time. I thank you Allah for sustaining my life throughout this endeavor.

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ABSTRACT

Managing environmental disaster requires the use of technology into how technology is used to minimize the casualties and loss incurred when disaster strikes. This research study the relationship between SMART tunnel maintenance works, flooding and traffic flow management. SMART is an acronym for “Stormwater Management and Road Tunnel”. This project is located in Kuala Lumpur the capital metropolitan city of Malaysia. The SMART Tunnel project was initiated by the Former Prime Minister Tun Dr. Mahathir Mohammad under the Malaysian Development Plan. The project was a joint venture project between the government and the private sector corporation. This study investigates the relationships between SMART Tunnel maintenance works, flooding and traffic flow in Kuala Lumpur City Centre, Malaysia. The study adopted quantitative and qualitative approaches. Ten respondents were interviewed to achieve the research objectives, where eight of them are from Drainage and Irrigation Department, while the remaining two are from the Malaysian Highway Authority. Correlation and percentage value analysis were used to achieve the research objectives. The study reported that there are significant relationships between SMART Tunnel maintenance works with flood occurrences and SMART Tunnel maintenance work with traffic flow. When there is enough maintenance works, flood occurrence will be very low and vice versa. The research shows that SMART Tunnel plays an important role in decongestion of traffic to and from the Kuala Lumpur City Centre. It diverts approximately 30,000 cars a day. This research contributes in providing valuable frontier and offers means to improve the maintenance works of SMART Tunnel to optimize the utilization on flood disaster and traffic flow management in Kuala Lumpur City Centre. It also updates people about the roles of SMART Tunnel in Kuala Lumpur City Centre.
ABSTRAK

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CHAPTER 1

INTRODUCTION

1.1 Introduction

A tunnel is a passage way that carries people or vehicle across a destination that have obstruction or to shorten the travelling time. Tunnels in the olden days are used mainly for mining works. As technology evolves with time, tunnels construction had become more commonly used as transport routes in places where roads or bridges are impossible to be built or the cost is too high. 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 (Kumar, 2010). 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 over the world and the method of construction is getting more advanced and this allows the tunnels that are impossible to build are now done (Kannapiran, 2005). Although tunnels have their own advantages and uses, the effectiveness of tunnel may not outweigh the costs associated with building and maintaining such tunnel. This is especially true as tunnels get older due to wear and tear. To understand the effectiveness of tunnels
towards their intended purpose, this research focuses on one such tunnel i.e the SMART tunnel in Kuala Lumpur Malaysia. This tunnel is very unique because this is the only one kind of tunnel in the world that combines the wet and dry systems. This tunnel is used as a pathway to transport vehicles and also as channel for stormwater diversion from the city centre of Kuala Lumpur (Kumar, 2010). This SMART tunnel was built using two Slurry Shield TBM machines which allows the drilling and tunnel lining work to be done continuously without setbacks. These machines also eliminate the hazard of tunnel stability during construction and the ground water drawdown that cause sink holes. Thus, it is important to focus on the maintenance work of SMART tunnel for flood diversions from the Kuala Lumpur city Centre.

1.2 Research Background

Malaysia is fortunate that it is not directly affected by serious disasters like earthquake, hurricanes, typhoon, tornadoes, tsunamis and volcanic eruptions. This country is also blessed with water resources and is experiencing an abundant amount of rain every year. The average annual rainfall is 2,400 mm for Peninsular Malaysia, 3,800 mm for Sarawak and 2,600 mm for Sabah (Chan, 2002).

Malaysia lies in a geologically stable region which is free from earthquakes, volcanic activities, and strong winds such as tropical cyclones which periodically affect some of its neighbors. It lies geographically just outside the “Pacific Ring of Fire”. Hence, it is free from volcanic eruptions and earthquakes. It also lies far south of the major typhoon paths, although tail-ends of tropical storms have occasionally hit it. However, that does not mean Malaysia is totally free from natural disasters and calamities, as it is often hit by floods, droughts, landslides, haze, tsunamis, and human made disasters (Poula, 2009). Annually, disasters such as floods account for a significant number of casualties, disease epidemics, properties and crop damages and other intangible losses (Chan, 2002). In the past few decades, the country has experienced various extreme weather and climatic events, including El Nino in 1997 (which led to
severe droughts), La Nina in 2011 and 2012 (which brought floods), freak thunderstorms almost every year (which brought wind damage, flash floods and landslides), monsoonal floods (which brought 499 cases of losses, including loss of life in many parts of the country exposed to monsoon winds), and haze (which brought about poor air quality, extreme heat and drought). Monsoonal floods are an annual occurrence which varies in terms of severity, place and time of occurrences with the 2010 flood in Kedah and Perlis being among the worst flood ever experienced by the country (Foong, 2010). The total economic loss and the financial burden on the government were enormous.

When two or more of these events coincide such as the “Terrible twins” (La Nina and the monsoon season) that hit the federal capital of Kuala Lumpur and Selangor in December 2011, the damage is compounded (The Star, 2011). The haze phenomenon in 1997/98 also caused significant problems due to losses in tourist income, health effects and hospitalization costs, and mitigation losses (Kannapiran, 2005). The 2005 haze episode in Malaysia was a week-long choking haze (at its worst on August 11) that affected mostly the central part of Peninsular Malaysia. The air quality in Kuala Lumpur was so poor that health officials advised citizens to stay at home. A state of emergency was declared in Port Klang and Kuala Selangor. The event also led to crisis talks with Indonesia and caused widespread health effects and inconvenience (Ahmad et al., 2006). The Asian Tsunami which hit in December 2004 was also very severely felt on the coasts of Peninsular Malaysia, most notably in Penang, Kedah, Perlis and Langkawi (Chan, 2009).

Due to Malaysia’s wet equatorial climate regime with frequent heavy rain storms of high rainfall intensities, landslide disasters are common. In recent decades, landslide disasters in the Klang Valley Region and elsewhere have caused significant loss of life, property and infrastructure damage, environmental destruction and anxiety (Chan, 2012). In addition, the country is also regularly hit by manmade disasters such as fires, accidents and the collapse of structures and buildings, which cause considerable damage to property and loss of life (Hussein, 2007). In terms of human-made and human-enhanced disasters, Abdul Malek (2005) listed the following major disasters: fire and explosions at the Bright Sparklers factory in Sungai Buloh in 1991 which claimed 22 lives; fire and explosions at South Port Klang in 1992 which claimed 10 lives; collapsed
of the Highland Towers apartment blocks in Hulu Kelang in 1993 which claimed 48 lives; massive landslide at the Genting Highlands in 1995 which claimed 20 lives; mudslides in Pos Dipang, Perak, on 29 August 1996 which claimed 44 lives; severe haze episodes in 1997 and 1998 which caused loss in tourist revenues in the millions of dollars and hospitalized thousands of people; landslide at Sandakan, Sabah, in February 1999 due to heavy downpour which claimed 17 lives; luxury home collapsed on 21 November 2002 in the Ulu Kelang area killing eight people.

Arguably, of all the disasters in Malaysia, floods are the most frequent and bring the greatest damage annually. Flood is therefore considered as the most severe type of disaster experienced in Malaysia (The Star, 2011). Historically, there have been big flood events in 1886, 1926, 1931, 1947, 1954, 1957, 1965, 1967, 1970/1971, 1988, 1993, 1996, 2000, 2006/2007, 2008, 2009, and 2010. Of these floods, the 1926 flood which was known as “The storm forest flood” because it destroyed hundreds of square kilometers of lowland forest on the flood plains of the Kelantan and Besut rivers. Records show that the flood was accompanied by gale force winds (DID, 2011). According to the Drainage and Irrigation Department (DID, 2011), this flood was considered “the biggest flood in living memory” in Malaysia as it affected almost the entire length and breadth of Peninsula Malaysia, causing extensive damage. In 1996, floods brought by Tropical Storm Greg in Keningau (Sabah State), claimed 241 lives, caused more than USD 97.8 million damages to infrastructure and property and destroyed thousands of houses. In 2000, floods caused by heavy rains that killed 15 people in Kelantan and Terengganu, and caused more than 10,000 people to flee their homes in northern Peninsular Malaysia. The December 2006/January 2007 floods in Johor caused 18 deaths and USD 489 million in damage (Hussaini, 2007). In 2008, floods occurred in Johor again, killing 28 people and causing damage estimated at USD 21.19 million. In 2010, the floods affected transportation in and around Kedah and Perlis, shutting down rail, closing roads including the North-South Expressway (The Star, 2010c) and the airport in Kedah’s capital city of Alor Setar leaving helicopters as the only mode of aerial transport into Kedah and Perlis (The Star, 2011). Water supply in Kedah and Perlis was contaminated, forcing these two states to seek supplies from their neighbor Perak. Kedah and Perlis are the “Rice Bowl” of Malaysia, and the floods
destroyed an estimated 45,000 hectares of rice fields with the government pledging USD8.476 million in aid to farmers in both states. The floods killed four people, with more than 50,000 evacuated.

Kuala Lumpur has witnessed rapid population and economic growth since the early 1980s. Similarly, one result of this growth has been a marked increase in flash flooding in the area, occurring almost annually. The urbanization of Kuala Lumpur has encroached on the Klang and Gombak rivers, which merge in the center of the city. The average annual flooding for the Klang River has increased nearly 300 percent, from about 148 cubic meters per second before 1985 to 440 cubic meters per second since 1985 (Chan, 2011).

However, the Malaysian government has monitored the situation since the early 1970s, and responded with the development of the Klang River Basin Flood Mitigation Project. The government has attempted to control flooding by creating holding ponds and increasing river channel capacity, but this has had only limited success. In 2001, the government sought proposals of SMART Tunnel for a more effective solution to flooding, to prevent disruption to the city’s center during a typical flood event with duration of three to six hours. The original idea was for a tunnel to divert and store the storm water, but the idea progressed into the concept of a mixed-use tunnel that would allow traffic flow when the tunnel was empty of water. One factor in this evolution was that for liability reasons, the tunnel had to run below government-owned land, which led planners to consider locating the tunnel beneath a road. This led to the idea of integrating a tolled motorway into the project. By allowing a portion of the tunnel to be tolled for traffic, private sector participation in a Public-Private Partnership (PPP) could be secured, reducing the costs of the project for the Malaysian government (McCann & Cordi, 2011).
1.3 Problem Statement

The SMART tunnel effective dual functions depend on the operative management and maintenance of the tunnel’s system. SMART tunnel Kuala Lumpur had been experiencing challenges regarding operational issues that includes “disruptions and errors in materials, information, and equipment” (Kothari & Karim, 2014) as well as coordination problems among and between staff and management. According to Abdulraheem in an interview with the researcher in September 2014, the consequences of these failures can range from minor inconveniences to major catastrophes. These errors and disruptions occurred several times and from different sources. The most devastating errors are in tunnel’s maintenance and inspections which is supposed to be carried-out weekly on the automated flood control gates, the water tight gates on either end of the motorway tunnel within the stormwater section (Ismail, 2013). The gates convert the system into a flood tunnel to divert floodwaters from the holding water basin and storage reservoir into the Sungai Kerayong and back into the Sungai Klang. This is not been done weekly as it is in the SMART tunnel operations manual but, rather it is carried out once in a month (Moris et al., 2011).

Similarly, another component that supposed to be checked frequently, at least twice a week according to the SMART tunnel operations manual, are the water-tight doors that lead to the SMART equipment areas, it is also not maintained and checked as prescribed in the operational manual but, it`s been carried out once in two weeks (Kannapiran, 2012). Furthermore, Fuad and explained that the monthly maintenance works that involves the whole major system of the SMART tunnel including software checks has limited maintenance in 2010 with 10 times checks and maintenance whilst 11 times and 10 times in 2012 and 2013 respectively. This is contrary to the operations manual of SMART tunnel. These tremendously affect the image of SMART tunnel in delivering services to the nation by weakening the process of flood disaster management and thus, inflicting direct harm to employees and end users.

Delay in operations is another issue that affects the image of SMART tunnel Kuala Lumpur (Ecke et al., 2013). Residents in the vicinity of Ampang Jaya and Pandan who
have been inundated by flash floods have allegedly accused the management of the SMART Tunnel of delay in the discharge of their responsibilities as operators (Ecke et al., 2013). The image of SMART tunnel is massively declining as a result of detainment in operation. Flood occurrences at the same time contribute to traffic congestion when the tunnel is in flood mode operation the tunnel could not be used for traffic flows.

1.4 Research Questions

This research work seeks answers to the following questions:

1. Is there a relationship between Kuala Lumpur SMART tunnel maintenance work and frequency of flood occurrence in Kuala Lumpur City centre?
2. Does Kuala Lumpur SMART tunnel operating system affects the frequency of flood occurrence in Kuala Lumpur City centre?
3. Does Kuala Lumpur SMART tunnel operating system affects the traffic flow in Kuala Lumpur City centre?

1.5 Objectives of the Research

The objectives of this research are:

1. To examine the relationship between the maintenance work of Kuala Lumpur SMART tunnel and frequency of flood occurrences in Kuala Lumpur City center.
2. To investigate whether Kuala Lumpur SMART tunnel operative system affects the frequency of flood occurrence in Kuala Lumpur City centre.
3. To investigate whether Kuala Lumpur SMART Tunnel operative system affects the traffic flow in Kuala Lumpur City centre.
1.6 **Scope of the Research**

This is a study on the relationships between the maintenance works, flooding and traffic flow in Kuala Lumpur city centre. This capital city of Malaysia has experienced abundant rain as a result it is prone to flooding and traffic congestion which resulted in initiating SMART Tunnel with the aim of solving flash flooding and traffic congestion in the city centre of Kuala Lumpur. The valley area has 4.7m registered cars which contribute to the traffic congestion in the city centre of Kuala Lumpur. Data was collected through document reviews and interviews with the members of two organizations i.e Drainage and Irrigation Department and Malaysian Highway Authority. The data were analyzed using correlation, percentage value and thematic network analysis as the research is quantitative and qualitative (mixed method) in nature.

1.7 **Structure of the Thesis**

This thesis is structured into five chapters and the content of the chapters are as follows.

Chapter 1: This chapter contains brief context of the research introduction, background, research questions, objectives as well as the scope of the research.

Chapter 2: This chapter reviews the literature on the roles of SMART Tunnel, technology used in constructing the SMART Tunnel, rationale behind building SMART Tunnel in the city centre of Kuala Lumpur Malaysia, flooding around the world, technologies used to manage disasters around the world.

Chapter 3: This chapter presents details of the methodology adopted for this research. Qualitative and Quantitative methodology were used. Justification for adopting this approach is outlined alongside with the specific methods employed for data collection.
Chapter 4: This chapter presents the results obtained from the study. Data analysis and presentation from the data collected were explained in this chapter.

Chapter 5: This chapter presents the discussion and the summary of the research, limitations of the research, conclusions and recommendations for further research.

1.8 Definitions of Key Terms

For the purpose of consistency and to avoid ambiguity, it is necessary to give definition to the key terms used in this research. This is important to ensure that it gives meaning and understanding in the proper context for the study. The terms involved in the importance of writing include:

SMART Tunnel: This is an acronym for Stormwater Management and Road Tunnel. It was built in Kuala Lumpur Malaysia.

Maintenance: Maintenance involves fixing any sort of mechanical, plumbing or electrical device should it become out of order or broken. It also includes performing routine actions which keeps the device in working order or prevent trouble from arising. Maintenance may be defined as all actions which have the objective of retaining or restoring an item to a state in which it can perform its required function.

Flood: A flood is an overflow of water that submerges land which is usually dry. The European Union (EU) Floods Directive defines a flood as a covering by water of land not normally covered by water.

Traffic: Traffic on roads consists of pedestrians, ridden or herded animals, vehicles, street cars, buses and other conveyances, either singly or
together, while using the public way for the purpose of travel from one place to another. It is also a passage of people or vehicles along routes of transportation.

Kuala Lumpur: Kuala Lumpur is the national capital and most populous city in Malaysia. The city covers an area of 243 km² and has an estimated population of 1.6 million as of 2010. Greater Kuala Lumpur, covering similar area as the Klang Valley. It is an urban agglomeration of 7.5 million people as of 2012. It is among the fastest growing metropolitan regions in South-East Asia, in terms of population and economy.

Operating Systems: Operative system is a software that manages SMART Tunnel’s hardware and software resources and provides common services for SMART Tunnel’s program.

1.9 Summary

This chapter has introduced the topic and research questions that have brought about the undertaking of this research. It has shown how these reasons have led to the research questions and onto the objectives of the research. This chapter contains introduction, research problems, research questions, research objectives, scope of the research as well as structure of thesis. The next chapter presents the reviews of the related literature of this research work with the aim of having a clear focus on the research.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter comprises of a comprehensive review of literature relating to the tunnel and its maintenance, natural disasters as well as the technologies used to manage natural disasters around the world. Emphasis is given to the tunneling technology, its construction, roles, performance as well as the maintenance work.

Literature review is very important in a research to get a deeper understanding of issues relating to the previous research by using the appropriate framework to achieve the research objectives. According to Chua (2007), literature review is an integral part of the whole research process, helping to get the comprehensive and extremely valuable input in preparing the research measures. Thus, literature review helps researchers to identify the gap area which is still not explored by the previous researches.

The review of the literature is considered a systematic and critical review of the most important published scholarly literature on a particular topic. Scholarly literature refers to published and unpublished data based literature and conceptual literature materials found in print and non-print forms (Cruz et al., 2010). This chapter looks at a review of relevant literatures that give a background of the SMART tunnel, which are related to the improving of its performance in flood disaster management.
2.2 Use of Technology to Manage Natural Disaster

As we are in a new century and millennium, natural hazard management is set to play a vital role in global efforts to reduce human suffering and damage to property. Disaster reduction is very possible if the sciences and technologies related to natural disaster are employed accurately. The extent to which society puts this knowledge to effective use depends firstly upon the political will of its leaders at all levels (UN-ISDR, 2010). Coping with hazards whether natural or attributable to human activity is one of the greatest challenges of the applications of science and technology in the 21st Century (UN-ISDR, 2010). While we cannot prevent an earthquake or a hurricane from occurring, or a volcano from erupting, we can apply the scientific knowledge and technical know-how that we already have to increase the earthquake and wind resistance of houses and bridges, to issue early warnings on volcanoes and cyclones and organize proper community response to such warnings (UN-ISDR, 2010).

However, over the last three decades, scientific knowledge of the intensity and distribution in time and space of natural hazards and the technological means of confronting them have developed. The Resolution of the United Nations General Assembly which proclaimed the International Decade for Natural Disaster Reduction (1990-1999) called for a concerted worldwide effort to use the existing scientific and technical knowledge, adding new knowledge as needed, in order to underpin the adoption and implementation of public policy for disaster prevention (UN-ISDR, 2010). The International Strategy for Disaster Reduction is the successor of the decade and provides a framework for each nation to fully utilize existing knowledge on the lithosphere, atmosphere, and biosphere and the know-how on disaster protection gained in prior years, and to build effectively and creatively upon past accomplishments so as to meet the projected needs for safer communities. Progress in the science and technology of natural hazard and of related coping mechanisms have made it possible over the past years to introduce significant changes in the integrated approach to the problematic of natural disasters. Science and technology help us to understand the mechanism of natural disaster of atmospheric, geological, hydrological, and biological origins and to analyze
the transformation of these hazards into disasters. Scientific knowledge of the violent forces of nature is made up of an orderly system of facts that have been learned from study, experiments, and observations of floods, severe storms, earthquakes, landslides, volcanic eruptions and tsunamis, and their impacts on humankind.

The scientific and technological disciplines which are involved include basic and engineering sciences, natural, social and human sciences. They relate to the hazard environment (i.e. hydrology, geology, geophysics, seismology, volcanology, meteorology, and biology), to the built environment (i.e. engineering, architecture, and materials), and to the policy environment (i.e. sociology, humanities, political sciences, and management science) (UN-ISDR, 2010). Major progress has been made in the growth of global meteorological models and their employment to large scale weather prediction. The critical information currently provided on global climate change and its implication on the global environment is the fruit of this growth. Although earthquake prediction is still not possible, considerable options exist today to make more accurate forecasts and to give warnings of several impending hazard events (UN-ISDR, 2010). Warnings of violent storms and of volcanic eruptions hours and days ahead have saved many lives and prevented significant property losses.

Modern technologies have been developed that reduce the exposure to natural hazard of the physical and built environment and other elements of socio-economic life (UNOOSA, 2012). Owing to progress in design and construction engineering, earthquake-resistant structures, including high-rise buildings, critical lifelines and industrial facilities, are technically feasible and have become a reality. One component of these breakthroughs in disaster reduction, in some instances, has been enhanced capacity to control or modify the disaster events themselves. Scientific and technological solutions to the complex problems of disasters must be rooted in social realities, in the fullest sense of the term. Science needs to be seen as part of a continuum of action extending from the design of interdisciplinary research to the communication of results to diverse non-specialist user groups (UN-ISDR, 2010). In this regards, scientists will have to share with policy-makers and other people, the responsibility for scientific risk assessment and management. Without science and technology, and their blending with other disciplines, there can be no world safer from natural disasters (UN-ISDR, 2010).
2.3 Types of Technology Used in Disaster Management

The development of technological tools makes the world of today safer and gives the opportunity to take righteous action against a given phenomenon. Technological tools are commonly used in disaster management in the world today.

2.3.1 Geographic information system (GIS)

The first known use of the term "Geographic Information System" was by Roger Tomlinson in the year 1968 in his paper "A Geographic Information System for Regional Planning". Tomlinson is also acknowledged as the "father of GIS". It is a collection of hardware, software, geographic data, and personnel designed to capture, maintain, store, organize, update, manipulate, analyze, and display geographically referenced information (Helmersen, 2010). GIS can also maintain and retrieve large quantities of data, manipulate spatial and related tabular data, perform complex spatial analysis, rescale data for analysis. GIS is suitable in doing things such as Map production, allowing the user to design map, tables, graph, charts and images. Searching and selecting geographic features of interest based queries, logical queries, arithmetic queries, and spatial relationships. Selecting and displaying map features based on location.

Analyzing spatial data based on conditions of proximity, containment and adjacency. Measuring distances between mapped locations as well as calculating summary statistics such as count, sum, average, and variance. GIS can also edit spatial layers and their attribute tables, importing spatial layers from a variety of other sources as well as creating new spatial layers through digitizing from the screen or digitizing tablet, intersecting and “clipping” of vector spatial layers. The acronym GIS is sometimes used for geographical information science or geospatial information studies. In the simplest terms, GIS is the composite of cartography, statistical analysis,
and computer science technology. GIS is used in so many countries in the world for disaster management.

### 2.3.2 Space Technology

Space technologies are becoming gingery to modern day disaster management. Earth observation (EO) satellites provide images at various wavelengths that assist rapid-mapping in all phases of the disaster management cycle, mitigation of potential risks in a given area, preparedness for eventual disasters, immediate response to a disaster event, and the recovery/reconstruction efforts following it (Brief, 2011). Global navigation satellite systems (GNSS) such as the Global Positioning System (GPS) has helped all the levels by providing accurate location and navigation data to manage land and infrastructures, and aiding rescue crews by coordinating their search efforts. Communications through satellites allow the transfer of information (voice, images/maps, video) when usual communications cadre are disabled by the disaster event (Brief, 2010). The emergency communications carried out using semi-mobile terminals and handheld satellite phones are particularly useful during immediate response activities, including damage assessment, search and rescue efforts, news reporting, aid coordination, and telemedicine activities (Brief, 2010).

![Figure 2.1 Space Technology](source: Space Generation, (2012))
It should be noted that the UN Office for Outer Space Affairs (Brachet, 2012) has established the UN Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER, 2013) which oversees and assists nations affected by disasters to obtain various kinds of space-based information, regardless of whether or not they have their own space capabilities (Brachet, 2012). UN-SPIDER is being implemented as an open network of providers of space-based solutions to support disaster management activities. Besides Vienna (where UNOOSA is located), the program also has an office in Bonn, Germany and will have an office in Beijing, China. Additionally, a network of Regional Support Offices multiplies the work of UN-SPIDER in the respective regions (McCann & Cordi, 2011). Space technology plays a tremendous role in disaster management due to its accuracy in generating information.

### 2.3.3 Tunneling Technology

A tunnel is an underground passageway, completely enclosed except for openings for entrance and exit, commonly at each end. A tunnel is a passage way that carries people or vehicle across a destination that shortens the travelling time. Tunnels in the olden days are used for mainly mining works. As a result of technological development with time, tunnels construction had become more commonly used as transport routes that links places, rails links, vehicles and also as canals for water diversion (Mott MacDonald, 2006).

### 2.4 Tunnels

Tunnels in early days are used especially in mining. Tunnelling and mining are together since beginning of the industry. Before mining, tunnels in an ancient history were used for water carriage. In cities such as ancient Rome, tunnels are designed to carry water
supply from aqueduct nearby (Bahwani, 2005). The technology of tunneling has advanced from ancient days until now. Sometimes tunneling becomes most soluble solution, but constructing tunnels are still under major studies because we need to upgrade the design according to time and needs (Manfre, 2012).

When the scientist from China invented the gun powder, it gave way to new methods for tunneling work to presume. Gunpowder since then has advanced into more severe usage in the tunneling industry. Gunpowder gave way to much more powerful nitro-glycerin, quickly followed by dynamite, introduced by Nobel in 1967 (Bahwani, 2005). 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:

(i) Soft ground
(ii) Hard Rock
(iii) Underwater

Tunnels are also 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 (Lincoln Tunnel, 1998).

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 (Brachet, 2012).
2.5 History of Tunnels

There are various tunnels that are famous in history. Among them are:

(i) 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 (Lincoln Tunnel, 1998).

(ii) 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 (Lincoln Tunnel, 1998).

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

Figure 2.2: Interior of the Thames Tunnel, London, 1943.

Source: Bartlett (2014)

(iv) 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 4 years from 1995 to 1999 (Lincoln Tunnel, 1998).
2.5.1 Tunnel Design

In the real world, tunneling is one of the common solutions to solve the design problems in existing cities with a lot of obstruction or heritage path in nature such as mountain areas, cross the channel or ocean and other basic obstructions. All these had an influence on the development of tunneling technologies in the recent years.

There are some common characteristic that had to be considered when considering the area of tunneling. The entire factors below will finally decide the suitable construction method in that area to complete the tunnel project (Kannapiran, 2005). The key factors are:

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

2.5.2 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:

(i) Reinforced concrete walls with steel struts, pre-stressed tie-backs or self-supported.
(ii) 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 (Kannapiran, 2005).
2.6 Underground Road Tunnels

Development of countries had brought new technologies particularly on engineering design. Innovation in engineering also plays a vital role in upgrading existing services and invention of infrastructures such as long bridges, tunnels, skyscrapers, etc. Road tunnels development are actually very famous in Europe compared to Asia. But currently it is getting more attention in Asia as there are numerous advantages from this type of development (Asia, 2010). There are different types of road tunnels development in the world such as:

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<th>Table 2.1 Tunnels around the world</th>
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<tr>
<td><strong>Country</strong></td>
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2.6.1 Laerdal tunnel

In June 1992 the Norwegian Parliament decided to construct the world's longest road tunnel (Borg et al., 2014). The 24.5km-long stretch of tunnel stretches between Aurland and Laerdal on the new main highway connecting Oslo and Bergen (Borg et al., 2014). The construction was approved to traverse a section of country with relatively poor
levels of reliability in road transport due to the mountainous area and narrow roads combined with many fjord crossings. The Laerdal tunnel is an important part of the extension of a ferry-free, reliable road link between the two largest cities in Norway. The decision to build a tunnel rather than refurbish existing roads was taken to avoid difficult terrain with high risks of rock falls. From an environmental perspective, the tunnel was seen as a justifiable investment to avoid destroying sections of the unspoiled natural landscape (Helmersen & Pedersen, 2014).

### 2.6.2 Gudvanga Tunnel

Gudvanga Tunnel is located in the municipality of Aurland in Sogn og Fjordane Norway (Gehandler, 2015). The tunnel connects the village of Gudvangen, at the head of the fjord, with the undredalen valley and is part of European route. At 11,428 metres in length, it is Norway's second longest road tunnel. It was opened on 17 December 1991. After passing through the Gudvanga Tunnel, drivers pass through a number of other tunnels. About 500 metres east of the eastern exit from the Gudvanga Tunnel a new tunnel begins; the long Flenja Tunnel which ends at Flam. Approximately 1 km after that tunnel is the Fretheim Tunnel. About 7 km further to the east (near Aurlandsvangen) is the entrance to the long Laerdal Tunnel, which is the world's longest road tunnel. In August 2013 a truck caught fire in the tunnel, resulting in 55 people being hospitalized (Gehandler, 2015).

### 2.6.3 Fréjus Tunnel

Fréjus Tunnel is a tunnel that connects France and Italy. It runs under Col du Fréjus in the Cottian Alps between Modane in France and Bardonecchia in Italy. It is one of the major trans-Alpine transport routes between France and Italy being used for 80% of the
commercial road traffic (Stroe, Ragazzi, Rada, & Ionescu, 2014). Construction of the 13 km long tunnel started in 1974, and it came into service on 12 July 1980, leading to the closure of the moto rail shuttle service in the Fréjus rail tunnel. It cost 2 billion Francs (equivalent to €700 million). It is the fifth longest road tunnel in the world. The French section is managed by the French company SFTRF, and the Italian section by the Italian firm SITAF. The French politician Pierre Dumas was chairman of SFTRF from 1962 to 1989. The tunnel can be reached from the Italian side by the A32 Torino-Bardonecchia motorway, or by SS335 from Oulx, which joins SS24 (“del Monginevro”), and reaches Bardonecchia after 20 km. From the French side, it can be reached by the A43 (‘l’Autoroute de la Maurienne’) from Lyon and Chambéry. A toll is charged to all traffic. Over 20 million vehicles passed through the tunnel during the first 20 years (Stroe et al., 2014).

In 2007, an 8 meter wide rescue tunnel parallel to the main highway was constructed. Following an accident in the Mont Blanc tunnel in 1999, safety in the tunnel was improved at the start of 2000. A strict 70 km/h speed limit and a safe distance of 150m between vehicles were imposed. The tunnel was equipped with the latest smoke and flame detectors, and a system of video cameras in the tunnel to detect the speed of traffic, as well as fire and smoke. Temperature sensors were installed at short distances throughout the tunnel, monitored from a central control post (Majumder et al., 2008). Fire hydrants were installed every 130m, fed from large water tanks. There are 11 safety points along the tunnel, equipped with telephones and loud speakers connected to the control room, with a separate ventilation duct to supply fresh air. These are separated from the main tunnel by two fire doors; the outer door closes automatically when the temperature in the tunnel reaches a certain level. Finally there is a ‘thermal gate’ system at each entrance to identify any overheating vehicles. Despite these measures, on 4 June 2005, a fire caused the death of two Slovak lorry drivers, and the closure of the tunnel to traffic for several weeks. It reopened to cars on 4 August 2005, and later to commercial vehicles. The firefighting team consists of four intervention teams: positioned on the Italian and French sides, and two inside the tunnel, about 4 km from each end (Ângelo, & Chambel, 2013).
2.6.4 Zhongnanshan Tunnel

Zhongnanshan Tunnel is in Shaanxi province China, is the longest two-tube road tunnel in the world (Ye et al., 2009). It is also the second longest road tunnel overall in the world, after the Lærdal Tunnel in Norway. The 18,040-metre long tunnel, crosses under the Zhongnan Mountain (Zhongnanshan). It opened on 20 January 2007, becoming part of the Xi’an-Ankang Highway between the Changan and Zhashui counties. The cost of building this tunnel was 3.2 billion yuan (US$410 million). The maximum embedded depth of the tunnel is 1640 metres below surface level (Ye et al., 2009).

2.6.5 Gotthard Tunnel

Gotthard Tunnel is in Switzerland runs from Goschenen in the Canton of Uri at its northern portal to Airolo in Ticino to the south and it is 16.942 km in length below the St. Gotthard Pass. It is the third-longest road tunnel in the world after Norway's Lærdal Tunnel (24.5 km), and China's Zhongnanshan Tunnel (18 km) (Popov et al., 2012).

In response to the automobile boom in Switzerland and the popularity of Italy as a travel resort, the Swiss government gave approval in July 1969 for the construction of the 16-kilometre Gotthard Road tunnel. The tunnel is longer than any existing road tunnel, and would provide year-round road link between central Switzerland and Milan to be used in place of the Gotthard Pass. The now widely used motorway tunnel was opened on September 5, 1980. It remains a single bore tunnel with just one lane operating in each direction (Husen et al., 2012).

It has four large ventilation shafts and an additional side gallery between 10 and 18 metres from the main tunnel, having its own independent ventilation system in order to facilitate the cutting of a second tunnel, should future traffic levels require it. On
Friday, October 24, 2001, a collision of two trucks created a fire in the tunnel, killing eleven and injuring many more, the smoke and gases produced by the fires being the main cause of death. Despite reports that petrol was the cause of the fire, the truck that was hit was a diesel truck. Its driver, Bruno Saba, who survived the fire, kept on driving as he was afraid his diesel might catch fire (Liu et al., 2012). The effects of even small fires in a confined space like a tunnel are extremely serious because of the inability of gases and heat to disperse. For instance, carbon monoxide is highly toxic at very low concentrations; having this trapped in a confined space allows concentrations to build well beyond a fatal level. The tunnel was closed for two months after the accident for repair and cleaning. The St. Gotthard railway tunnel close but separate from the expressway tunnel, handles rail traffic on the north-south line in Switzerland. It was opened in 1882. In this category, however, it is no longer the record-holder. The Seikan Tunnel in Japan and the Channel Tunnel between the United Kingdom and France are both in excess of 50 km (31 miles).

Gotthard Base Tunnel is being built for the use of trains travelling from northern Switzerland to the Ticino area and beyond. The St. Gotthard tunnel forms part of the A2 motorway in Switzerland, running south from Basel through the tunnel down to Chiasso on the border with Italy. Traffic flows through only one tunnel, which carries traffic both ways, with each direction allocated only one lane. The tunnel’s speed limit is 80 km/h (Caliendo et al., 2012). Heavily used, the tunnel often has traffic jams, on both the north and south ends. In contrast, another tunnel through the Alps, the San Bernardino road tunnel in the canton of Graubunden farther east, is relatively uncongested and shorter, but the road taken on that expressway is longer than the direct route through the St. Gotthard tunnel (Liu et al., 2012).

In the tunnel, a distance of 150m between each truck is enforced. In first instance it was only built for safety: an escape route in case of accidents. This second tunnel can be built out to a full road tunnel, allowing four lanes of traffic. Efforts to do this have failed, blocked by political resistance. The Alpine Initiative "for the protection of the Alpine region from transit traffic", which raised barriers against road tunnel construction, was initially blocked by the Swiss Parliament. However, in February 1994 Alpine Initiative passed (with 52% of the vote), and Parliament upheld the referendum