RESEARCH FINAL REPORT

FRGS15-192-0433

IDENTIFYING THE MINIMUM INVASIVE ACTIVE FIRE PROTECTION MEASURES FOR MALAYSIAN HERITAGE BUILDINGS TOWARDS BETTER PRESERVATION OF THE BUILT HERITAGE

SPONSORED BY:

MINISTRY OF HIGHER EDUCATION MALAYSIA

AUTHOR:

DR. NURUL HAMIRUDDIN BIN SALLEH
DEPARTMENT OF ARCHITECTURE,
KULLIYYAH OF ARCHITECTURE & ENVIRONMENTAL DESIGN
INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA
JALAN GOMBAK, SELANGOR

18 SEPTEMBER 2018

TABLE OF CONTENTS:

1.0 EXECUTIVE SUMMARY

In the case of a heritage building, until today, no proper legal requirements have been endorsed to protect historic contents and structures from fire. According to many international fire experts, fire safety systems in heritage buildings must be sympathetically designed in order to minimise the impact on the historic character (authenticity) of the buildings. Nevertheless, although many lessons have been learned and approaches to fire safety in heritage buildings have grown more sophisticated, one simple fact remains: most fires occur as a result of human action or negligence. Special considerations should be applied in upgrading fire safety systems in heritage buildings. Not only must the systems aim to comply with the relevant standards and provide the intended levels of protection, but additionally their impact on the building and its fabric must meet a range of tests. Furthermore, it is essential that full consideration be paid to the risks of potential damage to original fabric as well as the aesthetic impact fire systems might have on heritage buildings. Any changes to a listed building must not only address fire protection needs but must fully comply with the law in respect of listed building consent. The main objective of this study is to identify and evaluate active fire protection (AFP) measures in heritage buildings that able to provide an acceptable level of safety for both people and property with minimum invasive into the historic fabrics. Other than literature reviews, a series of observations, interviews with fire experts and case studies will be employed to provide primary data in this study. At the end of the study, a practice guidance in selection and installation of active fire protection measures in Malaysian heritage buildings has been recommended.

Keywords: Fire safety, Heritage building, building conservation, historic, Malaysia

2.0 INTRODUCTION

During the last decades, great concern on the conservation of cultural heritage including fire protection has risen among various countries authorities, fire experts, conservationists and citizens (Papaioannaou, 2009). Many literatures including books and research reports continuously highlight that heritage buildings are more exposed to fire than new buildings (Kidd, 1998; Feilden, 2003; Lilawati, 2001). In general, there are two problems of fire safety in heritage buildings. Firstly, most of them are relatively more exposed to fire risks due to their existing structures and contents that are particularly vulnerable to fire. The hazards present at fires involving heritage buildings generally arise from the building itself, the contents of the building, the nature of the fire situation, the function of the building, and environmental consideration (Kidd, 2005). Most of them are widely exposed to several fire risks such as follows:

i. Existing structures which are weak on fire resistance, aging or decaying building materials and combustible materials (e.g., timber).

ii. Inadequate fire prevention and protection systems, notably passive fire protection.
iii. Lack of fire safety awareness among building owners, managers, staff and public.
iv. Low standard of management, housekeeping and maintenance.
v. Being located at the busiest areas or narrow roads without good access to fire brigade.
vi. Existing electrical wiring which has not been upgraded or replaced accordingly where few historic buildings are still using old electrical wiring.
vii. Storage for many flammable but priceless contents, artefacts or heritage collections such as old books, manuscripts, traditional costumes and antique furniture.
viii. Large numbers of visitors where most are open daily to public.
ix. Dangers from renovation works.
x. Possible dangers from natural factors such as lightning and overheating.
xi. Dangers due to carelessness and arson.

The second problem concerns the method of upgrading fire safety in heritage buildings (Kidd, 1998; Nurul Hamiruddin, 2011). The responsibility of fire safety of heritage buildings lies mainly in the hands of the owner. Nevertheless, upgrading fire safety measures in heritage buildings may result in conflict between fire safety standard requirements and the historical significance of the buildings, particularly when the use of a building is changed (adaptive re-use). For example, difficulties will often arise when additional staircases for means of escape and the installation of fire precautions hardware, such as exit notices, emergency lighting and fire detection systems, are required (Kidd, 1995). It is noted that, in cases of conflict between the needs of fire protection and the need to minimise the intrusion into historic structures, a logical and systematic approach to the assessment of fire safety requirements is needed in order to reveal alternative methods of achieving adequate, appropriate, and cost-effective standards of fire safety (Kidd, 1995).

In Malaysia, at least one heritage building has been destroyed or damaged by fire almost every year. The worst fire occurred in 2008, where a total of 59 heritage buildings were involved in five different fire incidents. These tragedies emphasise the vulnerability of heritage buildings and their contents to fire and its aftermath. Electrical fault was recorded as the highest cause of fire in the buildings (Table 1). However, until today, no proper legal requirements have been endorsed to protect historic contents and structures from fire in Malaysia

Table 1: Fire statistics of heritage buildings in Malaysia from 1992 – 2010

Date	Building	Year of Built	Function	Estimated Loss (RM)	Cause
16 March & Dec. 1992	**The High Court Building,** Kuala Lumpur	1896 / 1904	Court		
17 Sept. 1992	**The National Museum Malaysia** Kuala Lumpur	1959	Museum	100,000	Suspected origin from portable water heater or smoking
12 Sept. 1996	**The Sultan Abu Bakar Royal Museum**, Johor	1866	Museum	Undisclosed	Arson (Molotov cocktail)
15 March 1997	**The Sultan Abu Bakar Royal Museum**, Johor	1866	Museum	Undisclosed	Undisclosed
2 Dec. 2001	**The People's Museum**, Melaka		Museum	**Undisclosed** (Exhibition Hall is totally damaged. Several copies of Dutch manuscripts, old paintings and artefacts were destroyed)	Short-circuit
20 Oct. 2003	**Pak Ali's House,** Kampung Kerdas, Gombak	1876	Museum	> 1 million	Short-circuit
27 June 2005	**23 Shop houses of pre-World War**, Meru, Klang	1920 - 1930	Shop house	5 million	
27 June 2005	**13 Shop houses of pre-World War**, Kampung Sentosa, off Jln Klang Lama, KL	1920 - 1930	Shop house	> 500,000	
30 May 2006	**The Handcraft Village,** Jalan Semarak, Kuala Lumpur		Handcraft centre	300,000	
17 July 2006	**Shop house**, Jalan Laksamana, Bandar Hilir, Melaka	> 1806	Shop house		
27 July 2006	**The Sarawak Club**, Kuching	1876	Club house		
24 July 2007	**The Royal Malaysian Police Voluntary Club** Ipoh	1910	Club house		
30 Sept. 2007	**The PULAPOL Senior Police Quarters,** Jalan Semarak, KL	1940	Quarters	300,000	Short-circuit
19 Mac. 2008	**6 old shop houses,** Taiping, Perak	1895	Shop	> 300,000	
05 May 2008	**38 units of Punan Bah longhouse,** Belaga, Sarawak		Residential	> 500,000	
11 July 2008	**The Memorial Datuk Onn Jaafar,** Batu Pahat.		Memorial	Destroyed 70% of the building and artefacts	Undisclosed
09 Dec. 2008	**7 old wooden shop houses,** Tamparuli, Sabah	1950s	Shop house	(Totally destroyed)	unreported
11 Dec. 2008	**7 old shop houses,** Lebuh Armenian, Penang **(In World Heritage Site zone)**	> 50 years	Shop house	± 600,000	unreported
21 Dec. 2009	**7 shop houses,** Jalan Gambier, Kuching, Sarawak	> 100 years	Shop house		
6 Feb. 2010	**4 shop houses,** Jalan Wayang, Kuching, Sarawak	> 100 years	Shop house		

In a series of survey and observation conducted by Nurul Hamiruddin from September 2007 until May 2008 at 37 heritage buildings located in the nine states of Malaysia has identified various fire safety management problems in the heritage buildings. Ten leading problems identified are as follows:

i. Buildings without fire safety plan (100%)
ii. No periodical fire training for staff (100%)
iii. Buildings without fire certificate (97%)
iv. Buildings without emergency escape plan (97%)

v. Buildings not disabled friendly (97%)
vi. Buildings without fire policy (95%)
vii. Buildings without periodical risk assessment (89%)
viii. Buildings without direct link to the local fire brigade (86%)
ix. Buildings without periodical fire drill (84%)
x. Buildings without insurance (68%)

In addition, it is also discovered in the interview surveys that the problems occurred mainly due to three factors which are lack of fire safety guidelines, poor fire safety awareness, and lack of enforcement by respective authorities. Escape Consult (2006) states that, in protecting and preserving the historical fabric of heritage buildings, there are some major differences which is a challenge for the architect or fire protection engineer in the application of general fire protection principles. Most heritage buildings face difficulty in meeting the prescriptive-based approach of fire safety that could harm the building's historic character. The challenge is to maintain their historical fabric while providing a reasonable level of fire safety to the occupants (including staff and visitors) and contents (particularly those with historical value). For example, retrofitting a means of escape in a heritage building may damage the historical fabric of the building. Thus, the consultants, such as architect and engineer, will need to have the sensitivity and ingenuity approach to provide innovative means of escape that do not damage the historical fabric of the building. In other words, the consultants should come out with a concept of balancing fire engineering with conservation aims in their mind. Any fire protection measures should give maximum safety with minimum damage. There should be as little physical damage to the fabric of the building as possible and minimum aesthetic intrusion. Fire protection systems should never be allowed to dominate the building. Hence, the situation should always be analysed thoroughly before any installation of fire protective systems (Karlsen, 2008).

3.0 PROBLEMS STATEMENT

There are two main problems of fire safety in heritage buildings:

i. heritage buildings are relatively more exposed to fire risks due to their existing structures and contents that are particularly vulnerable to fire. The hazards present at fires involving heritage buildings generally arise from the building itself, the contents of the building, the nature of the fire situation, the function of the building, and environmental consideration.
ii. Upgrading fire safety measures in heritage buildings may result in conflict between fire safety standard requirements and the historical significance of the buildings, particularly when the use of a building is changed (adaptive re-use). Most fire safety codes are designed

fundamentally to protect people but not for the protection of the collections or the preservation of the historic fabric of the building or the collections.

4.0 RESEARCH QUESTIONS

What are the appropriate active fire safety measures with minimum invasive approach for protection of Malaysian heritage buildings?

5.0 RESEARCH OBJECTIVES

This study embarks on the following objectives:

i. To identify and evaluate minimum invasive active fire safety measures for protection of Malaysian heritage buildings,
ii. To recommend the practice guidance in selection and installation of active fire protection measures for heritage buildings.

6.0 METHODOLOGY

The first stage involved literature review, where both conservation and general fire safety literatures were reviewed in order to identify key issues and recent research that relate or were significant to the research topic. The second stage involved the collection of primary data through interviews and observations. The interview sessions specifically involved the fire expects (e.g. BOMBA officers and fire engineers). The interviews have been conducted mainly to gather information on the current active fire protection systems and its application in heritage buildings.

In the third stage, six (6) heritage buildings were selected as the case studies to observe directly the current application of active fire protection measures in the buildings. The existing active fire protection measures in the selected heritage buildings have been observed and recorded, as well as taking photos for research purposes. The buildings are National Textile Museum, Kuala Lumpur; Istana Ampang Tinggi, Negeri Sembilan; Negeri Sembilan's Traditional Malay House; Sultan Abdul Samad Building, Kuala Lumpur; Ipoh Town Hall Building, Ipoh and Sultan Azlan Shah Gallery, Kuala Kangsar.

In the last stage, recommendations and conclusions have been made based on the analysis of the literature and the collected data. It is hoped that the recommendations will be a useful guidance to assist those involved in conserving any heritage buildings particularly consultants (e.g. architects & fire engineers) in selecting and installing appropriate active fire protection measures for the buildings.

7.0 FINDINGS

As mentioned earlier, there are 6 (six) case studies selected in this research. The case studies are as follows:

Table 3: List of the selected case studies

No	Name of Building
1	National Textile Museum, Kuala Lumpur
2	Istana Ampang Tinggi, Seremban, Negeri Sembilan
3	Rumah Tradisional Negeri Sembilan, Seremban
4	Sultan Abdul Samad Building, Kuala Lumpur
5	Sultan Azlan Shah Gallery, Kuala Kangsar, Perak
6	Ipoh Town Hall, Ipoh, Perak

7.1 Case Study 1 – National Textile Museum, Kuala Lumpur

Figure 1: The Façade of National Textile Museum, Kuala Lumpur

7.1.1 Introduction

National Textile Museum is currently located inside JKR Building 26 in Lot 50 Seksyen 70, Jalan Sultan Hishamuddin, Kuala Lumpur. Originally opened in 1896, the building was constructed about the same time as the neighbouring Bangunan Sultan Abdul Samad. The person responsible for the design of the building was a British Architect named A. B. Hubback. The architecture of the building was inspired by the elements of Mughal-Islam and consists of red and white stripes throughout the whole building made using red bricks and white plaster laid alternately. Two octagonal-shaped towers are located on both sides of the building with a large concrete dome placed on top of them. The original main

entrance was located facing Jalan Sultan Hishamuddin but a new lobby space made out of glass was introduced in 2008 on the opposite side of the building to serve as the main entrance to the building. In 1905, the building served as the main headquarters for the Federated Malay States Railway and was later given to the Selangor government to be used by Jabatan Kerja Raya Selangor in 1917. The building was also later occupied by Jabatan Kerja Air Selangor, Bank Negara, and Bank Pertanian between the 1959 and 1980 before it was given to Urban Development Authority Holdings (UDA) in the year 1981. In 1986, the building was leased by Perbadanan Kemajuan Kraftangan Malaysia to serve as a textile museum and display area for handycrafts and works of art. However, from the year 2001 to 2004, the building served as the High Court (Appellate and Special Powers) and the Gallery of Justice prior to the conversion of the building into the current National Textile Museum in October 2007. This was due to the approval of the Cabinet regarding the proposal for the establishment of National Textile Museum mentioned in the Memorandum of the Minister of Culture, Arts and Heritage-No. 527/2468/2005 dated the 13th of July 2005.

The building was gazetted as a heritage building on 13 October 1983 under the Antiquities Act 1976 and the conversion into National Textile Museum was part of the Ninth Malaysia Plan (2006-2010). The building is a 2 ½-storey building situated within 3259 m^2 of land with a total floor area of 3145.3 m^2. The conservation work of the building started in August 2007 and completed in June 2009 before it was opened to the public on the 9th of January 2010.

The building consists of 5 galleries, each with their own particular theme. 2 galleries, Pohon Budi and Pelangi, are located on the floor. Pohon Budi Gallery showcases the origin of textiles throughout the period of time as well as their involvement with trading whereas the Pelangi Gallery highlights selected heritage collections from the Malay, Chinese, Indian, and ethnics from Sabah and Sarawak. The other 3 galleries are located on the 1st floor of the building which consists of Ratna Sari, Teluk Berantai, and Saindera. The Ratna Sari Gallery is designated for jewelry items and person adornments made from various types of materials while Teluk Berantai Gallery exhibits the details of the Malay textile heritage through elements such as embroidery. The office is situated on the mezzanine floor above the 1st floor whereas the cafe and souvenir shop are located on the ground floor.

7.1.2 Active Fire System

National Textile Museum features a variety of active fire system implemented throughout the whole building. These include both the detection and suppression of fire system. However, due to its function as a museum and nature as a heritage, proper application of active fire system may be limited or slightly constrained. One of the most commonly seen active fire system found in the building is the

smoke or heat detector system. The placement of these devices can be seen throughout the whole building and implemented within each space of the building with the exception of the outer walkway corridor since they are open to the outside environment. As for the escape lights and exit signs, they are installed in most parts of the building so visitors will most likely be able to identify them during an emergency. The exit signs can be found on top of most of the doors in the building.

In most part of the building, equipment such as fire extinguisher, hose reel, and fire alarm are only found within the corridor. They are mostly installed close to one another and situated right next to a column located near to a door. Gas suppression system can also be found on the ground floor of the building situated by the reception counter and control panel at the entrance. Based on the number of gas cylinders seen, it is most likely that the system only covers a certain particular area of the building.

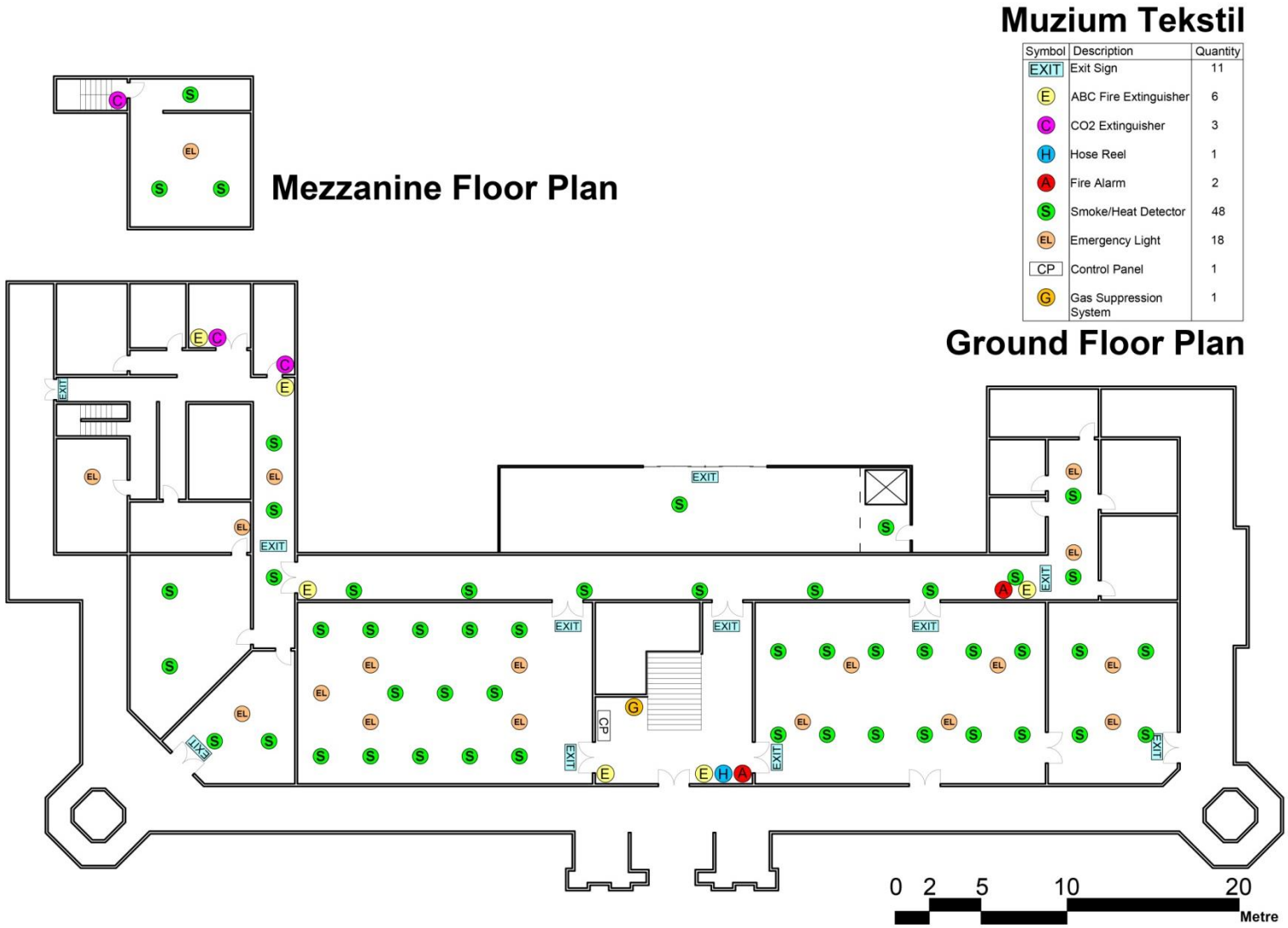


Figure 2: Location of active fire protection measures in Ground Floor Level of National Textile Museum

Figure 3: Location of active fire protection measures in First Floor Level of National Textile Museum

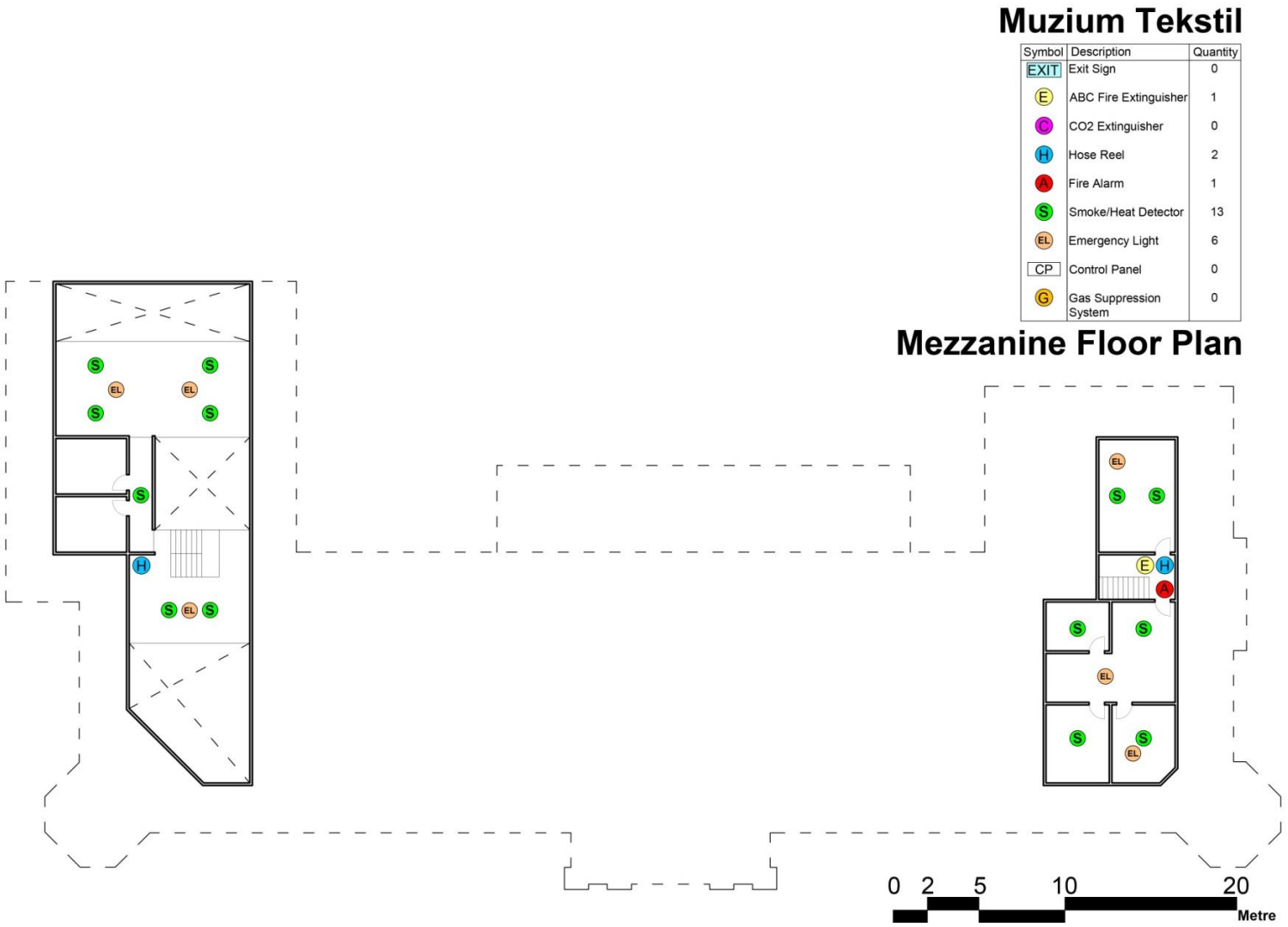
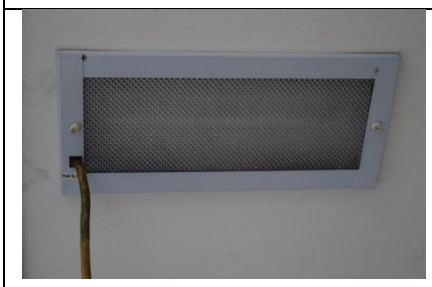
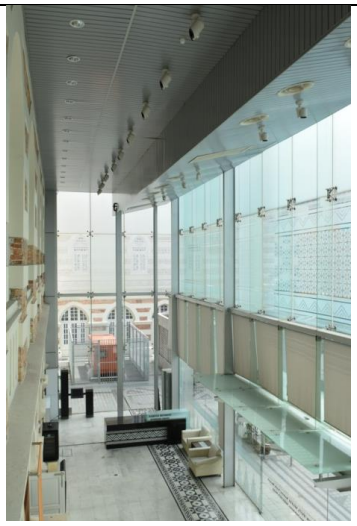
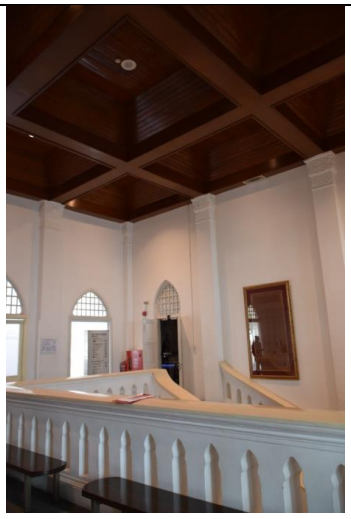
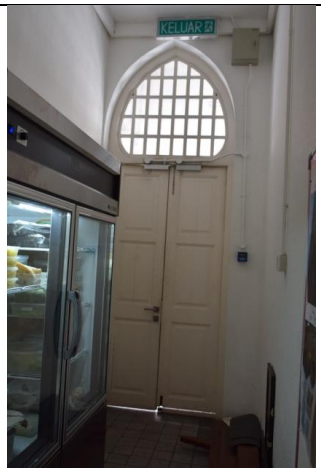
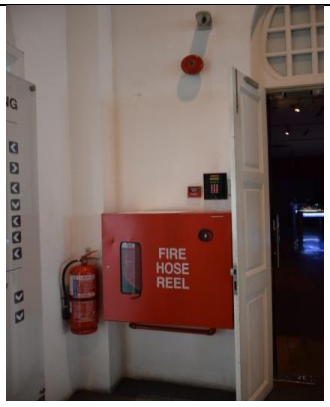


Figure 4: Location of active fire protection measures in Mezzanine Floor Level of National Textile Museum

Picture	Description
	The building mainly uses heat detectors in every area of the building and considered to be effective. However, heat detectors will only activate when the fire has reached flaming combustion. In terms of design, the detector generally blends well with the white ceiling found in most part of the building and the wiring is hidden within the ceiling.
	The installation of the emergency light was designed to be as part of the ceiling. The wirings are hidden within the ceiling. However, some of the emergency lights are no longer functioning and require immediate replacement.
	In the glass lobby area, the detectors are installed at the centre of the ceiling in a single row. The white detector blends well with the colour of the grey ceiling. While the number of detectors is more than enough to cover the whole area, the ceiling height is too high for a smoke/heat detector to function properly. The distance between the floor and ceiling is more than 6 metres and it will already be too late by the time the detectors are able to detect the presence of fire.
	On top of the main staircase, the detectors are installed at the centre of each box on the ceiling. The detectors are white in colour but blends well with the timber ceiling due to its positioning. While the number of detectors is more than enough to cover the whole area, the ceiling height is too high for a smoke/heat detector to function properly. The distance between the floor and ceiling is roughly around 6 metres and it will already be too late by the time the detectors are able to detect the presence of fire.

	The exit sign is installed above the door but the placement may be too high for the occupants to notice. This is most likely to prevent the sign from disturbing the design of the door. However, exit signs are usually installed directly on top of the door frame and are supposed to be easily spotted during emergency to point out the evacuation direction.
	Some of the doors which lead into the galleries are equipped with an automated lock system as a security measure. This system can only be manually unlocked by the museum staff during non-emergency situation. Even though it prevents visitors from easily roaming around the building, locked exit doors may act as a hindrance during escape process if it did not respond at an appropriate speed.
	In certain areas of the building, exit doors are blocked or obstructed by various utilities/furniture and museum's unused display items. By doing so, it will create an obstacle for the occupants to pass through during an evacuation situation. This may also cause the door to become unusable if it is completely blocked by these particular items.
	ABC Fire extinguishers and hose reels were installed alongside one another in most area of the building. They are usually placed next to the gallery entrance or door and can be easily spotted by the building occupants. However, due to the design of the hose reel storage box, it may not blend well the building aesthetics.

	CO^2 fire extinguishers were mostly placed in services room or next to electrical utilities. They are generally more effective in dealing with such particular environment and well hidden within the room.

7.2 Case Study 2- Istana Ampang Tinggi, Negeri Sembilan

Figure 5: Façade of Istana Ampang Tinggi, Negeri Sembilan

7.2.1 Introduction

Istana Lama Ampang Tinggi was originally owned by Yamtuan Ulin, the 5th Yang Dipertuan Besar of Negeri Sembilan (1861-1869). The original location of the building was located within a paddy field area in Kampung Ampang Tinggi, Kuala Pilah, Negeri Sembilan. The building was constructed by several Malay carvers and most parts of the building such as doors, windows, and stairs were implemented with various traditional carvings. Elements such as *'awan berarak'* can be seen on the separating wall between the verandah and living area.

The building was completed and occupied by Yamtuan Ulin in 1865. The building was later given as a wedding gift to his daughter, Tunku Cindai and her husband, Tunku Muda Cik, son of Yamtuan Radin (1824-1861). After Yamtuan Ulin had passed away in 1869, both Tunku Muda Cik and his wife moved into the building. The building was later passed on to his daughter, Tunku Halijah. Tunku Halijah was married to Tuanku Muhammad who was the current Yamtuan Seri Menanti at that time (1888-1898). He was later appointed as the seventh Yang Dipertuan Besar Negeri Sembilan from the year 1898 to 1937. In 1921, Tunku Halijah had passed away but the building was continued to be occupied by the family members of Tunku Muda Cik.

The building was seemingly left abandon around the year 1930 without any proper maintenance. In 1953, with the approval of the 8th Yang Dipertuan Besar Tuanku Abdul Rahman, the old Istana Ampang Tinggi was dismantled and reassembled in Seremban. However, only components from the *'rumah ibu'* and *'rumah tengah'* were brought there and the construction was completed in 1954. The current British High Commissioner at the time, General Sir Gerald Templer, decided to convert the building into a state

museum. After the completion of the present Negeri Sembilan Cultural Complex in 1980, Istana Ampang Tinggi was once again relocated into the complex area as part of its display.

7.2.2 Active Fire System

Due to the small size of Istana Ampang Tinggi, only a few types of active fire system are implemented in the building. Based on observation, only one fire extinguisher is provided inside the building. However, since the building is located quite close to two fire hydrants within the compound of the Cultural Complex, one fire extinguisher for just the building is sufficient. Two emergency lights are provided within each area of the building and were installed at appropriate places.

As for the smoke or heat detector, three of them can be found within the verandah area whereas another three is located inside the living area. The coverage for the living area is adequate but as for the verandah, the current placement of each detector may limit the coverage due to the length of the area. The left end of the verandah may be left exposed since the closest detector is about 10 metres away.

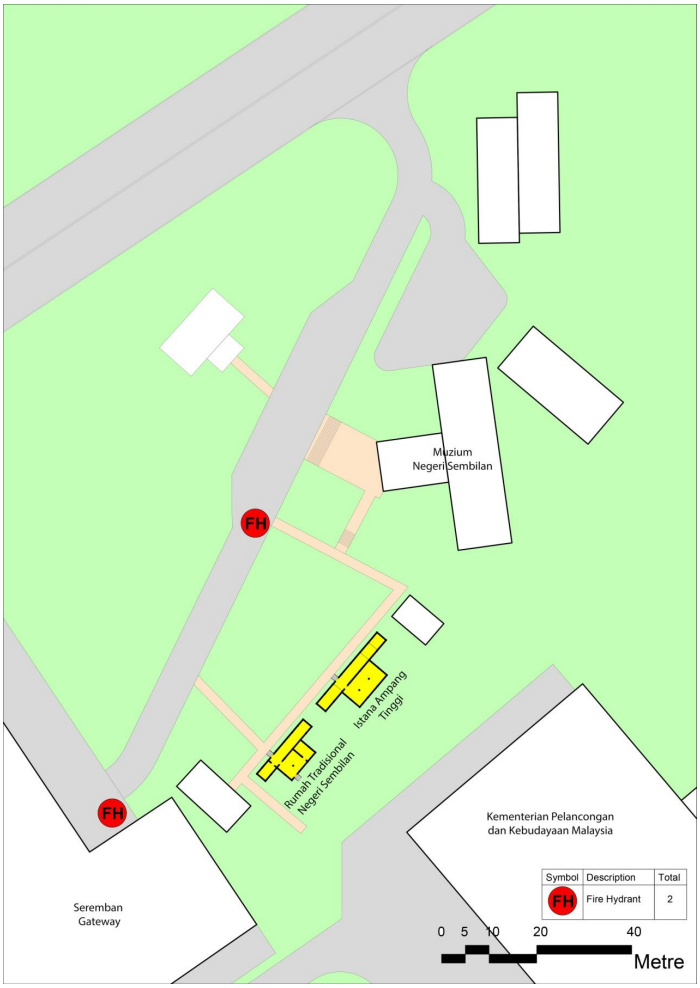


Figure 6: Location of fire hydrants at Istana Lama Ampang Tinggi, Negeri Sembilan

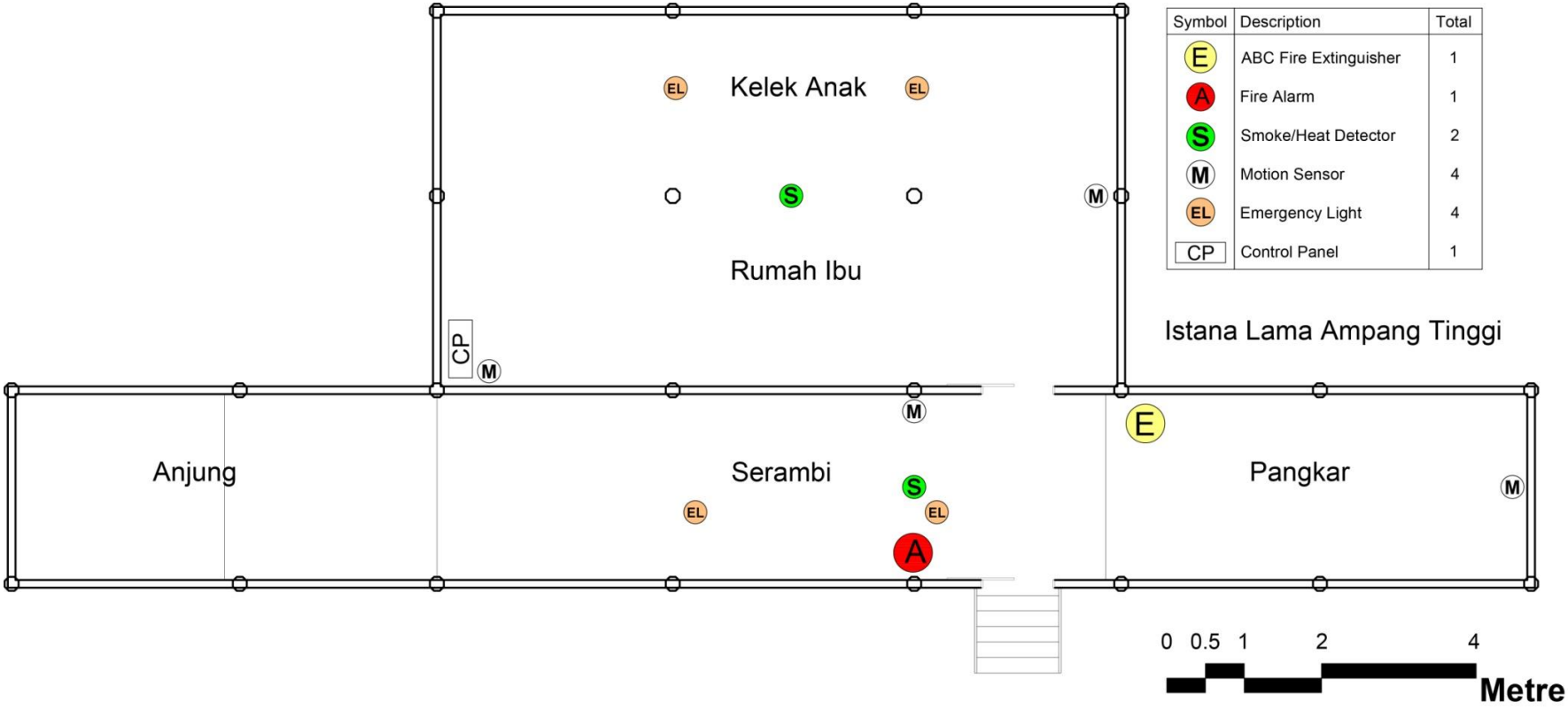


Figure 7: Location of active fire protection measures in Istana Lama Ampang Tinggi, Negeri Sembilan

Picture	Description
	One fire extinguisher is provided inside the building. Due to the size of the building, this may be fairly sufficient to cover both area of the building. The farthest distance from the extinguisher is only roughly 14 metres long.
	Several emergency lights were installed inside the building and still working properly. They are attached to the roof structure at the centre of the room. Both rooms have 2 light each and the wiring pipes are hidden by painting it with the same colour of the structure.
	Smoke detectors were installed in both areas of the building. They are attached to the roof structure at the centre of the room. Both rooms have several detectors each. Some of the wiring is hidden by painting it with the same colour of the structure while a minority is left with the original wiring colour.

7.3 Case Study 3 - Negeri Sembilan Traditional Malay House, Seremban

Figure 8: Facade of Negeri Sembilan Traditional House, Seremban

7.3.1 Introduction

Also known as 'Rumah Minangkabau', the house was originally owned by Tengku Saiyed Ismail bin Tengku Saiyed Abd. Rahman, Dato' Kelana of Sungai Ujong, and his wife, Cik Kundur. The house was originally located in Kampung Anak Air Garam, around 4 miles from Seremban heading to Port Dickson. The house was built by two Minangkabau craftsmen siblings named Haji Syahahbuddin and Kamaruddin in 1898 and the cost was estimated to be around RM400. One of the main attractions of the house is that most parts of the building are filled with beautifully carved elements.

In 1924, the house was disassembled and shipped to London by the British Administration to be displayed as part of the British Empire Exhibition in Wembley Park. The house is currently located within the compound of the Negeri Sembilan Cultural Complex next to Istana Ampang Tinggi. Prior to its current location, the house was previously located in Taman Tasik Seremban and was commonly known as a ghost house due to its black colour and was left unoccupied for a long period of time.

7.3.2 Active Fire System

Since the size of Negeri Sembilan Traditional Houseis slightly smaller than Istana Ampang Tinggi, the building has less active fire systems implemented. Similar to Istana Ampang Tinggi, only one fire extinguisher is provided since the building is located within the coverage of two fire hydrants inside the compound of the Cultural Complex. Two emergency lights were installed within the verandah area

and another one inside the living area. Based on observation, no smoke or heat detector is installed inside the building.

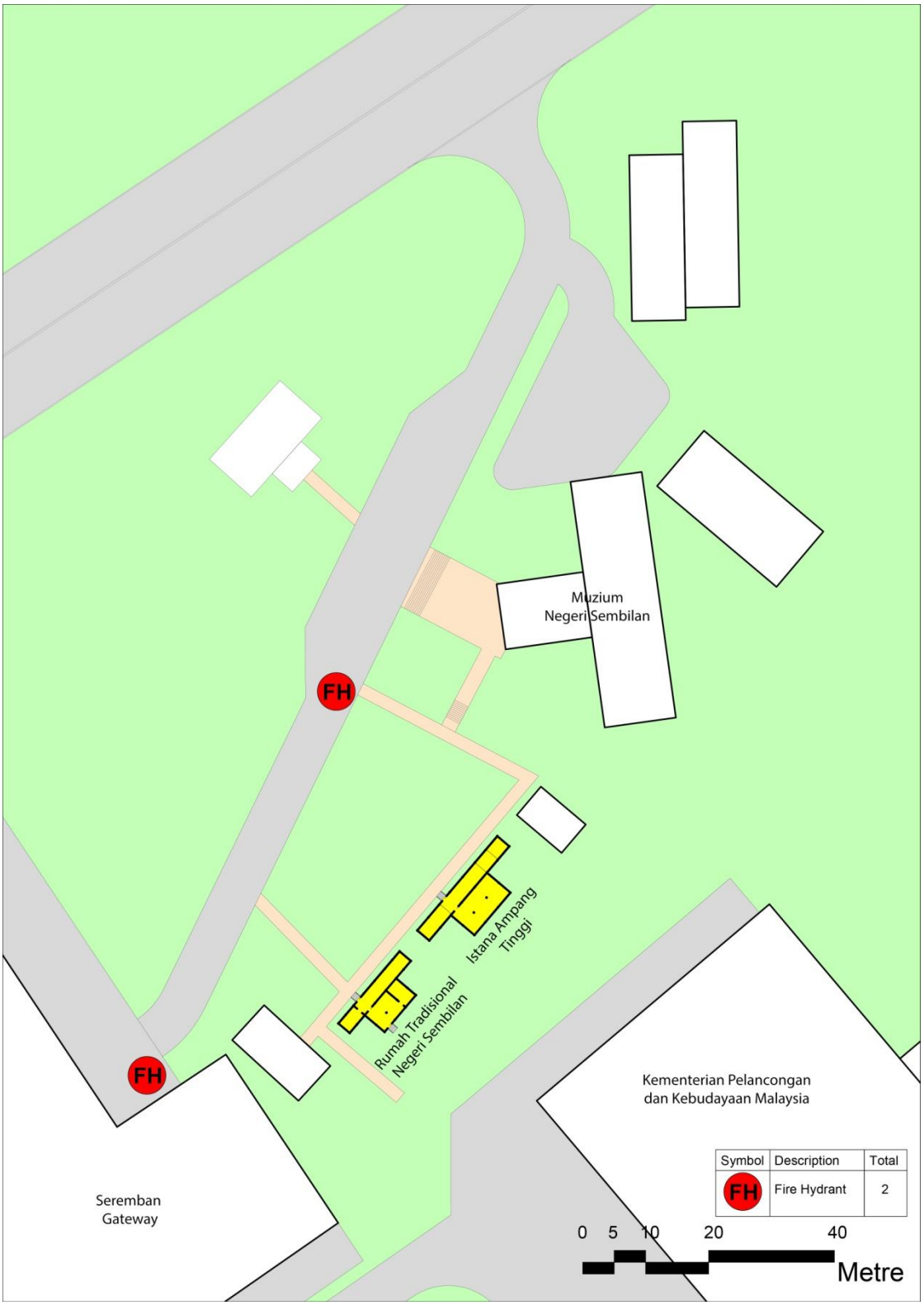


Figure 9: Location of fire hydrants at Rumah Tradisional Negeri Sembilan

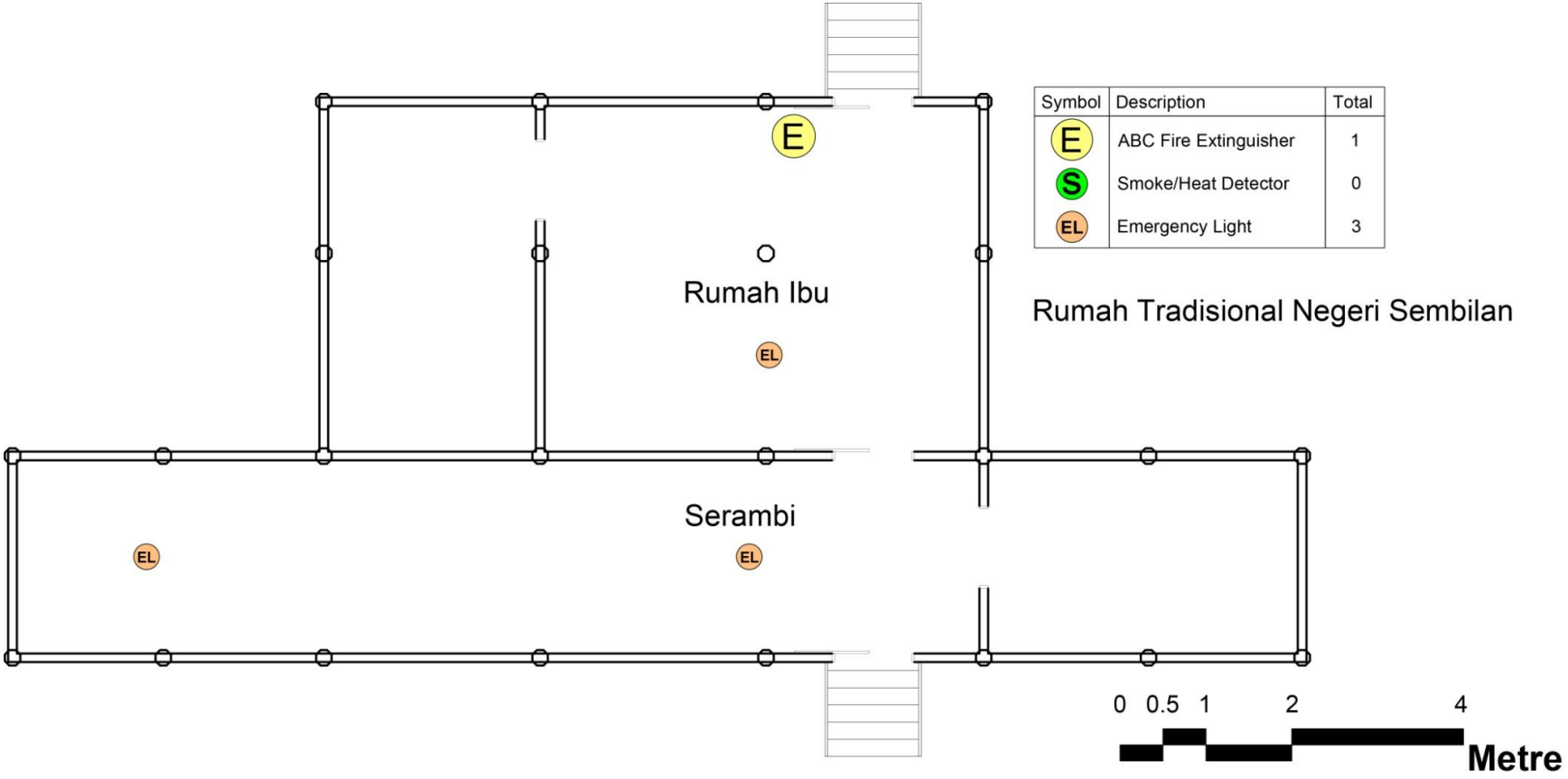
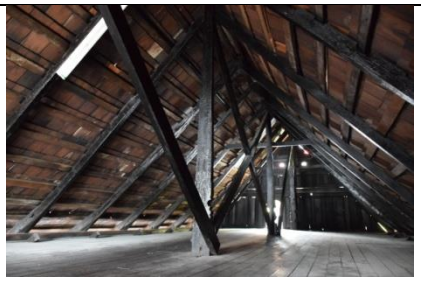


Figure 10: Location of active fire protection measures in Rumah Tradisional Negeri Sembilan

Picture	Description
	One fire extinguisher is provided inside the building. Due to the size of the building, this may be fairly sufficient to cover each area of the building.
	3 emergency lights were installed inside the building and still working properly. They are attached to the roof structure at the centre of each area and another one at the left of the building. The wiring pipes are hidden by painting it with the same colour of the structure.
	No smoke detectors were installed in any area of the building.

7.4 Case Study 4 - Sultan Abdul Samad Building, Kuala Lumpur

Figure 11: Façade of Sultan Abdul Samad Building, Kuala Lumpur

7.4.1 Introduction

Located at Jalan Raja, Kuala Lumpur facing Dataran Merdeka, Sultan Abdul Samad Building is considered as one of the most iconic heritage building in Malaysia. The construction of the building was completed in 1897, about the same time as the neighbouring National Textile Museum. The building was initially known as the new Government Office and later known as the Federal Secretariat when it was used by the Selangor Government before moving to their new building in Shah Alam in 1974. The building was later given the name Sultan Abdul Samad who ruled the state from 1857 to 1898.

The construction of the building was during the peak of Kuala Lumpur development in the late 19th Century. The project was part of the "Massive Building programme' under the supervision of Maxwell/Spooner, the planner and architect responsible for administration building of Kuala Lumpur at that time. British Architect, A.C. Norman was responsible for the design of the building with the help of R.A.J. Bidwell and A.B. Hubback. The beginning of the construction was launched by H.E. Sir Charles B.H. Mitchell K.C.M.G. (Governor of Straits Settlements) on the 8th of October 1894. After its completion in April 1897, it was estimated that the cost of the whole project was RM152,824 during the two years and seven-month construction period. Sultan Abdul Samad Building was considered as the first government building constructed under the Federated Malay States administration and was officially opened on the 4th of April 1897 by Sir Frank Swettenham, the General Resident of the time.

The objective of the construction of Sultan Abdul Samad Building was to house several administrative departments of Federated Malay States as a centralized administrative building. The lists of administrative departments involved are as follow:

i. Government Secretariat Office
ii. Council Chamber
iii. Sanitary Board
iv. Judicial Commissioner
v. Public Works Department
vi. Audit and Treasury
vii. Land Office
viii. Department of Mines
ix. Post Office
x. Public Works Department District Office

The design of the building was mainly influenced by the Islamic 'Moorish' or 'Mahometan Style' originated from the public buildings in India. Emphasis was given to two unique styles, the grand proportion and classical symmetry, as can be seen in the building's design which bears similarities to the styles of European historical buildings. The decorations of the building are based on "the Raj style" which reflects the main purpose of its construction in this region. Another iconic element of Sultan Abdul Samad Building is the Clock Tower with the height of 41.5 m. The Clock Tower is well known to most people due to its historical involvement during the Malaysian Independence Day on the 31st of August 1957.

After the relocation of the Selangor Government offices to Shah Alam in 1974, the building was renovated and later occupied in 1978 by the Court of Appeal, High Court, and the Supreme Court, later known as the Federal Court. In March 2007, both the Federal Court and Court of Appeals were relocated to the Palace of Justice in Putrajaya. The building is now currently being occupied by the Ministry of Information, Communications, and Culture of Malaysia and was later joined by Jabatan Warisan Negara in 2014. Throughout this period of time, numerous conservation and refurbishment works were conducted to preserve the condition of the building. Currently, the front side of the main building is occupied by the Ministry whereas the rear wing of the main building and Old Post Office building is occupied by Jabatan Warisan Negara.

7.4.2 Active Fire System

Various types of active fire system were implemented inside Sultan Abdul Samad Building and each serves its own purposes. These include the installation of fire detector system, fire suppression system, and means of escape. However, due to its nature as a heritage building, certain type of system such as water sprinkler system was not installed inside the building.

Both the main building and the Old Post Office Building feature the smoke and heat detector system. However, there is a slight difference regarding the placement of both of these detectors in each building. The heat detectors for the main building can only be found at the rooftop level of the building. The ground floor, first floor, and mezzanine floor make full use of the smoke detector system. As for the Old Post Office building, the heat detectors can be seen installed at the walkway corridor, services room, and also the rooftop level. The rest of the building areas are equipped with the smoke detector system.

For the suppression system, hose reel system and fire extinguishers are provided in most part of the building. Based on the observation conducted at the Old Post Office Building, hose reels can be found on each four corners of the building alongside the fire alarm. However, due to the complicated inner layout of the building, it is unsure on whether or not the allocated amount and location of each hydrant is appropriate in order to provide the right amount of coverage towards each area. Meanwhile, the allocation of hose reels in the main building seems to be appropriate and can be easily found alongside every part of the building's corridor.

Inside Bangunan Sultan Abdul Samad, two different types of fire extinguishers were identified. One of them is filled with ABC Powder while the one is filled with CO^2. While both of the extinguishers serve the same purposes, the placement of each extinguisher differs in term of area size and function. ABC Powder extinguishers are commonly placed next to hose reels and fire alarms while some are also placed individually in workspace area or area with frequent occupants. On the other hand, CO^2 extinguishers are mostly placed inside of services area and smaller space areas such as storage which have a very minimum amount of occupants during most of the time.

As a means of escape for the occupants, exit signs and emergency lights are installed in each part of the building. Most of these equipments appear to be relatively new and are still functioning properly. The wiring of these equipments are mostly hidden within the ceiling and does not disturb the aesthetic of the building.

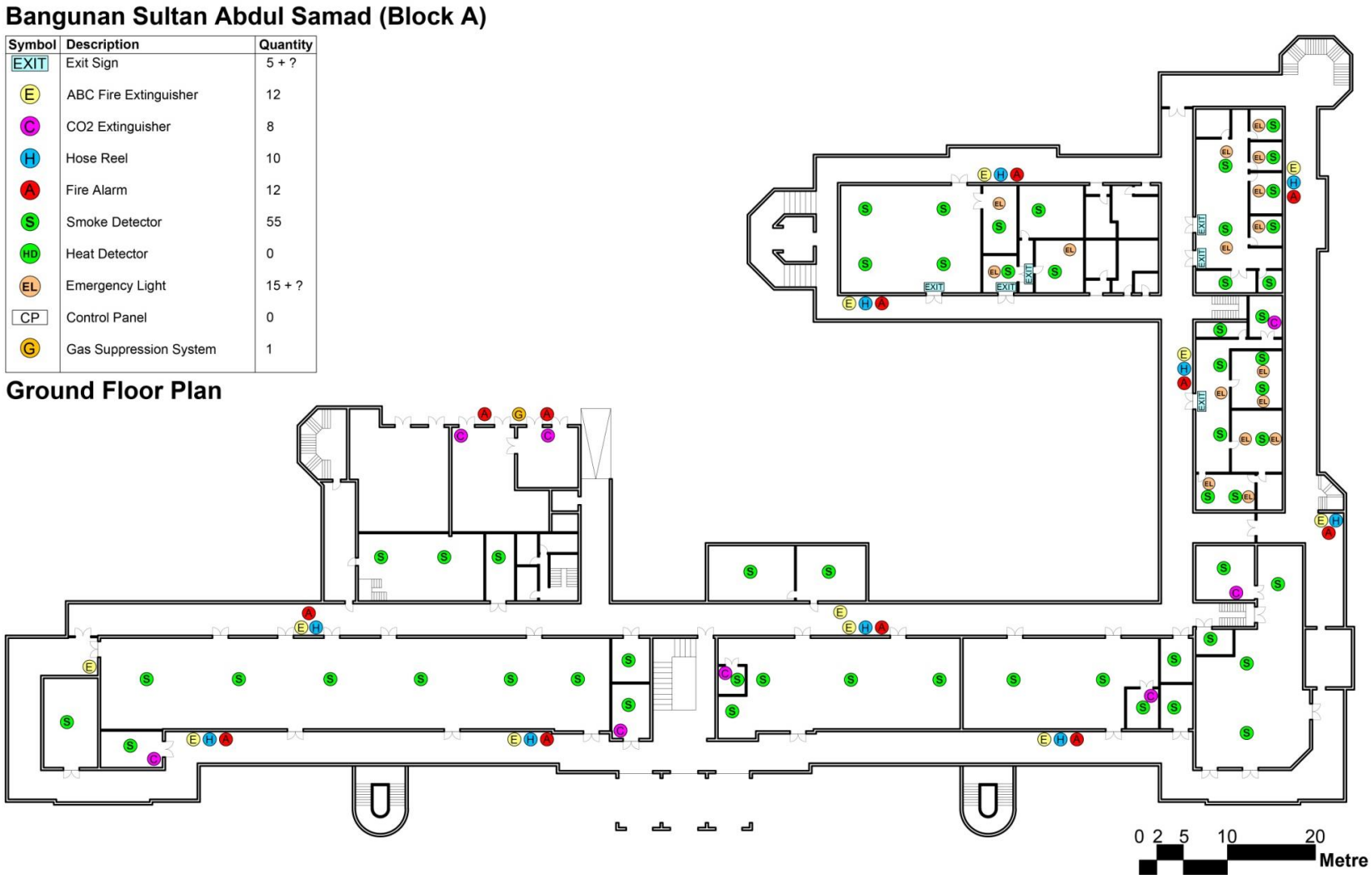


Figure 12: Location of active fire protection measures at Ground Floor level of Sultan Abdul Samad Building

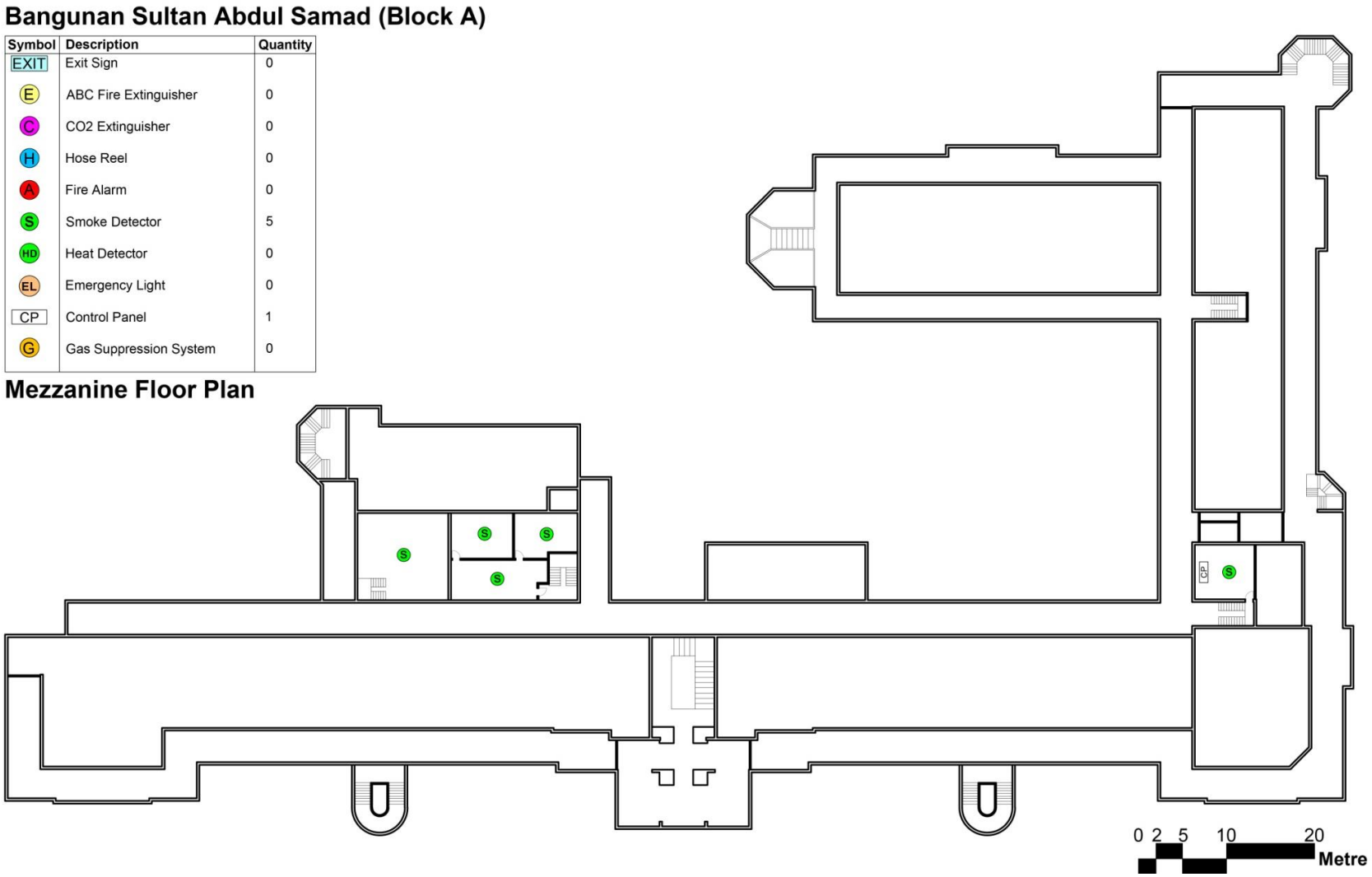


Figure 13: Location of active fire protection measures at Mezzanine Floor Level of Sultan Abdul Samad Building.

Bangunan Sultan Abdul Samad (Block A)

Symbol	Description	Quantity
EXIT	Exit Sign	5 + ?
E	ABC Fire Extinguisher	14
C	CO2 Extinguisher	8
H	Hose Reel	14
A	Fire Alarm	15
S	Smoke Detector	102
HD	Heat Detector	0
EL	Emergency Light	13 + ?
CP	Control Panel	0
G	Gas Suppression System	1

First Floor Plan

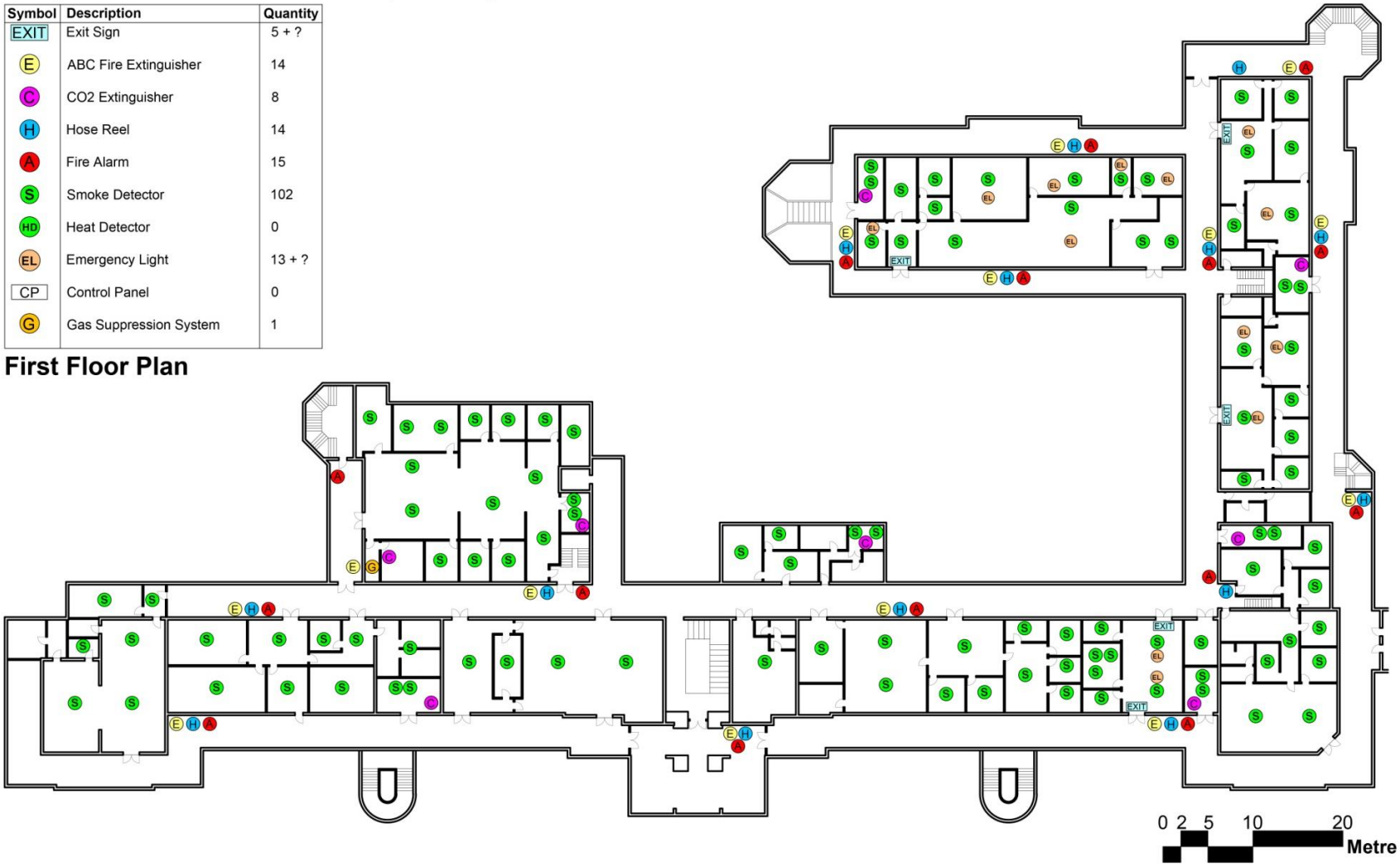


Figure 14: Location of active fire protection measures at First Floor Level of Sultan Abdul Samad Building.

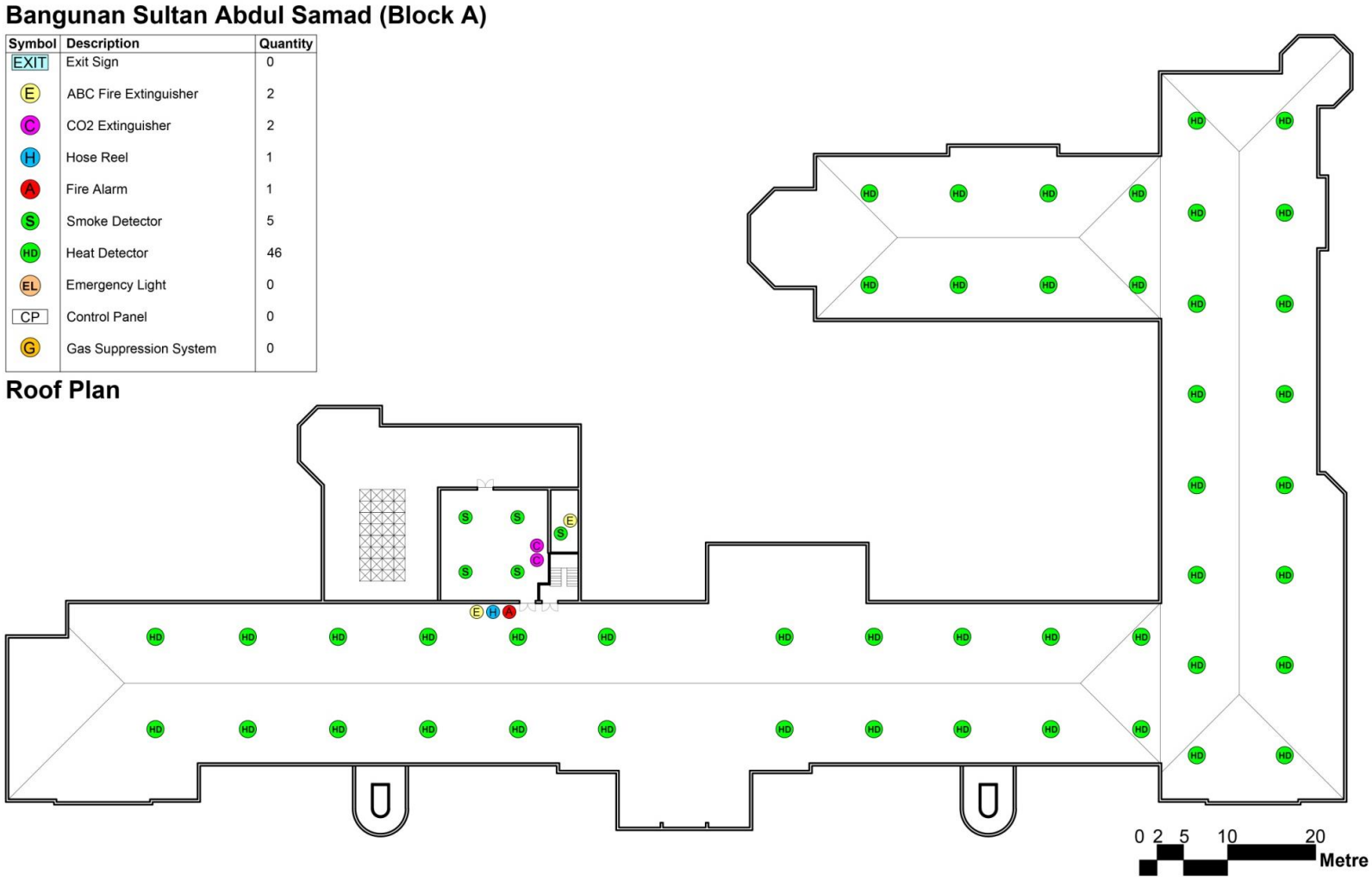


Figure 15: Location of active fire protection measures at Roof Level of Sultan Abdul Samad Building

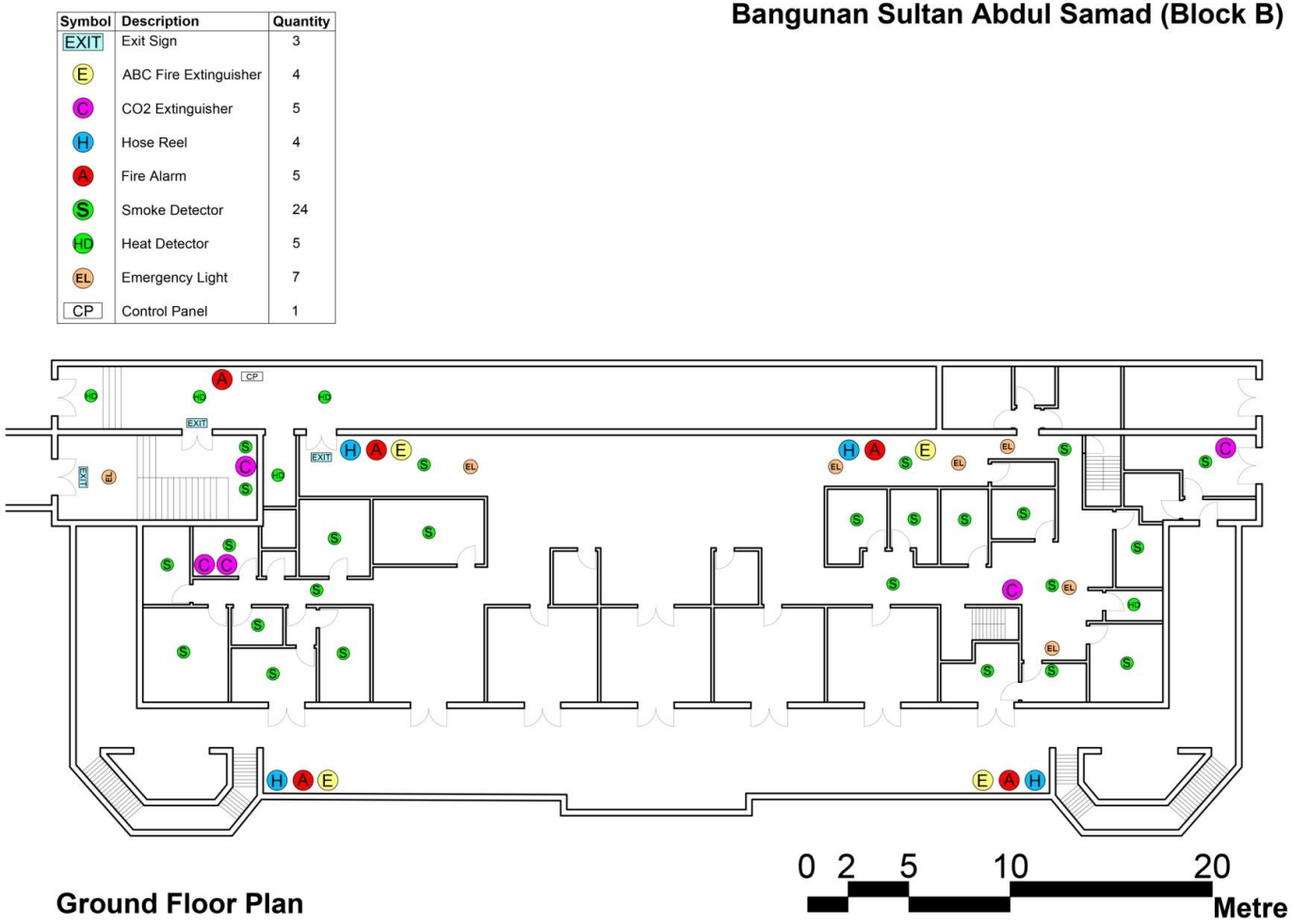


Figure 16: Location of active fire protection measures at Ground Floor Level of Sultan Abdul Samad (Block B)

Symbol	Description	Quantity
EXIT	Exit Sign	0
E	ABC Fire Extinguisher	2
C	CO2 Extinguisher	2
H	Hose Reel	2
A	Fire Alarm	2
S	Smoke Detector	33
HD	Heat Detector	5
EL	Emergency Light	17
CP	Control Panel	0

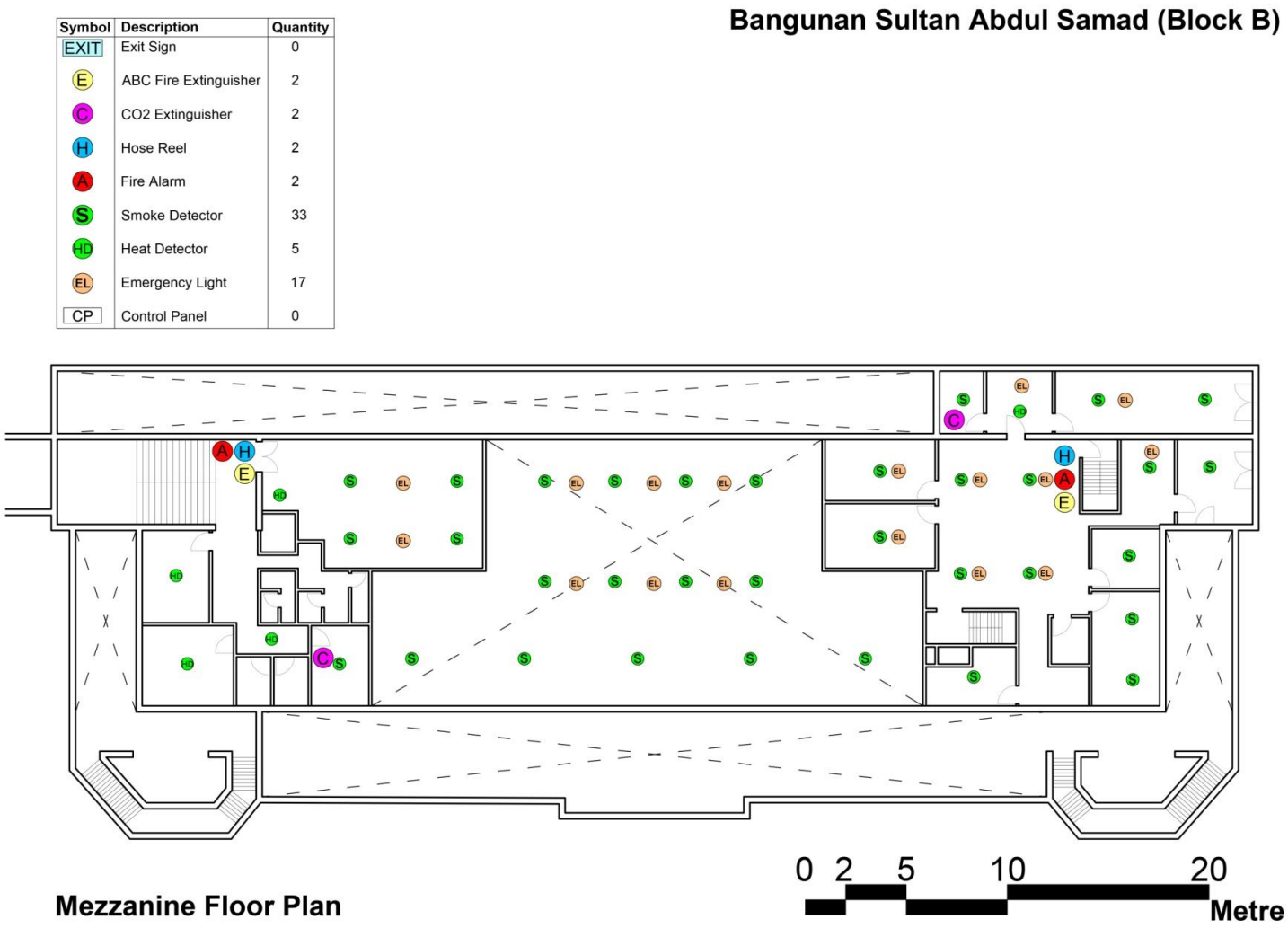


Figure 17: Location of active fire protection measures at Mezzanine Floor Level of Sultan Abdul Samad (Block B)

Symbol	Description	Quantity
EXIT	Exit Sign	4
E	ABC Fire Extinguisher	7
C	CO2 Extinguisher	5
H	Hose Reel	4
A	Fire Alarm	4
S	Smoke Detector	40
HD	Heat Detector	10
EL	Emergency Light	16
CP	Control Panel	0

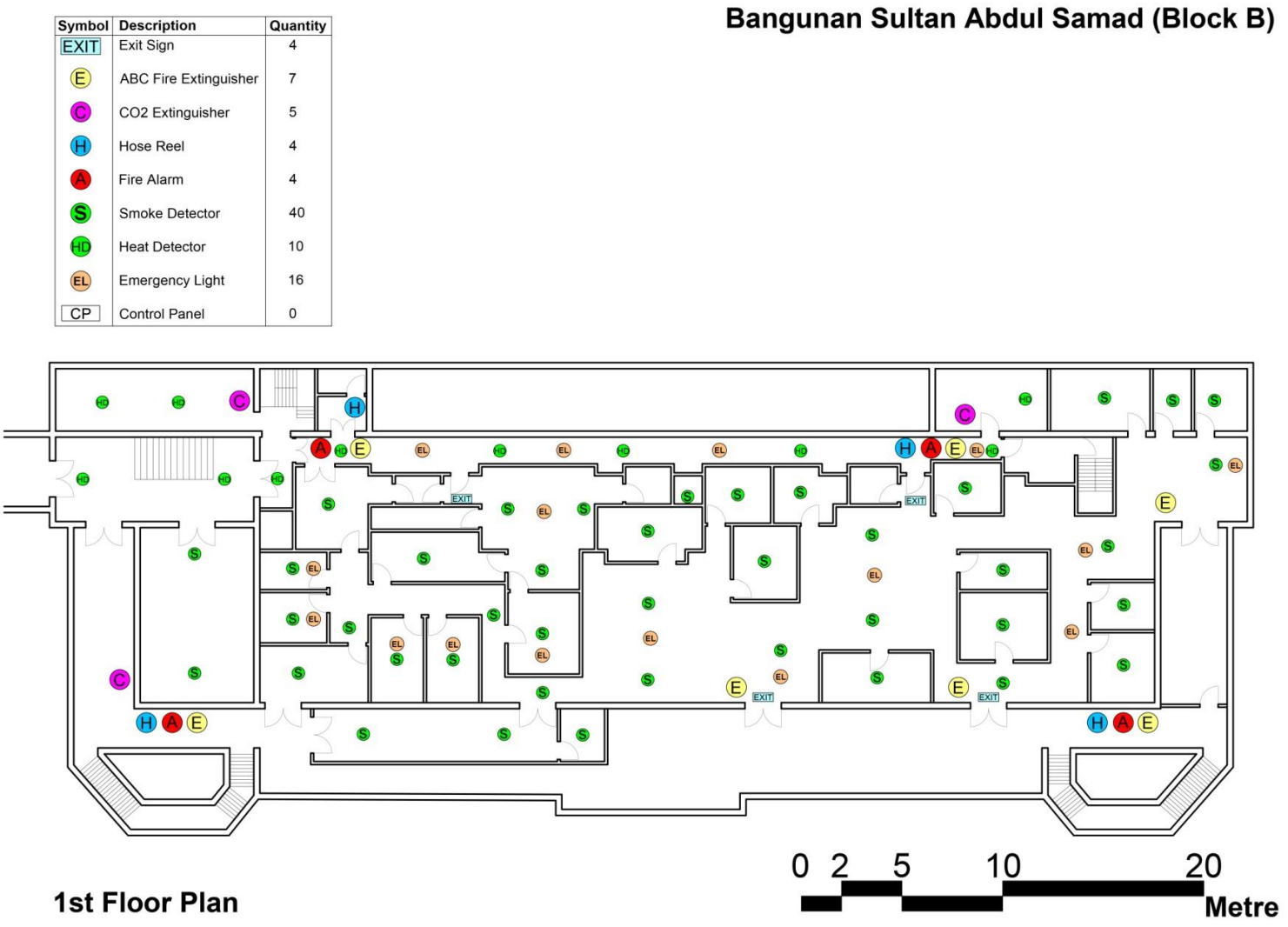


Figure 18: Location of active fire protection measures at First Floor Level of Sultan Abdul Samad (Block B)

Symbol	Description	Quantity
EXIT	Exit Sign	0
E	ABC Fire Extinguisher	2
C	CO2 Extinguisher	3
H	Hose Reel	2
A	Fire Alarm	2
S	Smoke Detector	18
HD	Heat Detector	15
EL	Emergency Light	5
CP	Control Panel	0

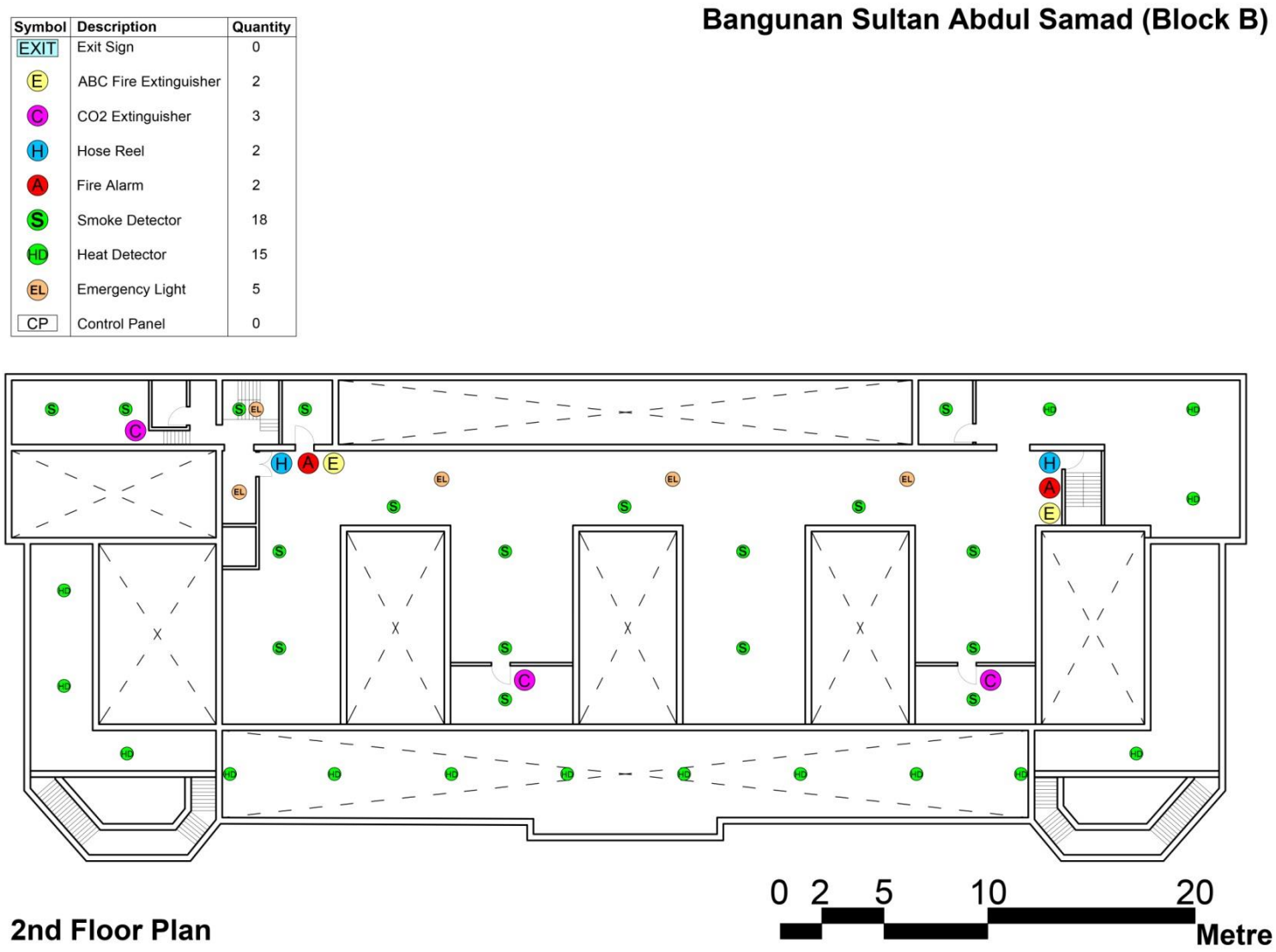


Figure 19: Location of active fire protection measures at Second Floor Level of Sultan Abdul Samad (Block B)

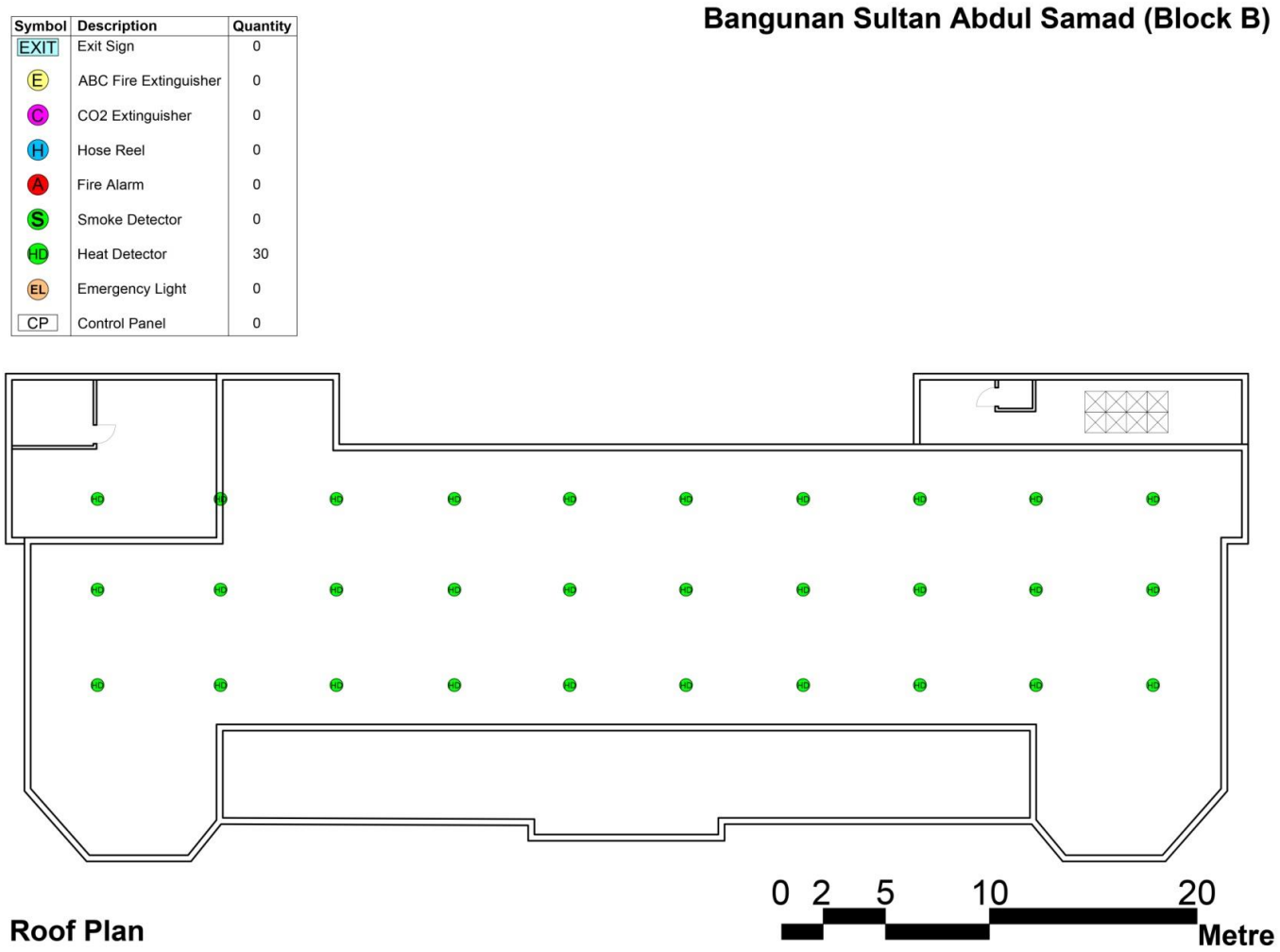
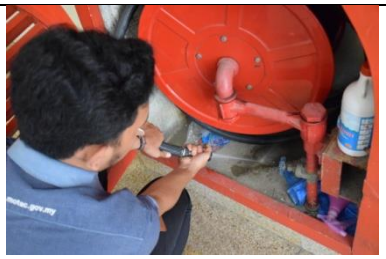
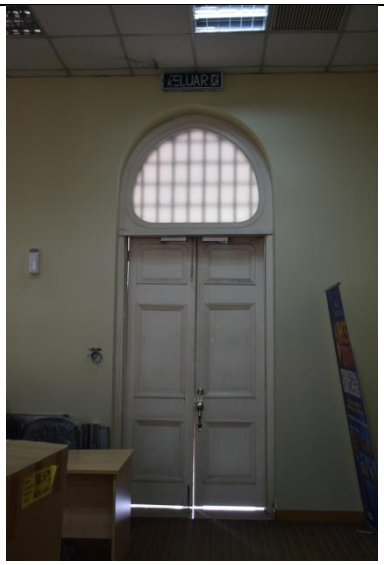


Figure 20: Location of active fire protection measures at Roof Floor Level of Sultan Abdul Samad (Block B)

a) Main Building

Picture	Description
	Heat detectors are installed only at the rooftop. Heat detectors are generally not recommended in area which involves the threat of life safety. The wiring for the detectors is hidden within the ceiling and the colour of the detector blends in with the white ceiling.
	Smoke detectors were installed in most area of the building except the rooftop. Smoke detectors are more efficient at detecting smoke particles during the early stage of fire. The wiring for the detectors is hidden within the ceiling and the colour of the detector blends in with the white ceiling.
	ABC Fire extinguishers and hose reels were installed alongside one another in most area of the building. They are placed inside a storage box and are clearly visible to the occupants of the building. Most of them are situated alongside the corridor of the building. The design of the hose reel storage blends in quite efficiently with the building aesthetic in comparison to fire extinguisher storage.
	Water flow for the hose reels operates at an appropriate pressure.
	The installation of the emergency light was designed to be as part of the ceiling. The wirings are hidden within the ceiling. Emergency light were installed in every area of the building and appears to be working properly.

Picture	Description
	The exit sign is installed above the door but the placement may be too high for the occupants to notice. This is most likely to prevent the sign from disturbing the design of the door. However, exit signs are usually installed directly on top of the door frame and are supposed to be easily spotted during emergency to point out the evacuation direction.
	The exit sign throughout the whole building appears to be quite new. However, some of the Exit signs are in terrible condition and may be required to be replaced immediately.

b) Old Post Office Building (Block B)

Picture	Description
	Heat detectors are installed at the walkway corridor and services room. Heat detectors are generally not recommended in area which involves the threat of life safety. The wiring for the detectors is hidden within the ceiling and the colour of the detector blends in with the white ceiling.
	Smoke detectors were installed in most area of the building. Smoke detectors are more efficient at detecting smoke particles during the early stage of fire. The wiring for the detectors is hidden within the ceiling and the colour of the detector blends in with the white ceiling.

Picture	Description
	ABC Fire extinguishers and hose reels were installed alongside one another in most area of the building. They are generally placed at each corner of the building and provide enough coverage throughout the whole building. While the fire extinguishers are placed inside a storage box, the hose reels are left exposed. As a result, the untangled hose becomes an eyesore and disturbs the aesthetic of the building.
	CO^2 fire extinguishers were mostly placed in services room or next to electrical utilities and smaller area such as storage room with minimum occupants. They are generally more effective in dealing with such particular environment and most of them are well hidden within the room.
	The installation of the emergency light was designed to be as part of the ceiling. The wirings are hidden within the ceiling. Emergency light were installed in every area of the building and appears to be working properly.

Picture	Description
	The exit sign is installed above the door but the placement may be too high for the occupants to notice. This is most likely to prevent the sign from disturbing the design of the door. However, exit signs are usually installed directly on top of the door frame and are supposed to be easily spotted during emergency to point out the evacuation direction.

7.5 Case Study 5 –Ipoh City Hall Building, Ipoh, Perak

Figure 21: Façade of Ipoh City Hall

7.5.1 Introduction

Situated next to Jalan Dato Panglima Bukit Gantang Wahab and facing towards the Ipoh Railway Station is the Ipoh City Hall building. The building was designed by Arthur Benison Hubback and was constructed from the year 1913 to 1916 by the British East Hindia Company. The design of the building was influenced by the Neo-Renaissance Victorian style and showcased the usage of huge Greek and Roman columns at each side of the facade. The City Hall is directly connected to the old post office section at the back and can be considered as a single building. However, both sections are currently under the supervision of different government authorities.

In 1948, the building was temporarily used as the district police headquarters for several years. Aside from being used by local community and government to host various types of events, the City Hall also served as a place where the Indian poet and Nobel Laureate, Rabindrath Tagore, addressed a speech to the Perak's English and vernacular school teachers regarding education in 1927.

7.5.2 Active Fire System

Regardless of its size, the City Hall building seems to be severely lacking in terms of fire protection system. Upon observation, only two fire safety equipments were identified throughout the whole building which consists of exit signs and ABC powder fire extinguishers. The placement of exit signs can only be seen in the main hall area. The signs are installed on top of the doors on each side of the hall. However, despite the building's size, only three fire extinguishers can be found throughout the whole building. One is located in the lobby and the other two are situated hidden at the back of the stage.

Several hooks for holding the fire extinguisher are seen in most part of the building even though no other fire extinguisher can be found.

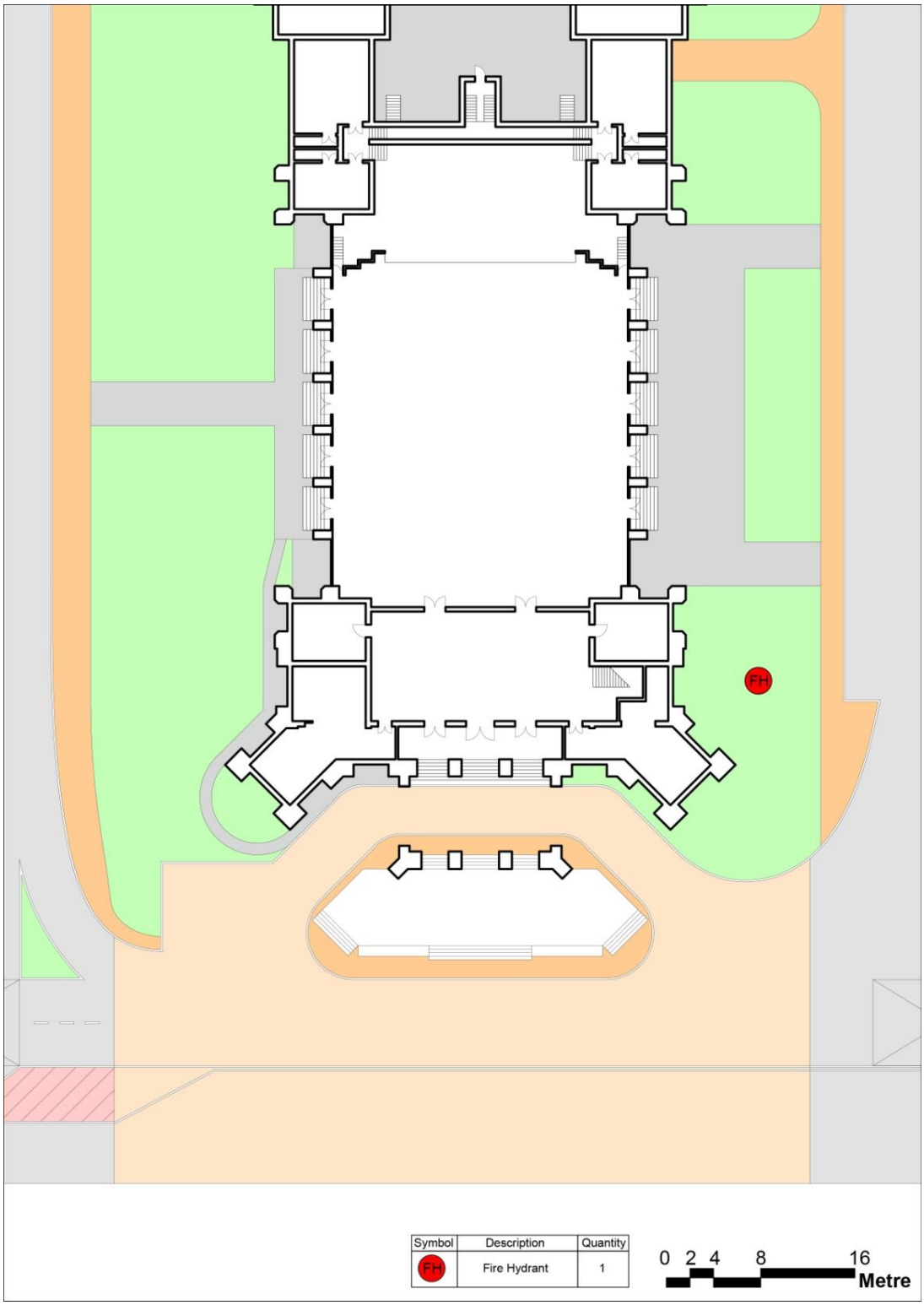


Figure 22: Location of fire hydrant at Ipoh City Hall

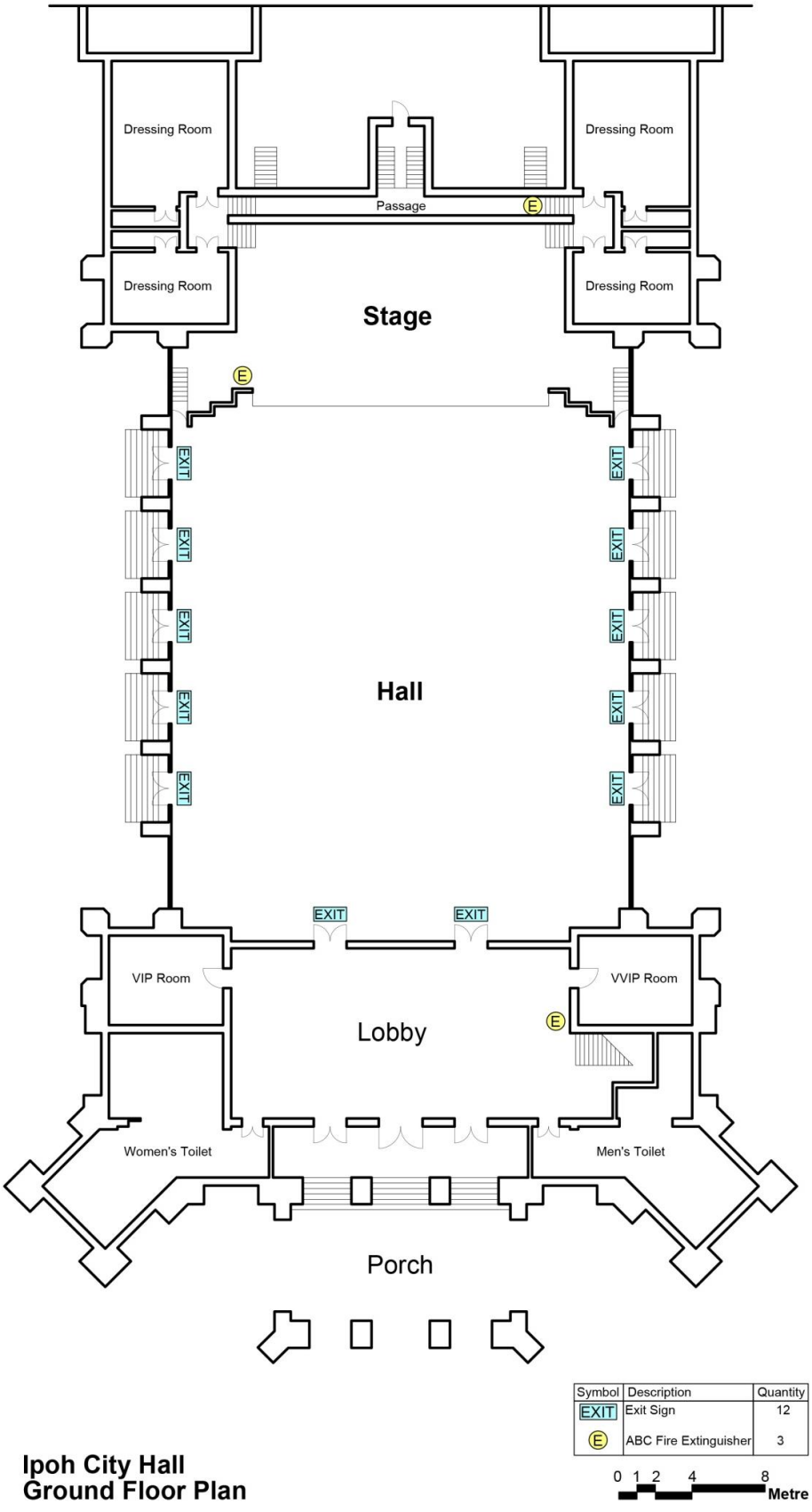


Figure 23: Location of active fire protection measures at Ground Floor Level of Ipoh City Hall

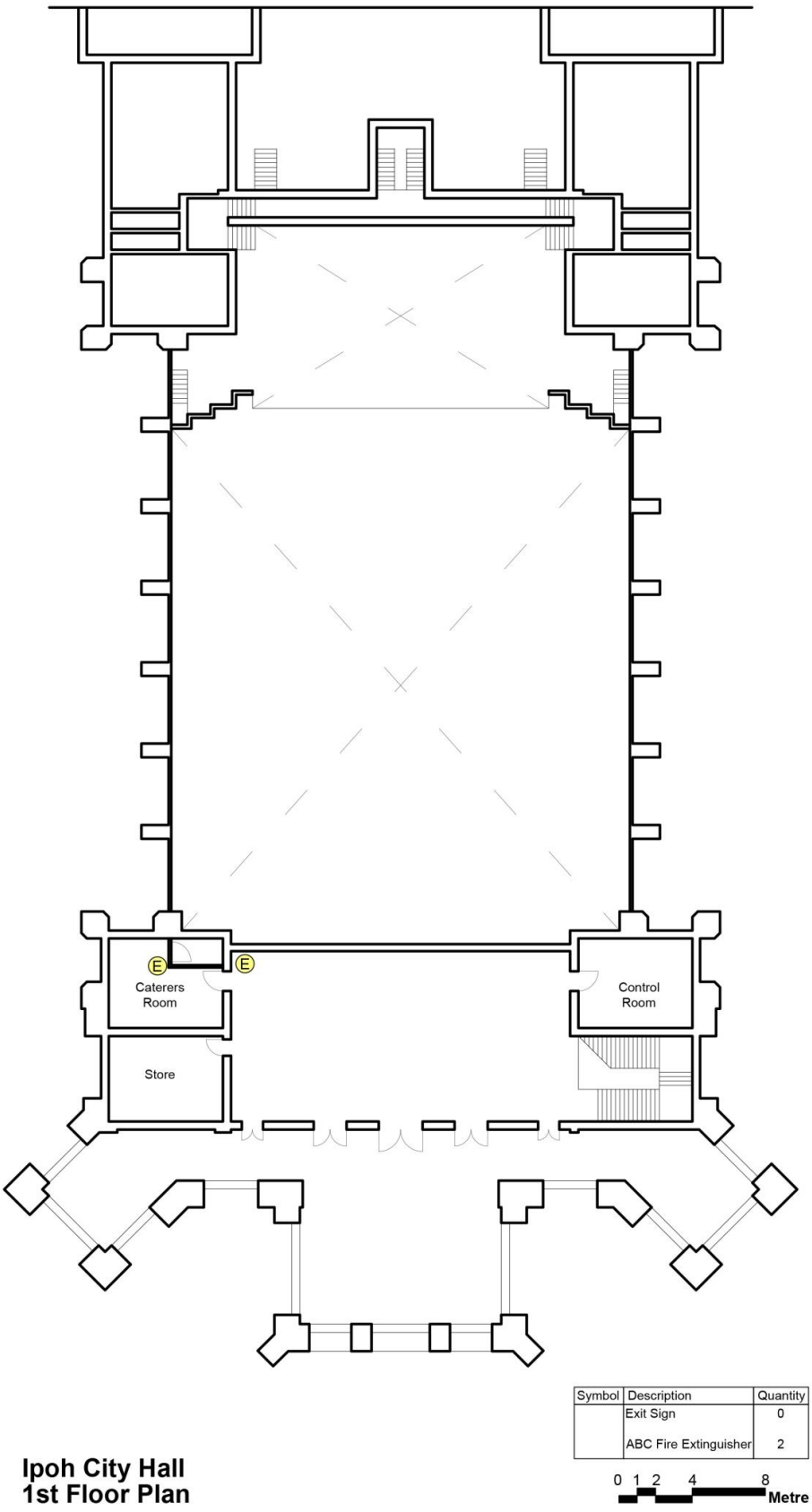


Figure 24: Location of active fire protection measures at First Floor Level of Ipoh City Hall

Picture	Description
	Several ABC fire extinguishers can be found on both floor of the building. However, the placement of each extinguisher barely covers any parts of the building. The distances between them are either too far apart or too close to one another. The main hall area is left without any extinguisher available.
	Throughout the whole building, multiple amount of fire extinguisher hook can be found. However, most of them are not attached with any fire extinguishers.
	The exit signs can only be found in the main hall area and are installed directly on top of each door in that particular area. This may seems appropriate considering it is the mainly used area of the whole building in any sorts of function.
	Throughout the whole area of the town hall, only one fire hydrant can be found within the building's premise.

7.6 Case Study 6 - Sultan Azlan Shah Gallery, Kuala Kangsar

Figure 25: Façade of Sultan Azlan Shah Gallery, Kuala Kangsar

7.6.1 Introduction

Originally known as Istana Ulu, the palace is located at Bukit Chandan, Kuala Kangsar and located not far from Masjid Ubudiah. The palace was originally the place of residence for the 28th Sultan of Perak, Sultan Idris Mursyidul 'Adzam Shah, who held the throne from the year 1887 to 1916. Istana Ulu was constructed in 1898 and completed in 1903. The palace was later occupied by Almarhum Sultan Abdul Jalil in 1918 and later by Almarhum Sultan Yussuf Izzuddin Shah, the 32nd Sultan of Perak reigning from the year 1948 to 1963.

The existence of Istana Ulu was the result of the location change of the Perak Sultanate government from the district of Sayong to Bukit Chandan. Istana Ulu is also known as 'Istana Cinta Berahi', 'Istana Cempaka Sari', and 'Istana Kota'. The palace was designed by Captain Maurice Alexander Cameron and the design was influenced the Acheh and Indian architecture. In 1954, the building was placed under the Ministry of Education and was used as a school from the year 1957 to 1996.

The palace was later converted into the Sultan Azlan Shah Gallery upon the approval of the Perak State Government Council in 2001. The project was under the supervision of the Public Works Department and work began in 2001 and was completed in 2003. The gallery was intended to provide the public with a glimpse into the life of Sultan Azlan Shah Muhibbuddin.

7.6.2 Active Fire System

Upon observation, various type of active fire protection system can be found throughout Sultan Azlan Shah Gallery. These include systems such as fire detection system, fire suppression system, and means of escape. The palace is considered to be well equipped since most parts of the building are installed with certain equipment. Externally, seven fire hydrants can be found throughout the whole compound of the complex.

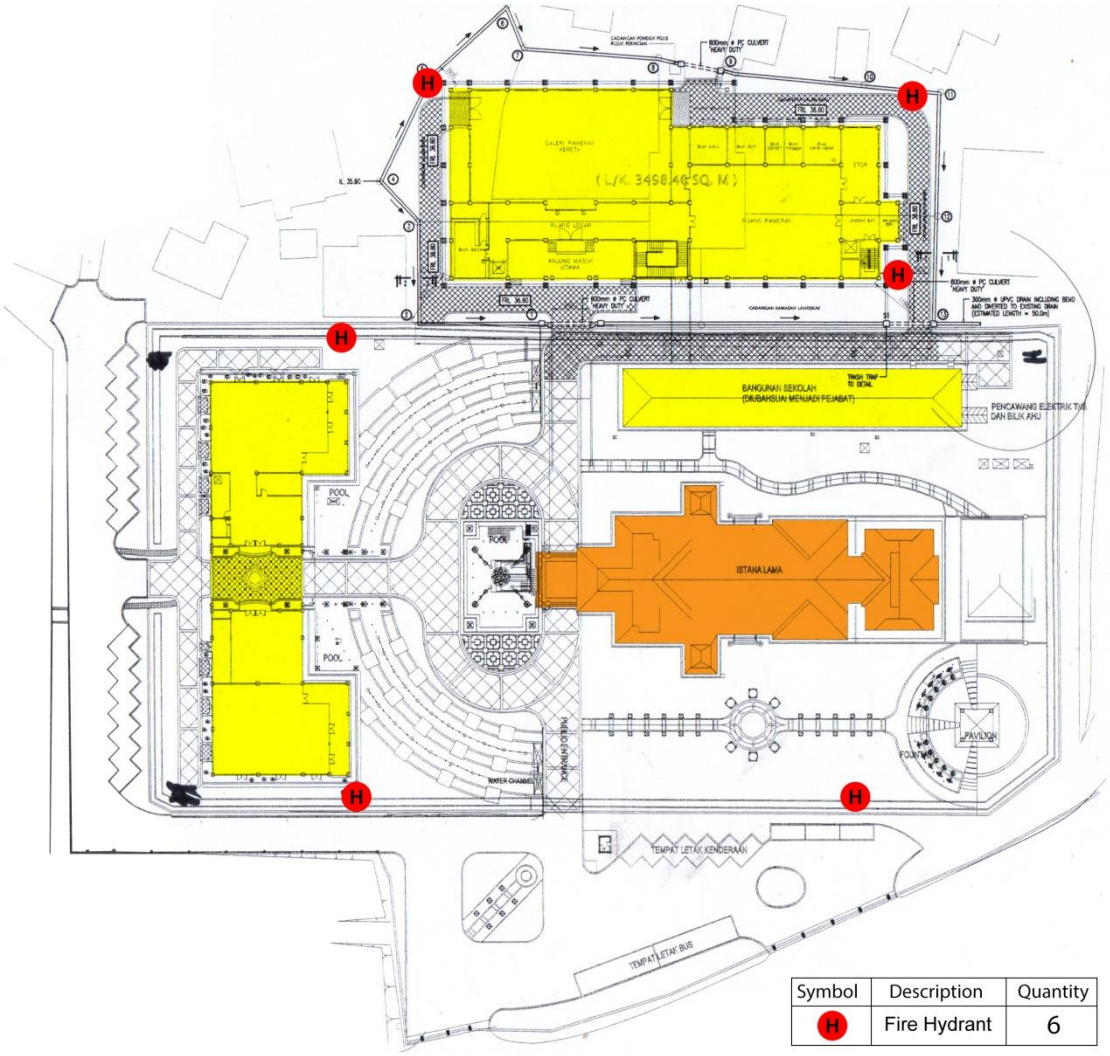


Figure 26: Location of fire hydrants at Sultan Azlan Shah Gallery

In terms of fire detection system, smoke detectors were installed in each part of the building with the exception of the new extension area of the building. The building is also equipped with a CCTV system which can be seen in most parts of the building. The interior of Sultan Azlan Shah Gallery is also equipped with two types of fire suppression system. These systems consist of ABC Powder fire extinguishers and hose reel system and are mostly hidden inside a cabinet.

As for the means of escape, only the usage of exit sign can be identified throughout the whole building. However, only limited amounts are installed and are mostly situated in a certain area of the building. For the ground floor, the exit signs can only be seen in the centre area of the building and another one at the rear section of the building. As for the first floor, one is located close to the stairs at the entrance and another one at the centre of the building. Another two can also be found close to the centre of the building. Similar to the ground floor, another exit sign can be found situated at the rear section of the building.

Figure 27: Location of active fire protection measures at Ground Floor Level of Sultan Azlan Shah Gallery

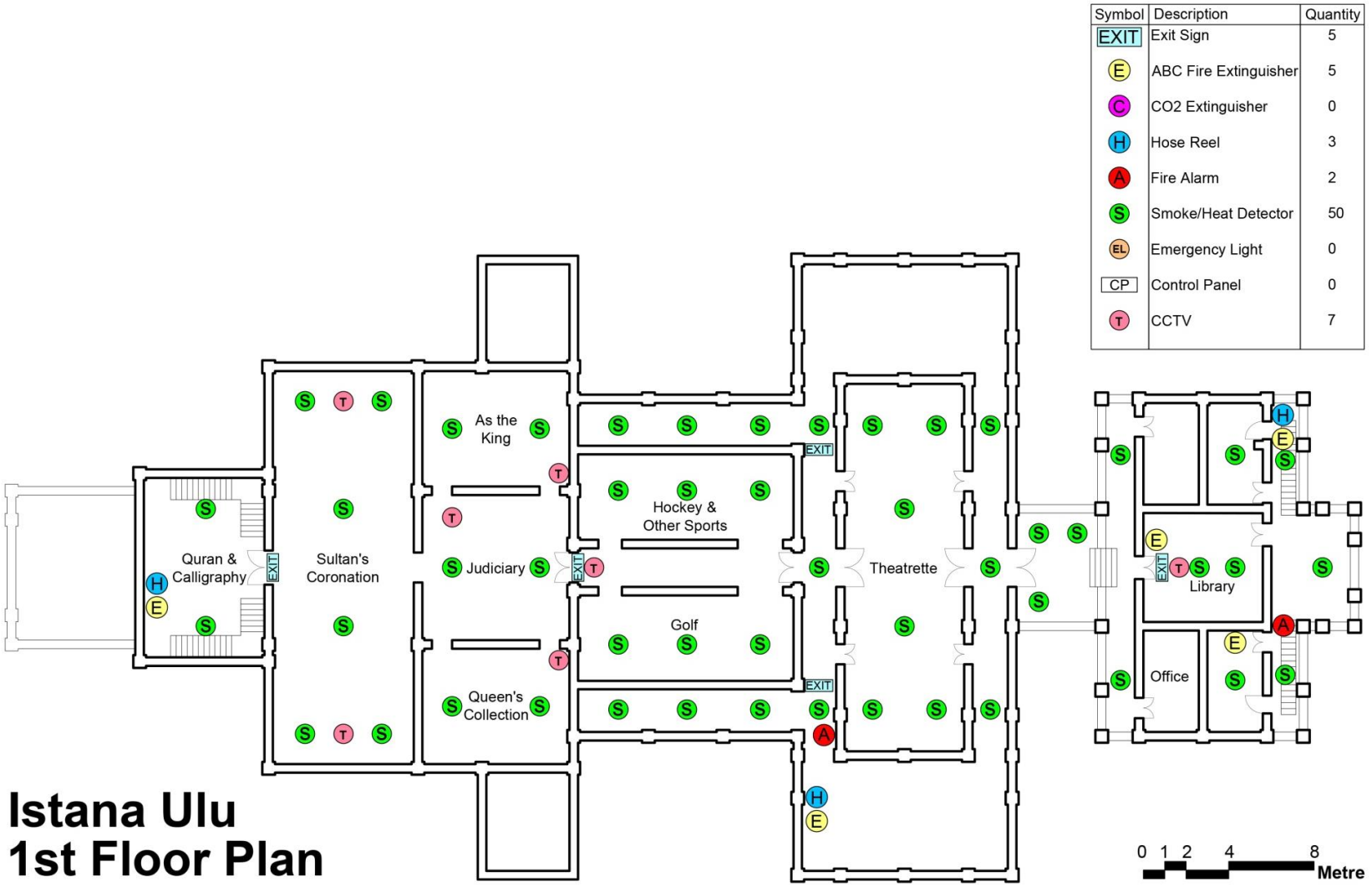


Figure 28: Location of active fire protection measures at FirstFloor Level of Sultan Azlan Shah Gallery

Picture	Description
	Smoke detectors were installed in most area of the building. The wiring for the detectors is hidden within the ceiling and the arrangement of the detector blends in well with the decor of the ceiling.
	CCTV camera can be found throughout most part of the building. Due to the nature of its design, it tends to stick out and can be obviously seen. The wiring of the system is all hidden within the ceiling. However, during the visit, it was stated that they are no longer functioning due to short circuit.
	Rather than using the typical box-shaped exit sign, Istana Ulu decided to use the thin acrylic led exit sign. As a result, the sign seems less intrusive to the building aesthetic and can still be easily spotted by the occupants and visitors.
	The amount of ABC fire extinguishers and hose reel are slightly limited and can only be found only at several parts of the building. They are often stored inside a timber storage box designed to fit the aesthetic of the building's interior. Some of them are equipped with a timber framed glass door while others are fully covered timber door and can be easily spotted.

Picture	Description
	Some of the fire extinguisher and hose reel storages are blocked or hidden by displayed item. Most of the display cases are quite large and heavy. As a result, these equipments cannot be easily access or identified during emergency situation.
	On the ground floor, the jewellery and medals display area is equipped with roller shutter doors. Upon activation, these doors will cover the items from any sort of threat and also double as a security vault for precious artefacts or items.
	Fire extinguishers hanging on the wall hook can only be seen in a certain room at the back of the building. This is mostly due to the limited space available to install another timber storage box.
	Seven fire hydrants can be found throughout the whole gallery compound. They are easily spotted and accessible in case of emergency.

7.7 FINDINGS SUMMARY

The existing active fire protection system in all studied buildings seems to fulfil the minimum fire safety requirements especially fire detection systems and fire suppression systems. National Textile Museum, Sultan Abdul Samad building and Sultan Azlan Shah Gallery are considered the most fire safety equipped among the studied buildings (Table 4). Nevertheless, there are still several issues that may raise some concerns such as lack of reliable fire protection measures and poor maintenance. The coverage of the fire suppression system may be limited and escape route may be ineffective for the building occupants. In term of installation, majority of the existing fire safety measures were installed with minimum invasive to the historic fabrics.

Table 4: Summary of active fire protection systems in the selected case studies

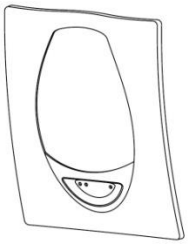
Building	Smoke Detector	Heat Detector	CCTV	Manual Alarm	Fire Extinguisher	Water Sprinkler	Water Mist	Hose Reel	Fire Hydrant	Water Cannon	Emergency Light	Exit Sign
National Textile Museum	√		√	√	√			√	√		√	√
Istana Ampang Tinggi	√			√	√				√		√	
Traditional House of Negeri Sembilan					√				√		√	
Sultan Abdul Samad Building	√		√	√	√			√	√		√	√
Sultan Azlan Shah Gallery	√		√	√	√			√	√		√	√
Ipoh Town Hall					√				√			√

8.0 RECOMMENDATION

The main purpose of active fire protection systems is to detect and give warning of an outbreak of fire and to control and extinguish a fire either manually or automatically. In order to ensure the effectiveness of the active fire protection systems, it is essential to select suitable systems dependent upon the size, usage and nature of the building. In addition, all installations and appliances shall conform to the relevant standards with little physical damage to the fabric of the building as possible and minimum aesthetic intrusion. Based on the conducted literature reviews and case studies, the research recommended Fire Detection Systems and Fire Suppression Systems in heritage buildings as in Table 5 and Table 6 below.

Table 5: Recommended Fire Detection Systems in Heritage Buildings

Type of Detector	Advantages & Disadvantages	Installation Method
Ionization Smoke Detector  • Activates upon the reduction/disruption of the circuit's current flow caused by the passing smoke particles. • Not suitable for kitchen and area exposed to high air velocity.	**<u>Advantages</u>** • Highly sensitive. • Capable of detecting very small smoke particles. • Quick response to flaming fire. • Affordable pricing. **<u>Disadvantages</u>** • Prone to nuisance tripping. • Slow response to smouldering fire. • No pre-installed alarm.	• Strategic placement to easily blend in with the surrounding building fabric/element. • Housing can be painted but should be avoided to prevent disruption to the equipment's sensor and not approved by most manufacturers. • Opt for cover plates with multiple colour choices provided by certain manufacturers.  • Electrical wiring/piping can be painted if necessary. • Use wireless detectors to avoid wiring installation in existing building.
Photo-electric Smoke Detector  • Activates when the light pulse from the light sensor is scattered/deflected due to smoke particles entering the device. • Suitable for residential and institutional applications.	**<u>Advantages</u>** • Response well to slow and smouldering fire. • Unaffected by wind and atmospheric pressure. • Less prone to nuisance tripping. • Affordable pricing. **<u>Disadvantages</u>** • Does not detect smaller smoke particles. • For wireless, some are installed with permanently built-in battery.	• Strategic placement to easily blend in with the surrounding building fabric/element.  • Housing can be painted but should be avoided to prevent disruption to the equipment's sensor and not approved by most manufacturers. • Opt for cover plates with multiple colour choices provided by certain manufacturers.

Type of Detector	Advantages & Disadvantages	Installation Method
• >4 m height: 150 m² 4-8 m height: 75 m²		• Electrical wiring/piping can be painted if necessary. • Use wireless detectors to avoid wiring installation in existing building.
Reflected Beam Smoke Detector  • Activates when the predetermined smoke level pass through and reduce the amount signal transmitted between the transceiver and reflector. • Suitable for area with high ceilings. >18 m: 1,840 m²	**<u>Advantages</u>** • Easy to install and align. • Multiple user selected sensitivity levels. • Paintable cover. **<u>Disadvantages</u>** • Requires wiring. • Relies heavily on infrared light beam. • Expensive.	• Strategic placement to easily blend in with the surrounding building fabric/element. • Cover can be painted to match the building's aesthetic.  • Electrical wiring/piping can also be painted if necessary.
Aspirating Smoke Detector  • Continuous analysis of airflow within the building through the sampling pipes to detect the presence of smoke particles. • Suitable for warehouse, data centres, laboratory, archive, museums, airports, large halls, historical buildings. • Max. monitoring area: 5760 m²	**<u>Advantages</u>** • Immune to disturbance such as dust, dirt, moisture. • Low profile installation due to small piping. • Requires very minimal amount of changes to existing building. **<u>Disadvantages</u>** • Requires meticulous planning for piping layout and positioning. • Noise distraction from fan. • Very expensive.	• Sampling pipes with suction holes to be installed in attics/ceiling to hide its presence. • Strategic placement of suction holes to easily blend in with the building's aesthetic. • Sampling pipes can also be installed within light fixtures and building ornaments. 
Fixed Temperature Heat Detector	**<u>Advantages</u>** • Fixed temperature fast response. • Low power. • Not affected by wind. • Affordable pricing depending on types of integration system.	• Strategic placement to easily blend in with the surrounding building fabric/element. • Housing can be painted but should be avoided to prevent disruption to the equipment's sensor and not approved by most manufacturers.

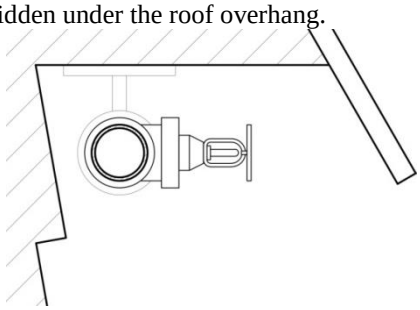
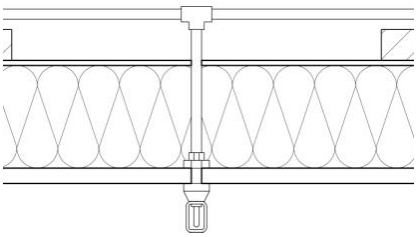
Type of Detector	Advantages & Disadvantages	Installation Method
 • Activates upon detecting heat reaching 58°c (54°c to 62°c). • Suitable for high heat output and clean burning (kitchen, garage, etc.) • >4 m: 60 m² (fire-proof buildings), 30 m² (ordinary building). • 4-8 m: 30 m² (fire-proof building), 15 m² (ordinary building).	**Disadvantages** • May not detect small fire. • May not be able to determine exact location of fire.	• Opt for cover plates with multiple colour choices provided by certain manufacturers if available.  • Electrical wiring/piping can be painted if necessary. • Use wireless detectors to avoid wiring installation in existing building.
Rate of Rise Heat Detector  • Activates upon rapid temperature increase (+9°c/minute) with fixed upper limit if temperature increase is too slow (58°c/93°c). • Applicable to area not suitable for smoke detector (dirty/smoky area). • >4 m: 90 m² (fire-proof building), 50 m² (ordinary building). • 4-8 m: 45 m² (fire-proof building), 30 m² (ordinary building).	**Advantages** • Quick response to fast temperature change. • Low power. • Fixed upper limit temperature. • Not affected by wind. **Disadvantages** • Delayed reaction to slow temperature change. • No pre-installed alarm. • Requires wiring.	• Strategic placement to easily blend in with the surrounding building fabric/element. • Housing can be painted but should be avoided to prevent disruption to the equipment's sensor and not approved by most manufacturers. • Opt for cover plates with multiple colour choices provided by certain manufacturers if available. • Electrical wiring/piping can be painted if necessary. • Use wireless detectors to avoid wiring installation in existing building.
Linear Heat Detector 	**Advantages** • Easy installation and highly flexible. • Less prone to false alarms. • Not influenced by other environmental factors. • Applicable with various fire control systems. • Low profile and easily hidden. • Suitable for outdoor usage.	• Strategic placement of wiring to easily blend in with the surrounding building fabric/element. • Install under the roof overhang or the edge of the ceiling to hide its presence.

Type of Detector	Advantages & Disadvantages	Installation Method
• The detection cable consists of two tightly wrapped conductors covered and separated by a special coating which melts when exposed to heat. The system activates when the two conductors comes into contact with each other. • Typical melting point for the special coating: 68°c • Capable of covering up to 1,500 mm distance in a single unit.	**Disadvantages** • Unable to determine the exact location of fire. • Requires immediate replacement after activation.	
CCTV Camera  • Group of video cameras installed throughout the building for surveillance purposes. • Monitored from a single location in the building or a different location outside of the building.	**Advantages** • Double as a security surveillance system. • Live visual feed of the entire building. **Disadvantages** • Requires constant human monitoring • Requires proper planning for camera positioning and wiring arrangement.	• Strategic placement to easily blend in with the surrounding building fabric/element. • Covered with an external casing/box made out of materials that can blend in with the building's fabric.  • Electrical wiring/piping can be painted to match the building's aesthetic.

Table 6: Recommended Fire Suppression System in Heritage Buildings

Type of Detector	Advantages & Disadvantages	Installation Method
ABC Dry Powder Fire Extinguisher  • Filled with ABC powder with Nitrogen gas propellant. • 5-30 discharge time depending on size. • Capacity 1-9 kg.	**Advantages** • Easy usage & quick to deploy. • Multi-purpose usage. • No damage to most items. • Highly affordable. **Disadvantages** • Difficult to clean. • May damage electrical components. • Risk when exposed to skin, eyes, and inhalation.	• Placed in location which can be easily spotted. • Avoid using the wall mounted hook which may disturb the building's aesthetic. • Placed in a custom base/box equipped with instruction manual and signage where necessary. 

Type of Detector	Advantages & Disadvantages	Installation Method
• Suitable for flammable liquids and gases, electrical hazards, organic surfaces, mechanical failures (home, office, factory).		
Carbon Dioxide (CO_2) Fire Extinguisher  • Filled with non-flammable carbon dioxide gas under extreme pressure. • Capacity 2-5 kg. • Suitable for fire involving liquid and electrical equipment (kitchen, offices, laboratories, mechanical rooms, flammable liquid storage area).	**Advantages** • Harmless to electronic devices. • Easy usage and quick to deploy. • No damage to items exposed and leaves no residue. • Highly affordable. **Disadvantages** • Dangerous for occupants. • Requires appropriate ventilation. • Incorrect usage can result to frost burns.	• Placed in location which can be easily spotted. • Avoid using the wall mounted hook which may disturb the building's aesthetic. • Placed in a custom base/box equipped with instruction manual and signage where necessary. 
Fire Hydrant  • System of pipework connected to hydrant outlets from the main water supply. • To be used by firemen. • Installed at least 45 m from firefighting access point and 90 m between one another. • Each building should be equipped with at least one hydrant.	**Advantages** • Very strong and applicable for medium to large sized fires. • Capable of long range and variety of angles. • Low maintenance and no leakage. **Disadvantages** • Manual activation. • May require more than one person to handle. • May cause damages due to strong pressure.	• Placed in location which can be easily spotted and near to the building.
Hose Reel System  	**Advantages** • Continuous water supply. • Hose can stretch up to 30 m from reel. • Easily operated by one person. **Disadvantages**	• Placed in location which can be easily spotted on each floor level. • Placed in a custom box that matches the building's aesthetic equipped with instruction manual and signage where necessary.

Type of Detector	Advantages & Disadvantages	Installation Method
• To be used by occupants during early stages of fire. • For every 800 m² of usable floor space and 30 m between one another. • 50 mm diameter pipework and not less than 25 mm diameter for individual feed. • Not suitable for area with electrical machinery and flammable liquids.	• Reliance on water supply. • Not portable. • Consume a lot of space. • Requires piping and modification to existing building.	
Water Sprinkler System  • Manual activation or automatic activation when the fluid expands and shattered the glass bulb when exposed to specific level of heat. • Multiple temperatures rating according to colour of fluid. • Suitable for light, ordinary, and extra hazards (Banks, hotels, shopping malls, factories, etc.).	**<u>Advantages</u>** • Provides protection to both lives and buildings. • Reduce fire damage and early fire control. • Highly reliable and flexible. **<u>Disadvantages</u>** • Requires piping throughout the building. • Possible leakage or accidental tripping. • Requires a separate water supply tank.	• Strategic placement of sprinkler head to easily blend in with the surrounding building fabric/element. • Hide the piping within the ceiling or behind the building's structure whenever possible. • Installation for external facade should be hidden under the roof overhang.  • Selection of piping material will help to naturally blend in with the building's fabric. • Piping can be painted to match the building's fabric.
Water Mist System  • Uses smaller water droplets to extinguish fire. • External usage can also act as water curtain. • Suitable for buildings with sensitive and fragile content (religious buildings, museums,	**<u>Advantages</u>** • Smaller piping and sprinkler head. • Can be easily hidden within the building. • Requires less amount of water. • Capable of sharing water from the main water supply. **<u>Disadvantages</u>** • High maintenance cost. • Expensive piping material. • Lack of expertise in certain locations.	• Strategic placement of sprinkler head to easily blend in with the surrounding building fabric/element. • Hide the piping within the ceiling or behind the building's structure whenever possible.  • Installation for external facade should be hidden under the roof overhang. • Selection of piping material will help to naturally blend in with the building's fabric. • Piping can be painted to match the building's fabric.

Type of Detector	Advantages & Disadvantages	Installation Method
historical buildings, old hotels, etc.).		
Water Cannon  • Located close to the building. • Shoots a line of water to prevent fire from spreading. • Suitable for buildings with large site coverage and location with multiple buildings close to each other. • Manual application or automatic activation through mechanical system.	**<u>Advantages</u>** • Capable of long range and slightly flexible shooting angle. • Quick response time. **<u>Disadvantages</u>** • Requires frequent maintenance. • Fire may not be fully extinguished. • Some parts of the building (opposite side) may be unreachable.	• Placed in location which can be easily spotted and near to the building. • Placed in a custom storage box that matches the building's design. 

9.0 FINANCIAL SUMMARY

Ministry of Higher Education Malaysia (MoHE) has approved a total of RM86,000.00 for this research under Fundamental Research Grant Scheme (FRGS). The research has utilized amounting of RM 63,335.30 which is 73.65% from the total allocation. Therefore, a balance of RM22,665.00 was unutilized. The financial details are summarized in Table 2 below.

Table 2: Summary of financial details

Vote Code	Description	Allocation (RM)	Disburse (RM)	Balance (RM)
V11000	Research Assistant (RA)	48,600.00	48,600.00	0
V21000	Travelling Expenses & Subsistence	12,400.00	1,379.80	11,020.20
V24000	Rental	0.00	0	0
V27000	Research Materials & Supplies	15,000.00	5,582.00	9,418.00
V29000	Professional Services & Other Services including Printing & Hospitality, Honorarium for subjects	10,000.00	4,664.91	5,335.09
V36000	Miscellaneous Research Advancement	0	0	0
	TOTAL	**86,000.00**	**60,226.71**	**25,773.29**

10.0 RESEARCH OUTPUTS

10.1 Human Capital Development

There two (2) master students have enrolled during this research. The details of the students are as follows:

STUDENT 1	
Student name	Muhammad Alif Wajdi Mohtar
I/C No	910715-02-5467
Student ID	G1526099
Master	Master of Science in Built Environment (MScBE) by research
Year of Graduation	Examination stage
Thesis Title	Minimum Invasive Active Fire Protection Systems In Heritage Timber Buildings

STUDENT 2	
Student name	Khairul Fikri Khairuddin
I/C No	941105-05-5361
Student ID	G1636009
Master	Master of Science in Built Environment (MScBE) by research
Year of Graduation	Still ongoing (writing stage)
Thesis Title	Construction Technique of the Traditional Malay Housed: A Case Study of Rumah Kutai, Perak

10.2 Publication

10.2.1 Indexed Journal

1. Nurul Hamiruddin Salleh & A Ghafar Ahmad (2017). Fire Safety in Museum Buildings: A Case Study of Perak Museum, Taiping, Malaysia. Advanced Science Letters, Vol. 23, Number 7 (July 2017). Pg. 6242 – 6246.
2. Nurul Hamiruddin Salleh & Muhammad Alif Wajdi Mohtar (2017). Evaluation of Fire Safety Measures on Heritage Timber Buildngs in Malaysia. (in process for publication)

11.0 ACKNOWLEDGEMENTS

The research undertakings including the fieldwork in six case studies were made possible by a research grant funded by Ministry of Higher Education Malaysia under the FRGS grant. The author also would like to convey their appreciation to all who have been kindly involved directly and indirectly in this research.

12.0 REFERENCES

Arkib Negara Malaysia. (N.D.) Rumah Melayu Negeri Sembilan. Retrieved from: http://www.arkib.gov.my/web/guest/rumah-melayu-negeri-sembilan

Kidd, S. (2010). Guide for Practitioners 7: Fire Safety Management in Traditional Buildings. Edinburgh: Historic Scotland.

Ipoh Tourist Information Centre. (2013) Ipoh Town Hall & Old Post Office. Retrieved from: http://ipohtourism.mbi.gov.my/?page_id=2433

Jabatan Warisan Negara. (2016) Bangunan Pejabat Pos Lama Ipoh, Perak. Retrieved from: http://www.heritage.gov.my/ms/konservasi/konservasi-bangunan/bangunan-awam/bangunan-pejabat-pos-lama-ipoh-perak

Lembaga Muzium Negeri Sembilan. (N.D.) Rumah Negeri Sembilan. Retrieved from: http://lmns.ns.gov.my/index.php/2012-09-28-00-22-39/2012-10-03-01-06-37/muzium-negeri

Lembaga Muzium Negeri Sembilan. (N.D.) Rumah Negeri Sembilan. Retrieved from: http://lmns.ns.gov.my/index.php/2012-09-28-00-22-39/2012-10-03-01-06-37/muzium-negeri

Kamarul Syahril Kamal. (2008). Bangunan Sultan Abdul Samad, Kuala Lumpur, Wilayah Persekutuan, Malaysia. Retrieved from: http://buildingconservation.blogspot.my/2009/03/bangunan-sultan-abdul-samad-kuala.html

Majlis Perbandaran Kuala Kangsar. (2016) Galeri Sultan Azlan Shah. Retrieved from: http://www.mpkkpk.gov.my/ms/pelawat/destinasi-menarik/galeri-sultan-azlan-shah

National Textile Museum. (2013). Sejarah National Textile Museum. Retrieved from: http://www.muziumtekstilnegara.gov.my/main/content/sejarah_131/?menuid=63

National Textile Museum. (2013). Sejarah National Textile Museum. Retrieved from: http://www.muziumtekstilnegara.gov.my/gallery/exhibition

NFPA 914: Code for Fire Protection of Historic Structures (2015). National Fire Protection Association

No Author. (N.D.). Istana Ampang Tinggi. Retrieved from: http://malaycivilization.ukm.my/idc/groups/portal_aperpatih/documents/ukmpd/adat_02141.pdf

Nurul Hamiruddin Salleh and A Ghafar Ahmad (2009). Fire Safety Management in Heritage Buildings: The Current Scenario in Malaysia. The 22nd CIPA Symposium. 11-15th October 2009, Kyoto, Japan. http://cipa.icomos.org/fileadmin/papers/Kyoto2009/11.pdf

Nurul Hamiruddin Salleh (2011). Fire Safety in Heritage Buildings: Life vs. Property Safety. In Ali Raza Soomro (Ed.), Heritage Study of Muslim World (p.61-72). Kuala Lumpur: IIUM Press

Nurul Hamiruddin Salleh (2011). Fire Safety and Protection Measures in Heritage Buildings with Special Consideration on Museum Buildings in Malaysia. Unpublished Ph.D. Thesis, Universiti Sains Malaysia Penang.

Nurul Hamiruddin Salleh (2015). Mixed Methods Approach for the Study of Fire Safety Management in Malaysian Heritage Buildings. In Noor Aziah Mohd Ariffin, Md. Mizanur Rashid and Nurul Hamiruddin Salleh (Eds.), Methodologies in Architectural Research (p.32-52). ISBN: 978-3142-24-8

Malaysian Standard (2015). Fire Safety in the Design, Management and Use of Buildings- Code of Practice (First Revision). MS 1183:2015. Department of Standards Malaysia.

Perak Muzium Board. (2015) Sejarah Pembinaan Istana Ulu. Retrieved from: http://gsas.perak.gov.my/index.php/en/kembara/galeri-pameran/10-latar-belakang/27-sejarah-pembinaan-istana-ulu

Pusat Pengajian Seni, Universiti Sains Malaysia. (N.D.). Sultan Abdul Samad Building. Retrieved from: http://www.dewanbudaya.usm.my/heritage/SultanAbdSamad.html

Yaakub Idrus. (1986). Melihat Seni Ukir Di “Rumah Minangkabau” Seremban. Warisan: Jurnal Persatuan Sejarah Malaysia

APPENDIX A

FIRE SAFETY CHECKLISTS

1) FIRE SAFETY CHECKLIST

Name	**National Textile Museum**
Address	Jalan Sultan Hishamuddin, 50050 Kuala Lumpur.
Building Owner	Jabatan Muzium Malaysia
Building Function	Museum
Building Material	Brick
Age of Building	119 years old
Building Size	Large
Nearest Fire Station	Balai Bomba Dan Penyelamat Pantai, Jalan Hang Tuah
Distance of Fire Station to Building	4-5 KM
Date of visit	29 September 2016
Fire Certificate	No
Building Insurance	
Fire Safety Policy	
Fire Safety Plan	

Life Safety Facilities

	Description	YES	NO	Remark
A	Emergency exit sign	√		
B	Emergency light	√		
C	Procedure during fire		√	
D	Notice of fire safety	√		
E	Protected staircases		√	
F	Protected corridor		√	
G	Exit door	√		
H	Storey exit	√		
I	Assembly point		√	

Fire Prevention Facilities

	Description	YES	NO	Remark
A	Automatic fire detector system	√		Smoke detector Heat detector
B	Fire alarm system	√		
C	Direct electrical or telephone line connected to fire station		√	
D	Command and control centre	√		

Fire Protection Facilities

	Description	YES	NO	Remark
A	Fire door			
B	Electrical wiring			
C	Compartment			
D	Fire stopping			
E	Fire dampers			

F	Smoke venting system			
G	Electrical isolation switch			

Fire Fighting Facilities

	Description	YES	NO	Remark
A	Fire extinguishers ABC Dry powder: Carbon Dioxide:	√		
B	Fire hydrant	√		
C	Pressurised fire hydrant		√	
D	Hose reel system	√		
E	Wet riser system		√	
F	Dry riser system		√	
G	Automatic sprinkler system		√	
H	Drencher system		√	
I	Carbon dioxide system	√		
J	Fire lift		√	
K	Fire fighting staircase		√	
L	Fire fighting access lobby		√	
M	Voice communication system		√	
N	Fire appliance access	√		
O	Water storage	√		
P	Foam storage		√	

Special Provision

	Description	YES	NO	Remark
A	Helipad		√	
B	Emergency window		√	

Fire Safety Organization in Premises

	Description	YES	NO	Remark
A	Fire brigade team			
B	Fire safety manager			
C	Fire safety officer			
D	Number of personnel			
E	Number of vehicles			
F	Equipment			
G	Fire drill			
H	Periodical training			

2) FIRE SAFETY CHECKLIST

Name	**Istana Ampang Tinggi**
Address	Kompleks Taman Seni Budaya Negeri Sembilan, Jalan Sungai Ujong, 70200 Seremban, Negeri Sembilan
Building Owner	Lembaga Muzium Negeri Sembilan
Building Function	Museum
Building Material	Timber
Age of Building	151 years old
Building Size	Small
Nearest Fire Station	Balai Bomba Dan Penyelamat Seremban
Distance of Fire Station to Building	10 KM
Date of visit	12 October 2016
Fire Certificate	No
Building Insurance	
Fire Safety Policy	
Fire Safety Plan	

Life Safety Facilities

	Description	YES	NO	Remark
A	Emergency exit sign		√	
B	Emergency light	√		
C	Procedure during fire		√	
D	Notice of fire safety		√	
E	Protected staircases		√	
F	Protected corridor		√	
G	Exit door		√	
H	Storey exit		√	
I	Assembly point	√		

Fire Prevention Facilities

	Description	YES	NO	Remark
A	Automatic fire detector system	√		Smoke detector Heat detector
B	Fire alarm system	√		
C	Direct electrical or telephone line connected to fire station		√	
D	Command and control centre		√	

Fire Protection Facilities

	Description	YES	NO	Remark
A	Fire door		√	
B	Electrical wiring		√	
C	Compartment		√	

D	Fire stopping		√	
E	Fire dampers		√	
F	Smoke venting system		√	
G	Electrical isolation switch		√	

Fire Fighting Facilities

	Description	YES	NO	Remark
A	Fire extinguishers ABC Dry powder: Carbon Dioxide:	√		
B	Fire hydrant	√		
C	Pressurised fire hydrant		√	
D	Hose reel system		√	
E	Wet riser system		√	
F	Dry riser system		√	
G	Automatic sprinkler system		√	
H	Drencher system		√	
I	Carbon dioxide system		√	
J	Fire lift		√	
K	Fire fighting staircase		√	
L	Fire fighting access lobby		√	
M	Voice communication system		√	
N	Fire appliance access		√	
O	Water storage		√	
P	Foam storage		√	

Special Provision

	Description	YES	NO	Remark
A	Helipad		√	
B	Emergency window		√	

Fire Safety Organization in Premises

	Description	YES	NO	Remark
A	Fire brigade team			
B	Fire safety manager			
C	Fire safety officer			
D	Number of personnel			
E	Number of vehicles			
F	Equipment			
G	Fire drill			
H	Periodical training			

3) FIRE SAFETY CHECKLIST

Name	**Rumah Tradisional Negeri Sembilan**
Address	Kompleks Taman Seni Budaya Negeri Sembilan, Jalan Sungai Ujong, 70200 Seremban, Negeri Sembilan
Building Owner	Lembaga Muzium Negeri Sembilan
Building Function	Museum
Building Material	Timber
Age of Building	118 years old
Building Size	Small
Nearest Fire Station	Balai Bomba Dan Penyelamat Seremban
Distance of Fire Station to Building	10 KM
Date of visit	12 October 2016
Fire Certificate	No
Building Insurance	
Fire Safety Policy	
Fire Safety Plan	

Life Safety Facilities

	Description	YES	NO	Remark
A	Emergency exit sign		√	
B	Emergency light	√		
C	Procedure during fire		√	
D	Notice of fire safety		√	
E	Protected staircases		√	
F	Protected corridor		√	
G	Exit door		√	
H	Storey exit		√	
I	Assembly point	√		

Fire Prevention Facilities

	Description	YES	NO	Remark
A	Automatic fire detector system		√	Smoke detector Heat detector
B	Fire alarm system		√	
C	Direct electrical or telephone line connected to fire station		√	
D	Command and control centre		√	

Fire Protection Facilities

	Description	YES	NO	Remark
A	Fire door		√	
B	Electrical wiring		√	
C	Compartment		√	

D	Fire stopping		√	
E	Fire dampers		√	
F	Smoke venting system		√	
G	Electrical isolation switch		√	

Fire Fighting Facilities

	Description	YES	NO	Remark
A	Fire extinguishers ABC Dry powder: Carbon Dioxide:	√		
B	Fire hydrant	√		
C	Pressurised fire hydrant		√	
D	Hose reel system		√	
E	Wet riser system		√	
F	Dry riser system		√	
G	Automatic sprinkler system		√	
H	Drencher system		√	
I	Carbon dioxide system		√	
J	Fire lift		√	
K	Fire fighting staircase		√	
L	Fire fighting access lobby		√	
M	Voice communication system		√	
N	Fire appliance access		√	
O	Water storage		√	
P	Foam storage		√	

Special Provision

	Description	YES	NO	Remark
A	Helipad		√	
B	Emergency window		√	

Fire Safety Organization in Premises

	Description	YES	NO	Remark
A	Fire brigade team			
B	Fire safety manager			
C	Fire safety officer			
D	Number of personnel			
E	Number of vehicles			
F	Equipment			
G	Fire drill			
H	Periodical training			

4) **FIRE SAFETY CHECKLIST**

Name	**Sultan Abdul Samad Building**
Address	Jalan Raja, 50050 Kuala Lumpur.
Building Owner	Ministry of Tourism and Culture Malaysia
Building Function	Office
Building Material	Brick
Age of Building	119 years old
Building Size	Large
Nearest Fire Station	Balai Bomba Dan Penyelamat Pantai, Jalan Hang Tuah
Distance of Fire Station to Building	4-5 KM
Date of visit	25 October 2016
Fire Certificate	No
Building Insurance	
Fire Safety Policy	
Fire Safety Plan	

Life Safety Facilities

	Description	YES	NO	Remark
A	Emergency exit sign	√		
B	Emergency light	√		
C	Procedure during fire		√	
D	Notice of fire safety	√		
E	Protected staircases	√		
F	Protected corridor		√	
G	Exit door	√		
H	Storey exit	√		
I	Assembly point		√	

Fire Prevention Facilities

	Description	YES	NO	Remark
A	Automatic fire detector system	√		Smoke detector Heat detector
B	Fire alarm system	√		
C	Direct electrical or telephone line connected to fire station		√	
D	Command and control centre	√		

Fire Protection Facilities

	Description	YES	NO	Remark
A	Fire door			
B	Electrical wiring			
C	Compartment			
D	Fire stopping			
E	Fire dampers			

F	Smoke venting system			
G	Electrical isolation switch			

Fire Fighting Facilities

	Description	YES	NO	Remark
A	Fire extinguishers ABC Dry powder: Carbon Dioxide:	√		
B	Fire hydrant	√		
C	Pressurised fire hydrant		√	
D	Hose reel system	√		
E	Wet riser system		√	
F	Dry riser system		√	
G	Automatic sprinkler system		√	
H	Drencher system		√	
I	Carbon dioxide system	√		
J	Fire lift		√	
K	Fire fighting staircase		√	
L	Fire fighting access lobby		√	
M	Voice communication system		√	
N	Fire appliance access	√		
O	Water storage	√		
P	Foam storage		√	

Special Provision

	Description	YES	NO	Remark
A	Helipad		√	
B	Emergency window		√	

Fire Safety Organization in Premises

	Description	YES	NO	Remark
A	Fire brigade team			
B	Fire safety manager			
C	Fire safety officer			
D	Number of personnel			
E	Number of vehicles			
F	Equipment			
G	Fire drill			
H	Periodical training			

5) FIRE SAFETY CHECKLIST

Name	**Ipoh City Hall, Ipoh**
Address	Jalan Panglima Dato Bukit Gantang Wahab 31650 Ipoh, Perak
Building Owner	Majlis Bandaraya Ipoh
Building Function	Event Hall
Building Material	Concrete
Age of Building	101 years old
Building Size	Medium
Nearest Fire Station	Balai Bomba Dan Penyelamat Ipoh
Distance of Fire Station to Building	5 KM
Date of visit	9 August 2017
Fire Certificate	No
Building Insurance	Yes (Building + People)
Fire Safety Policy	Yes
Fire Safety Plan	No

Life Safety Facilities

	Description	YES	NO	Remark
A	Emergency exit sign	√		
B	Emergency light		√	
C	Procedure during fire		√	
D	Notice of fire safety		√	
E	Protected staircases		√	
F	Protected corridor		√	
G	Exit door		√	
H	Storey exit		√	
I	Assembly point		√	

Fire Prevention Facilities

	Description	YES	NO	Remark
A	Automatic fire detector system		√	Smoke detector Heat detector
B	Fire alarm system		√	
C	Direct electrical or telephone line connected to fire station		√	
D	Command and control centre		√	

Fire Protection Facilities

	Description	YES	NO	Remark
A	Fire door		√	
B	Electrical wiring		√	
C	Compartment		√	
D	Fire stopping		√	
E	Fire dampers		√	

F	Smoke venting system		√	
G	Electrical isolation switch		√	

Fire Fighting Facilities

	Description	YES	NO	Remark
A	Fire extinguishers ABC Dry powder: Carbon Dioxide:	√		Limited amount
B	Fire hydrant	√		
C	Pressurised fire hydrant		√	
D	Hose reel system		√	
E	Wet riser system		√	
F	Dry riser system		√	
G	Automatic sprinkler system		√	
H	Drencher system		√	
I	Carbon dioxide system		√	
J	Fire lift		√	
K	Fire fighting staircase		√	
L	Fire fighting access lobby		√	
M	Voice communication system		√	
N	Fire appliance access		√	
O	Water storage		√	
P	Foam storage		√	

Special Provision

	Description	YES	NO	Remark
A	Helipad		√	
B	Emergency window		√	

Fire Safety Organization in Premises

	Description	YES	NO	Remark
A	Fire brigade team	√		2 + 5/6
B	Fire safety manager		√	
C	Fire safety officer		√	
D	Number of personnel		√	
E	Number of vehicles		√	
F	Equipment		√	
G	Fire drill		√	Only at MBI (2x/year)
H	Periodical training		√	

6) FIRE SAFETY CHECKLIST

Name	**Sultan Azlan Shah Gallery**
Address	Jalan Istana, Bukit Chandan 33000 Kuala Kangsar, Perak
Building Owner	Lembaga Muzium Negeri Perak
Building Function	Museum
Building Material	Brick
Age of Building	114 years old
Building Size	Medium
Nearest Fire Station	Balai Bomba Dan Penyelamat Kuala Kangsar
Distance of Fire Station to Building	4 KM
Date of visit	8 August 2017
Fire Certificate	No
Building Insurance	Yes (Building)
Fire Safety Policy	No
Fire Safety Plan	No

Life Safety Facilities

	Description	YES	NO	Remark
A	Emergency exit sign	√		
B	Emergency light		√	
C	Procedure during fire		√	
D	Notice of fire safety		√	
E	Protected staircases		√	
F	Protected corridor		√	
G	Exit door		√	
H	Storey exit		√	
I	Assembly point		√	

Fire Prevention Facilities

	Description	YES	NO	Remark
A	Automatic fire detector system	√		Smoke detector Heat detector
B	Fire alarm system	√		
C	Direct electrical or telephone line connected to fire station		√	
D	Command and control centre		√	

Fire Protection Facilities

	Description	YES	NO	Remark
A	Fire door		√	
B	Electrical wiring		√	

C	Compartment		√	
D	Fire stopping		√	
E	Fire dampers		√	
F	Smoke venting system		√	
G	Electrical isolation switch		√	

Fire Fighting Facilities

	Description	YES	NO	Remark
A	Fire extinguishers ABC Dry powder: Carbon Dioxide:	√		
B	Fire hydrant	√		
C	Pressurised fire hydrant		√	
D	Hose reel system	√		
E	Wet riser system		√	
F	Dry riser system		√	
G	Automatic sprinkler system		√	
H	Drencher system		√	
I	Carbon dioxide system	√		Safe Room
J	Fire lift		√	
K	Fire fighting staircase		√	
L	Fire fighting access lobby		√	
M	Voice communication system		√	
N	Fire appliance access		√	
O	Water storage		√	
P	Foam storage		√	

Special Provision

	Description	YES	NO	Remark
A	Helipad		√	
B	Emergency window		√	

Fire Safety Organization in Premises

	Description	YES	NO	Remark
A	Fire brigade team		√	
B	Fire safety manager		√	
C	Fire safety officer		√	
D	Number of personnel		√	
E	Number of vehicles		√	
F	Equipment		√	
G	Fire drill	√		Before 2011
H	Periodical training	√		By Private Company

APPENDIX B

JOURNAL PAPERS

Adv. Sci. Lett. 23, 6242–6246, 2017

RESEARCH ARTICLE

Advanced Science Letters
Vol. 23, Number 7 (July 2017)

Fire Safety in Museum Buildings: A Case Study of Perak Museum, Taiping, Malaysia

Nurul Hamiruddin Salleh[1], A Ghafar Ahmad[2]

[1]Department of Architecture, KAED, International Islamic University Malaysia, Selangor, Malaysia
[2] School of Housing, Building and Planning, Penang, Malaysia

In Malaysia, from 2001 to 2015 at least three museums have been involved in fires that destroyed the buildings and its contents. This is due to many factors such as insufficient fire safety systems, poor maintenance, and lack of fire safety awareness. In fact, the relevant authorities have also failed to provide sufficient guidance and good strategy in safeguarding the buildings that mostly gazetted as heritage buildings under the National Heritage Act 2005 (Act 645) from fire damages. The collection of primary data for this study was collected through on field observation as an approach to audit directly the practice of fire safety management in the heritage building. This study examines fire safety measures in the Perak Museum, a National Heritage building in Malaysia, with reference to the requirements of the Uniform Building By-Law (UBBL) 1984, the Fire Services Act 1988, the Occupational Safety and Health Act 1994 and four relevant Malaysian Standards that related to fire safety. The study discovers the studied building is relatively equipped with sufficient fire safety measures but the lack of proper fire safety management. The conflict between the security of contents and safety of people is also identified as a significant contribution of fire safety weaknesses in the building.

Keywords: Fire Safety, Fire Safety Management, Museum, Heritage Building, Building Conservation

1. INTRODUCTION

In Malaysia, from 2001 to 2015 at least three museums have been involved in fires that destroyed the buildings and its contents. The cases should be given higher priority because the buildings and its contents are categorized as historically valuable, priceless and irreplaceable. This is believed due to many factors such as insufficient fire safety systems, poor maintenance, and lack of fire safety awareness. In fact, the relevant authorities have also failed to provide sufficient guidance and good strategy in safeguarding museums that mostly gazetted as heritage buildings under the National Heritage Act 2005 (Act 645) from fire damages. In a study, Siti Rohamini has found that active fire protection systems in museums are still insufficient based on the ratio of their contents [1]. Fire in museums is not only a problem in Malaysia but also throughout the world [2]. The National Fire Protection Association (NFPA) estimates that an average of 89 museum and gallery fires each year in the United States of America (USA) [3]. In Canada, some 316 museums, art gallery and library fires occurred between 1982 and 1993 that caused an estimated loss of over USD 17 million [4]. In this study, the Perak Museum in Taiping, a National Heritage building was selected as a case study. Fire safety and protection measures in the building have been audited and examined with reference to the relevant requirements of the Uniform Building By-laws 1984 (UBBL 1984), the Fire Services Act 1988 (Act 341), the Occupational Safety and Health Act 1994 (Act 514) and the relevant Malaysian Standards. The primary objective of this study is an approach to audit directly the practice of fire safety management in the heritage building.

2. BACKGROUND

The Perak Museum built in 1883 in several phases. In the first phase (1883-1886), only the main building was

completed. The building served as a center for research as well as for exhibiting artifacts collected. It also housed the museum's office and library. Further construction was resumed in 1889 with the addition of two verandas to the front and rear of the building. From 1891 to 1893, another wing was added to the west of the building. In 1900, the British built an additional building two-storey high at the rear of the main building due to the increase in the museum collections. The annex building was completed in 1903. From November 2007 until January 2009, the Department of National Heritage, Malaysia was commissioned to restore the building. The restoration of the building was divided into three phases, at the cost of more than MYR 3 million [5]. In 2009, the Perak Museum was officially declared as a National Heritage under the Act 645. The Federal Government directly administrates the Perak Museum under the Department of Museums, Malaysia.

The museum is laid out in an L-shaped formation, with two galleries namely the Temporary Gallery and the Natural History Gallery, located in its main building. The Cultural Gallery and the Clay and Indigenous People Gallery are located on the left of the two-storey annex block at the rear of the main building. There are several covered and open outdoor display spaces on the grounds of the museum exhibits such as a mid-19th-century cannon and a 19th-century railway carriage (in use between 1885 and 1895)[6]. A two-storey of administration block is located on the right of the rear of the museum's main building. The block houses a curator room, three assistant rooms, a meeting room, general office and others. Other facilities provided in the museum compound are three outdoor exhibition areas, a small laboratory, a surau, a block of public toilets as well as coach parking and car parking spaces.

Figure 1: The front façade of the Perak Museum, Perak, Malaysia

3. METHODOLOGY

Being the first and the oldest museum in Malaysia, and listed as a National Heritage building, the Perak Museum (Figure 1) has been selected as a case study in this study. Data collection in this study was conducted in two stages. The first stage involved literature review in identifying key issues and recent research that relate or were significant to the study. The second stage involved the collection of primary data through an on field observation. In the observation stage, the existing fire safety and protection measures in the building were briefly audited in April 2009. The information manually recorded in a Fire Safety Checklist Form, a modified version of Form I (Reg.2) of the Fire Services Act 1988. The building also was examined by the requirements of three Legislations and four relevant Malaysian Standards that related to fire safety as listed in Table 1.

Table 1: List of referred Malaysian Legislations and Standards

No	Name of References	Category
1	The Uniform Building By-laws 1984 (**UBBL 1984**)	Legislations
2	The Fire Services Act 1988 (**Act 341**), Regulations and Order	
3	The Occupational Safety and Health Act 1994 (**Act 514**) & Regulations and Orders	
4	**MS 983:** 'KELUAR' Signs (Internally Illuminated) – Specifications (2004)	Malaysian Standards
5	**MS 1038: Part 1:** Specification for Emergency Lighting of Premises - Premises Other Than Cinemas and Certain Other Specified Premises Used for Entertainment (1986)	
6	**MS 1539: Part 3:** Specification for Portable Fire Extinguishers - Selection and Installation (2003)	
7	**MS 1539: Part 4:** Specification for Portable Fire Extinguishers - Maintenance of Portable Fire Extinguishers: Code of Practice (2004)	

4. FINDINGS

Before the restoration in 2009, a limited number of portable fire extinguishers were the sole fire protection system provided in the building. However, an extensive improvement of the museum fire protection systems was conducted during the building restoration in 2009. The total sum of MYR 96,260 from the restoration cost of MYR 3.6 million was allocated to upgrade active fire protection systems in the building [7]. Passive and active fire protection systems in the building are explained as follows:

4.1 PASSIVE FIRE PROTECTION

4.1.1 Means of Escape

Based on the site observations, there are four doors classified as fire exit doors in the building. Nevertheless, the main entrance located at the lobby is the only unlocked fire exit door in the building. The other fire doors are locked due to the security of the building collections and to control visitor circulation. Meanwhile, only one means of escape provided in the Clay and Indigenous People Gallery (with a total floor area of 275 square meters) at the upper floor of the annex block. Therefore, in the case of emergency, visitors have no other option but to evacuate the gallery through a steep and narrow timber staircase. Besides, there are few island showcases located along the evacuation routes in some gallery, particularly in the

Natural History Gallery. This situation may cause evacuation difficulties in the event of a fire.

4.1.2 Fire Appliance Access

The Perak Museum is located next to the main road with an approximately eight-meter-wide main entrance. This allows fire brigade vehicles to enter the building compound without any difficulty. In addition, there is a large parking space at the left side of the building. Nevertheless, there is only one fire hydrant available at the rear of the building that is in front of the Administration Block.

4.2 ACTIVE FIRE PROTECTION

The study found that seven types of active fire protection systems are provided in the building, namely portable fire extinguisher, exit (KELUAR) sign, emergency light, automatic fire detector, fire alarm system, hose reel system and fire hydrant system. The active fire protection systems in the building are explained as follows:

4.2.1 Portable Fire Extinguisher

Only one type of portable fire extinguisher provided to protect the Perak Museum galleries, which is 9-kg dry powder. There are 11 dry powder extinguishers in total where 10 of them are located on the ground floor. Meanwhile, only one dry powder extinguisher is provided to protect the Clay and Indigenous People Gallery. All extinguishers are placed in conspicuous positions with an average distance of 13.9 meters and mounted between 1.2 to 1.5 meters from the floor. However, the extinguishers are not accompanied by any signage.

4.2.2 Exit (KELUAR) Sign

There are five exit signs installed above the means of escapes leading to the outside of the building. Two types of exit signs used are a sign reading KELUAR with a pictorial illustration in white against a green background, and a sign reading KELUAR with a pictorial illustration in green against a white background. Both comply with the requirement of MS 983: 2004. The sign is internally illuminated by two separate systems of lighting, the main power supply, and a battery power supply for at least 3 hours whenever the main supply fails. However, there is no directional sign towards the means of escapes in this building.

4.2.3 Emergency Lighting

A total of 28 emergency lights is installed in the Perak Museum in which 22 of them are placed on the ground floor and the other six on the first floor. Two types of emergency lighting used are a light-emitting diode (LED) emergency lights mounted on the ceiling, and two fluorescent tubes of 8-watt emergency lights mounted on the wall. As recommended by the MS 1038: 1986-Specification for Emergency Lighting of Premises (Part 1), an emergency lighting should be powered by an independent source different from that of the standard lighting. Therefore, emergency lights used in the building have dual power systems, electricity power as the main power supply and battery backup up to 3 hours when the main power supply fails.

4.2.4 Automatic Fire Detectors

The primary function of fire detectors is to provide an early detection of fire that could significantly minimize damage as well as to alert people. There are 27 new automatic fire detectors installed during the recent restoration of the building. Two types of detectors are installed in the building, namely the ionization type smoke detectors and the heat detectors. All detectors are strategically placed on the ceiling that is divided into 23 detector zones and connected to a new alarm system. The control panel of the system is located in the lobby. A total of four ionisation-type smoke detectors is installed in the Cultural Gallery while, 23 heat detectors are installed in other parts of the building. As stated earlier, there are a few galleries with high ceiling such as the Natural History Gallery and the Temporary Gallery with a ceiling height up to 6.9 meters that may cause the automatic detectors to function ineffectively.

4.2.5 Fire Alarm System

A new fire alarm system was also installed during the previous restoration of the building. A manual call point break glass with alarm was the selected fire alarm system. The systems are mounted on the wall at five different locations in which four of them are located next to the fire exits (means of escape) and one system at the staircase area of the first floor. Based on the site observations, it is found that all of them are unobstructed by any objects.

4.2.6 Hose Reel System

One of the recent major improvements in fire safety in the Perak Museum was the installation of a new fire hose reel system inclusive of 2,400 gallons water tank and pump systems. The system that costs an approximately of RM40,950 was installed with sympathetic approaches to the existing building [7]. A series of hose reel pipes was placed under the existing timber flooring, and three units of hose reel cabinets were installed outside the museum to minimize damage to the existing fabric of the building. The hose system is powered by one electric pump (duty pump) and one diesel pump (standby pump).

4.2.7 Fire Hydrant

There is only one unit of fire hydrant provided in the compound of the Perak Museum. The hydrant, located in front of the Administration Block, is more than 90 meters away from the main block. Nevertheless, a covered car parking for the museum staff was built in front of the hydrant. This may obstruct the use of the hydrant in the event of a fire.

5. FIRE SAFETY WEAKNESSES IN THE PERAK MUSEUM

Based on field observation, this study has identified nine main fire safety weaknesses in the Perak Museum. The fire safety weaknesses are highlighted as follows:

5.1 Inappropriate fire safety management

The Perak Museum lacks proper fire safety management. The building operates without a proper fire safety policy in place. In addition, the management of the building has not conducted any fire drill, fire training, and risk assessment on a regular basis. The building and its collections are also not covered by insurance.

5.2 Single means of escape

As required by UBBL 1984: Section 166 (1), not less than two separate exits should be provided from each storey together with such additional exists as may be necessary. In other words, there should be alternative means of escape in most situations as there is always the possibility of escape being impassable by fire or smoke. However, only one means of escape is provided in the Clay and Indigenous People Gallery of the building. Therefore, in a case of emergency, visitors have to evacuate the gallery through a steep and narrow timber staircase. This situation may cause evacuation difficulties in the event of a fire.

5.3 Locked fire exits

There are four doors classified as fire exit doors in the building. In accordance with UBBL 1984: Section 173 (1), all exit doors should be openable from the inside without the use of a key or any special knowledge or effort. Nevertheless, the main door located in the lobby is the only unlocked fire exit door in the building. The other doors are locked due to security purposes. This situation may cause evacuation difficulties in the event of a fire. One of the common solutions to this problem is to install electromechanical or electromagnetic locking devices such as automatic door release, panic bar or emergency door release on the doors. In order to prevent unauthorized access, the doors should be integrated with the alarm system.

5.4 Showcases not designed to quick salvage collections

Showcases in the building are not designed with consideration to quick salvage the collections in the event of a fire. Collections are displayed in showcases with individual lock devices. This situation may cause problems in salvaging the collections in the event of a fire.

5.5 Showcases placed along evacuation routes

A few island showcases are located along the evacuation routes in some galleries, particularly in the Natural History Gallery. This situation may cause evacuation problems in the event of a fire.

5.6 No designated assembly points

There are no designated assembly points in the Perak Museum to assemble building visitors and collections in the event of a fire.

5.7 No fire safety signs/notices

There are no fire safety signs that provide information on the location of portable extinguishers and assembly points within the building. In addition, no directional signs are provided to navigate visitors to the fire exits of the building as required by UBBL 1984: Section 172 (2). Exhibition galleries in the Perak Museum are separated by a series of masonry walls and corridors that make direct view toward fire exits impossible.

5.8 Heat detectors installed in high ceiling spaces

This study discovered that automatic heat detectors are installed in several galleries with high ceilings such as the Natural History Gallery and the Temporary Exhibition Gallery. Both galleries are built with ceiling heights up to 6.9 meters that may cause the detectors to function ineffectively. Alternatively, beam detectors are more ideal for large spaces with a high ceiling.

5.9 Obstructed fire hydrant

Only one unit fire hydrant is provided in the compound of the Perak Museum. The hydrant is located in front of the Administration Block, which is more than 90 meters away from the main block. However, a covered parking for the building's staff was built in front of the hydrant. This then obstructs the use of the hydrant in the event of a fire. In fact, it is an offense to obstruct fire hydrants under Act 341: Section 26.

6. COMPLIANCE WITH THE MALAYSIAN LEGISLATIONS AND STANDARDS

In terms of compliance with the requirements of Malaysian Legislations and standards related to fire safety, evidence from this study has shown that the Perak Museum has complied with the majority requirements of the UBBL 1984, MS 983, MS 1038: Part 1 and MS 1539: Part 3. The building has fulfilled 50% from the total of 38 requirements but not fulfilled 39.5% of the requirements as summarized in Table 2 below.

Table 2: Summary compliance with the requirements of Malaysian legislations and Standards in Perak Museum.

Legislations / Standards	Relevant requirements	Fulfilled	Not Fulfilled	Partly Fulfilled	Not Applicable
UBBL 1984	20	10	10	0	-
Act 341	1	0	1	-	-
Act 514	3	0	2	0	1
MS 983	3	3	0	0	-
MS 1038: Part 1	6	3	1	2	-

MS 1539: Part 3	3	2	0	1	-
MS 1539: Part 4	2	1	1	0	-
TOTAL	**38**	**19 (50%)**	**15 (39.5%)**	**3 (7.9%)**	**1 (2.6%)**

7. CONCLUSIONS

The Perak Museum is relatively equipped with sufficient fire safety measures. The building managed by the Malaysia Department of Museums has undergone massive restoration works including an upgrade in its fire safety measures in 2009. The restoration project has proven that upgrading fire safety in an existing building does not require a significant amount of money as commonly assumed by many. A total of less than MYR 100,000 was utilized to install a completely new fire safety system in the building. With the new fire safety measures, the building has fulfilled 50% from the total of 38 requirements under the UBBL 1984, MS 983, MS 1038: Part 1 and MS 1539: Part 3. The major improvement of fire safety measures in the building is a new hose reel system. The system was installed with a sympathetic approach to the existing building in order to minimize damage to the existing fabric of the building.

Nevertheless, the building may still be considered as potential hazards not only to visitors but also to their contents in the case of fire. This study discovered that the building management more emphasized on the security of the contents rather than the safety of the people. The building operated without a proper fire safety management including no fire safety policy and plans in place, and not conducted a periodical fire drill, fire training, and risk assessment.

There is only one fire exit door in the building is unlocked due to security purposes and to control visitor circulation. This situation may cause evacuation difficulties in the event of fire particularly during peak seasons, such as public holidays and school holidays when the buildings usually receive large numbers of visitors. Furthermore, the majority of the collections in the buildings are exhibited in non-master-key showcases that may cause difficulties to salvage the collections in the event of fire quickly.

ACKNOWLEDGEMENT

This paper from the research sponsored by the Ministry of Higher Education of Malaysia with support from the International Islamic University Malaysia.

REFERENCES

[1] Siti Rohamini Yusoff (2002). Keselamatan Kebakaran Aktif dan Kesedaran Pengguna di dalam Bangunan Muzium (Active Fire Protection and Public Awareness in Museum Buildings). Master Thesis, School of Housing, Building and Planning, Universiti Sains Malaysia

[2] Nurul Hamiruddin Salleh (2011). Fire Safety in Heritage Buildings: Life vs. Property Safety. In Ali Raza Soomro (Ed.), Heritage Study of Muslim World (p.61-72). Kuala Lumpur: IIUM Press

[3] Kidd, S. (2005). Technical Advice Note 28: Fire Safety Management in Heritage Buildings. Edinburgh: Historic Scotland.

[4] Mills, A. (2007). The Scale of Fire Loss to Historic Buildings. In I. Maxwell (Ed.), COST Action C17: Built Heritage Fire Loss to Historic Buildings: Final Report Part 1 (p.15-32). Edinburgh: Historic Scotland.

[5] Nurul Hamiruddin Salleh (2011). Fire Safety and Protection Measures in Heritage Buildings with Special Consideration on Museum Buildings in Malaysia. Unpublished Ph.D. Thesis, Universiti Sains Malaysia Penang.

[6] Seow, M. and Gobal, L.J. (Eds.) (2004). Museums of Southeast Asia. Archipelago: Press, Singapore

[7] Rekabina Utama (M) Sdn. Bhd. (2007). Cadangan Kerja-kerja Konservasi Bangunan Muzium Perak, Taiping, Perak (Proposed Conservation Works of Perak Museum, Taiping, Perak). Unpublished Tender Document, Department of National Heritage of Malaysia.

Evaluation of Fire Safety Measures on Heritage Timber Buildings in Malaysia

Nurul Hamiruddin Salleh[1] and Muhammad Alif Wajdi Mohtar [2]
[12]*Kulliyyah of Architecture & Environmental Design, International Islamic University Malaysia*

[1] *hamiruddin@iium.edu.my*
[2] *alifwajdi@gmail.com*

Abstract
Malaysia has a significant amount of heritage buildings located in every part of the country. Most of these heritage buildings were mainly constructed using timber and symbolized the origin of the country architectural style as well as the historical representation of the local community and its surrounding context. Due to the combustible nature of timber, these heritage timber buildings are highly exposed to the risk of fire. Since most of these building have been adaptively re-used for public usage, it also adds another potential risk such as arson or wilfully set fire. Currently, there is no proper guideline for heritage timber building which can act as a reference for building owners or conservators. The purpose of this research is to identify existing methods of fire safety system for heritage timber buildings in Malaysia. The study is conducted through literature findings and evaluation on four selected heritage timber buildings. Based on the findings, a variety of fire safety measures are available for heritage timber building but their effectiveness differs according to the selection of equipment. The outcome of this paper is expected to provide a general example or reference towards implementing existing methods of fire safety systems in future conservation projects.

Key Words: *Fire Safety, Fire Safety System, Heritage Building Fire Risk, Heritage Timber Buildings*

Introduction

For any civilization or country, one of their most valuable historical assets is the existence of their heritage buildings. Heritage building can be easily depicted as a building constructed in the past which contains various historical value within its design or existence. As mentioned by Siemens Switzerland Ltd. (2015), the presence of heritage buildings contribute towards providing a general glimpse of the past of a specific community or civilization through the craftsmanship and technology used in the building's design and construction. In addition, the National Heritage Act 2005 further explained that the heritage building is defined as a building or groups of separated or connected building that stands out amongst the rest due to their architectural essence, their cultural homogeneity, or even their placement within the surrounding landscape from the perspective of history, arts, and science.

Fire is a recurrent risk towards most buildings and its contents due to the various types of destruction and damages that it may cause. In

the case of heritage building, fire is considered as a significant threat towards the historic essence of the building and its context especially with the increasing age of most of the building's material and the lack of safety provision in most of the heritage buildings. Historic Scotland (2005) stated that fire usually occurs due to the presence of three main elements which includes heat, oxygen, and fuel. The spread of fire within the building also easily take place when it is unhindered from any types of separation. This is the main concern to heritage buildings since most of them were constructed using traditional methods and tend to include numerous voids that fire can easily spread through.

Heritage Building Fire

At present, most of these heritage buildings no longer serve their original functions and are commonly used as public attractions and accessible to everyone. This creates a whole new different problem towards the building that should be solved immediately. As stated by Kidd (2001), these buildings face potential risk or arson or wilfully set fires by allowing public access. In addition, he also stated that due to the increase of number of visitors and occupants, proper consideration should be made towards improving the risk assessment programme. These buildings contain various iconic and historical building elements which should be protected from any sorts of damages. This is further emphasized by Confederation of Fire Protection Associations Europe (2013) in which they stated that the awareness towards the risk of fire and the possibility of its occurrences is vital towards the protection of the heritage building and its content.

Another concern regarding the change of heritage building functions or usage is the possibility of fire ignition caused by electrical faults. Currently, electrical systems are retrofitted into most of the heritage timber buildings mainly for lighting purposes. However, the wiring system may be outdated or obsolete due to the lack of maintenance or inappropriate methods of installation. These can lead to the occurrence of short circuits which may lead to the ignition of fire. Based on the record from the Fire and Rescue Department of Malaysia in 2013, about 14% of building fire that occurred in Malaysia was caused by electrical faults as shown in Table 1.

Table 1. Statistic on the cause of building fire in Malaysia in 2012 and 2013

Year	Fire Caused by Electrical Faults	Total Fire Incident	Percentage (%)
2013	834	5,817	14.3%
2012	1,270	5,447	23.3%

(Source: bomba.gov.my)

Heritage Timber Building

Since the early period of Malaysia, timber was the main choice of material for construction purposes. According to Zainab (2005), brick was eventually introduced in Malaysia 350 years but was not easily accessible to everyone and mostly used for government-related buildings. As a result, timber was considered as the easiest accessible material and can be easily constructed by anyone. A significant amount of timber buildings were constructed and most of them still continue to exist until today. Table 2 provides several examples of the heritage timber buildings that were gazetted under the National Heritage Act 2005 and several other heritage timber buildings acknowledged by Jabatan Warisan Negara. The list only highlights a small fraction of the amount of heritage timber buildings that are scattered throughout Malaysia.

Table 2. List of acknowledged heritage timber buildings in Malaysia

Types of Buildings	*List of Buildings*
Places of worship	1. Masjid Mulong, Kota Bharu, Kelantan 2. Balai adat Kampung Putera Jelebu, Negeri Sembilan 3. Masjid Kampung Laut, Kelantan 4. Masjid Insaniah Iskandariah, Kuala Kangsar, Perak
Residential	1. Rumah Tiang Kembar & Rumah Tiang Limas, Terengganu 2. Rumah Penghulu Mat Nattar, Jasin, Melaka*
Government administration	1. Bangunan Sanitary Road, Taiping, Perak 2. Muzium Islam, Kota Bharu Kelantan 3. Kota Ngah Ibrahim, Taiping, Perak
Palace	1. Istana Lama Ampang Tinggi, Negeri Sembilan* 2. Istana Jahar (Muzium Adat Istiadat Diraja), Kota Bharu, Kelantan* 3. Istana Kenangan (Muzium Diraja Perak), Kuala Kangsar, Perak 4. Istana Seri Menanti, Kuala Pilah, Negeri Sembilan*
Commercial	1. Gedung Raja Abdullah, Klang, Selangor*

* Buildings gazetted under National Heritage Act 2005

(Source: heritage.gov.my)

Heritage Timber Building Risks to Fire

Fire has a variety of reactions when exposed to different type of materials. The type of materials used for the construction of a building can greatly influence the building's resistance to fire. This has always been a major concern since most of the heritage buildings in Malaysia were constructed using timber as its main material. Due to the combustible nature of timber materials, heritage timber buildings are greatly exposed to the risk of fire.

According to Gerard & Barber (2013), the presence of exposed timber material will contribute to the combustible fuel load as well as the room fire behaviour and structural fire resistance. Several heritage timber buildings in Malaysia had already been destroyed by fire which results in a severe loss as shown in Table 3.

Table 3. Fire statistic for heritage timber buildings in Malaysia from 2003-2016

Date	*Building*	*Estimated Loss (MYR)*
2 May 2003	8 Double-storey wooden shop houses (1950), Batu Kawa Bazaar, Kuching	
25 July 2003	138-years old semi-wooden girls dormitory, St Joseph Home, Penang	100,000
20 Oct. 2003	Rumah Pak Ali (1876), Gombak, Kuala Lumpur	>1 mil.
5 May 2008	38 units of Punan Bah longhouse, Belaga, Sarawak	>500,000
5 Feb 2009	5 Heritage houses, Chew Jetty, Penang (In World Heritage Site Zone)	
24 Feb 2010	Ho Ann Kiong Temple, Kampung Cina, Kuala Terengganu	

(Source: thestar.com.my)

In comparison to other materials, the reaction of timber when exposed to fire consist of several different stages before the material is fully burned. According to U.S. Department of Housing and Urban Development (2007), there are roughly around four different stages of timber combustion. The first stage will occur at 100-150°c, in which the water inside the timber will start to evaporate and turn the timber brown. Upon reaching 200-250°c, the charring process will slowly begin and non-combustible gas will be released. The third stage will occur at roughly 300°c where volatile and combustible gas is released and smoke particles are becoming more visible. Finally, the fire will start to ignite at around 400-450°c and the charring process will occur at a steady rate. This will result in the permanent loss of strength and causing the timber the break down.

Timber is considered to have an unpredictable combustion nature since the charring rate varies according to the type of timber exposed to fire. According to Lowden & Hull (2013), the process are influenced by several different factors which include the density, continuity, oxidation-resistance, thermal insulation properties and permeability. In order to overcome this situation, Department of Standards Malaysia (2001) had identified a notional charring rates of Malaysian timbers according to their strength group as a solution to ease the calculation of residual section as

shown in Table 4. Through this reference, the process of estimating the needed amount of time to escape and fire prevention will be much easier.

Table 4. Notional rate of charring for the calculation of residual section

Strength Group	Charring Rate
SG 1: Balau, Bitis, Chengal, Penaga SG 2: Belian, Kekatong SG 3: Keranji, Kelat, Kembang Semangkok, etc.	0.5 mm/min
SG 4: Giam, Malabera, Merbau, etc. SG 5: Tembusu, Bintangor, Gerutu, etc.	0.7 mm/min

(Source: Department of Standards Malaysia 2001)

Fire Safety Approach in Heritage Timber Building

In order to prevent any potential risk of fire, great consideration should be made towards the implementation of an appropriate fire safety system in the heritage timber building. According to National Fire Protection Association (2015), one of the main objectives of historical preservation is to fully utilize the level of protection of the heritage building against damage and loss to fire. However, as highlighted by Kidd (2010), there are six different conservation principles to be considered during implementation of fire safety in a heritage building, which include the following:

i. Essential
ii. Appropriate to risk
iii. Compliant with legislation
iv. Minimally invasive
v. Sensitively integrated
vi. Reversible

As stated by Urquhart (2007), fire safety can be generally defined as a systematic approach which combines the usage of structural materials, building components, and protective system. In addition, he also stated that fire safety is generally divided into two separate categories: 'active' system and 'passive' system. The passive system mainly focuses on the physical aspect of the building such as compartmentation, escape routes, and ventilation system while active system makes use of additional equipment or group of system to detect and suppress the presence of fire. However, from a heritage conservation point of view, active fire safety system is considered to be more practical since it rarely disturbed the original physical properties of the building. Siemens Switzerland Ltd. (2015) stated that the implementation of fire safety system should contain the utmost minimal physical impact towards the fabric and decor of the building.

This is vital for heritage timber buildings since most of the physical elements of the buildings are irreplaceable and more fragile compared to other type of building materials.

Specific legislation were issued by every respective authority in order to provide a general guideline towards the implementation of fire safety system in a building. However, in most cases, these legislations were originally meant for new buildings and may not be compatible with existing buildings such as heritage buildings. According to Nurul Hamiruddin & Ghafar (2009), most of the legislations in Malaysia are still lacking in terms of a proper guideline for fire safety implementation in heritage buildings. Nonetheless, Kidd (2010) stated that while it may not be applicable to heritage building, it is important to not overlook the fundamental point of its implementation. These legislations can be used as reference to provide a performance-based standard that best fit into the objectives of heritage building fire protection measures.

Fire Safety Implementation in Heritage Timber Buildings

Selection of Case Study

In order to determine the ideal fire safety implementation in heritage timber buildings, it is important to identify the methods that are currently used by most of the heritage timber buildings in Malaysia. According to the National Heritage Act 2005, buildings which have been around for more than 50 to 100 years are considered as heritage buildings. Malaysia has a considerable amount of heritage timber buildings and throughout the years, most of these buildings were refurbished to be used as museums or public attractions. However, heritage timber buildings which are easily accessible to the public tend to have a higher level of fire risk potential. Thus, it is important for these buildings to incorporate an appropriate level of fire safety system to not only protect the visitors but also the building itself.

Currently, most of the well known or gazetted heritage timber buildings are under the supervision of the local authorities or private institutions. These buildings tend to have a specific budget allocated towards the implementation of fire safety to a certain degree. This may include the usage of detection system, suppression system, and methods of escape. The selection of buildings

to be used as case study is determined by the previously mentioned factors, which include the building's age (50-100 years), level of public accessibility (open to the public), and under the supervision of any administrative agency. By using these buildings as examples, it will help to determine the ideal method of implementation of fire safety in heritage timber buildings in Malaysia.

Based on the previously determined selection factors, four heritage timber buildings were identified, which includes Istana Ampang Tinggi and Rumah Tradisional Negeri Sembilan located in Negeri Sembilan (Figure 1), Muzium Matang located in Perak (Figure 2), and Muzium Kota Kuala Kedah located in Kedah (Figure 2). These four buildings are currently gazetted under the National Heritage Act 2005. Both Istana Ampang Tinggi and Rumah Tradisional Negeri Sembilan are under the supervision of Lembaga Muzium Negeri Sembilan whereas Muzium Matang and Muzium Kota Kuala Kedah are under the direct supervision of Jabatan Muzium Negara. Nonetheless, each of the respective buildings is provided with a specific allocation for fire safety implementation annually. In terms of function, all four buildings are currently used as a museum or in the case of Istana Ampang Tinggi and Rumah Tradisional Negeri Sembilan, are used as part of the museum display. These buildings are easily accessible to the public and opened throughout most of the year.

Figure 1. Istana Ampang Tinggi (left) & Rumah Tradisional Negeri Sembilan (right)

Figure 2. Muzium Kota Kuala Kedah

Figure 3. Muzium Matang

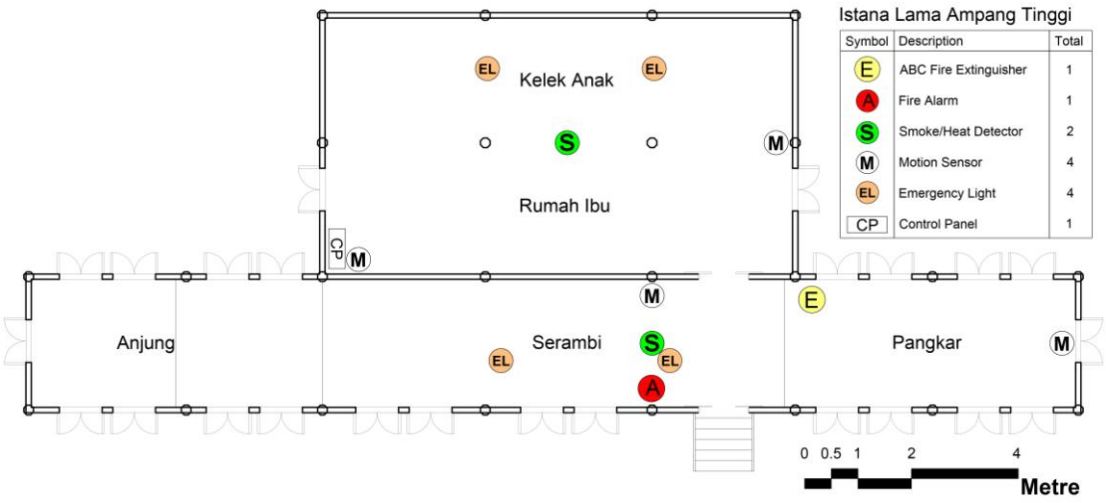


Figure 4. Location of Fire Safety Measures in Istana Ampang Tinggi

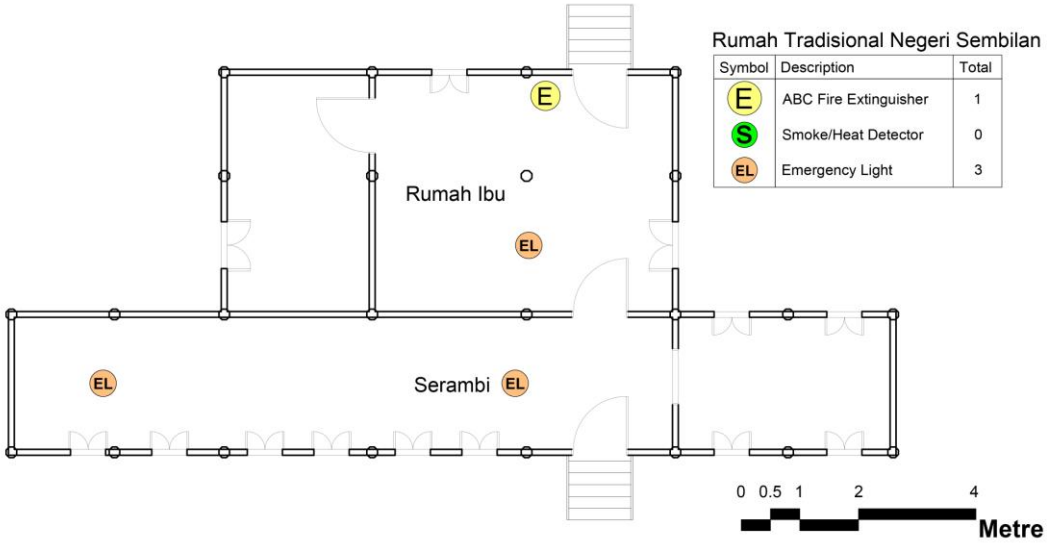


Figure 5. Location of Fire Safety Measures in Rumah Tradisional Negeri Sembilan

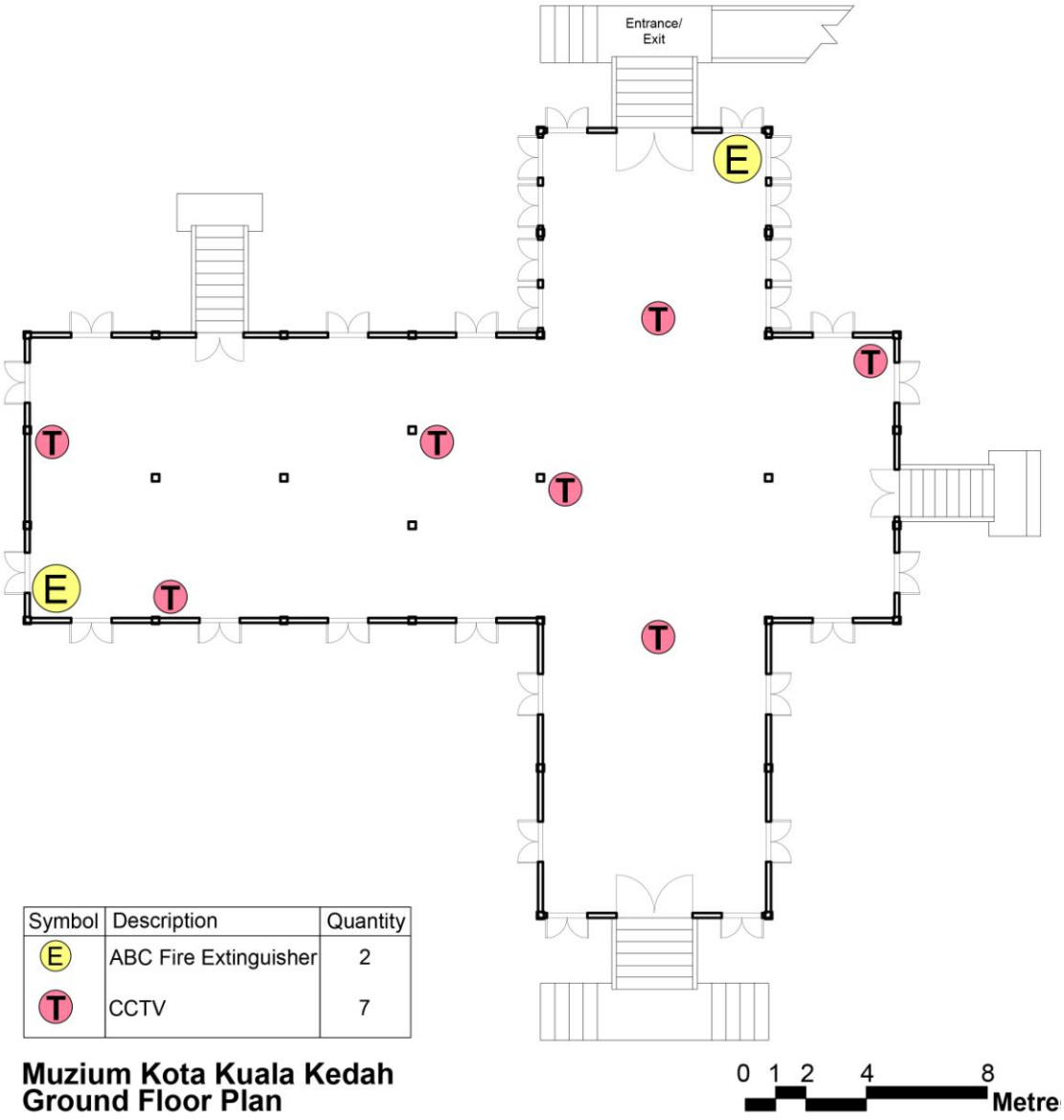


Figure 6. Location of Fire Safety Measures in Muzium Kota Kuala Kedah

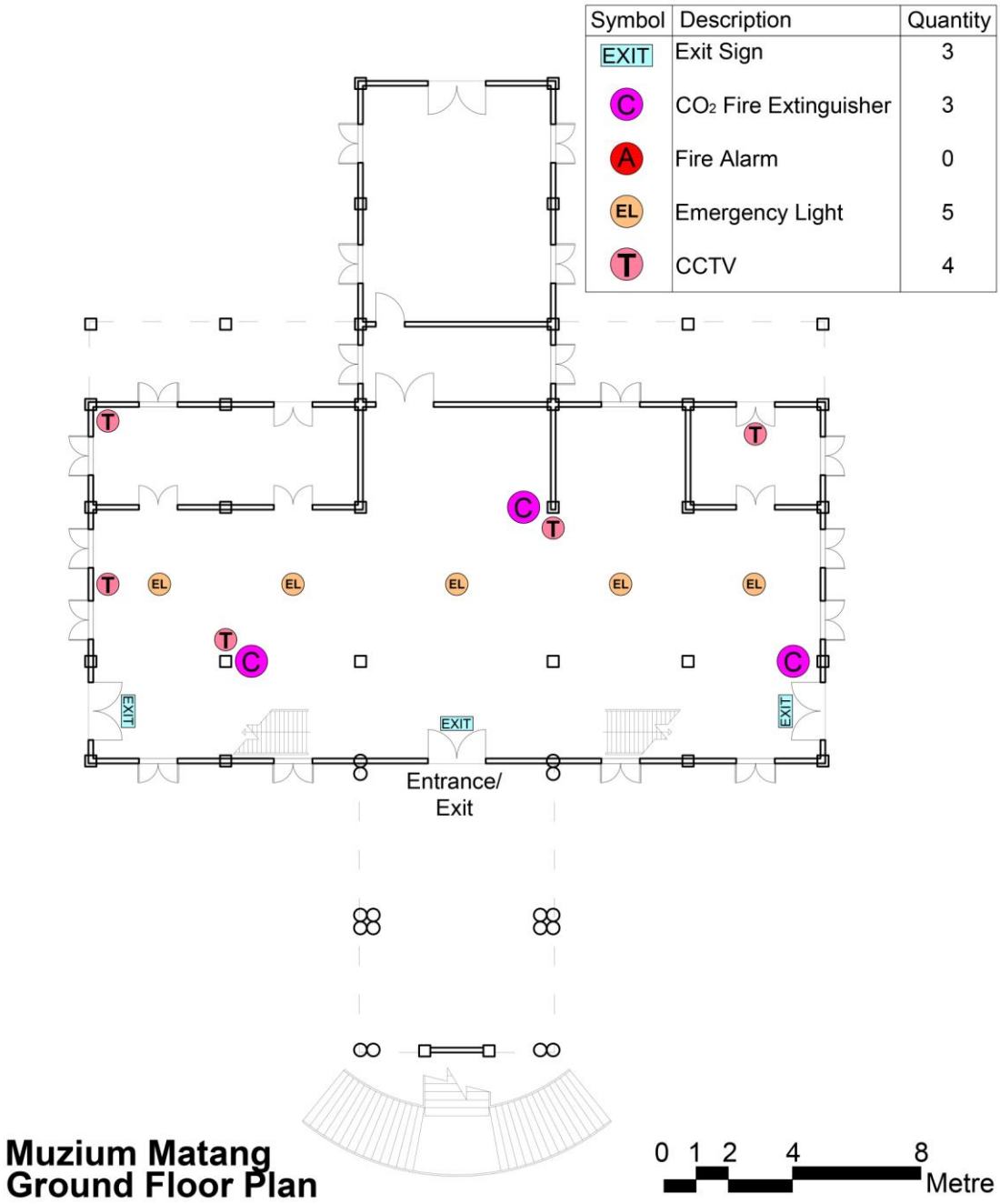


Figure 7. Location of Fire Safety Measures in Muzium Matang (Ground Floor)

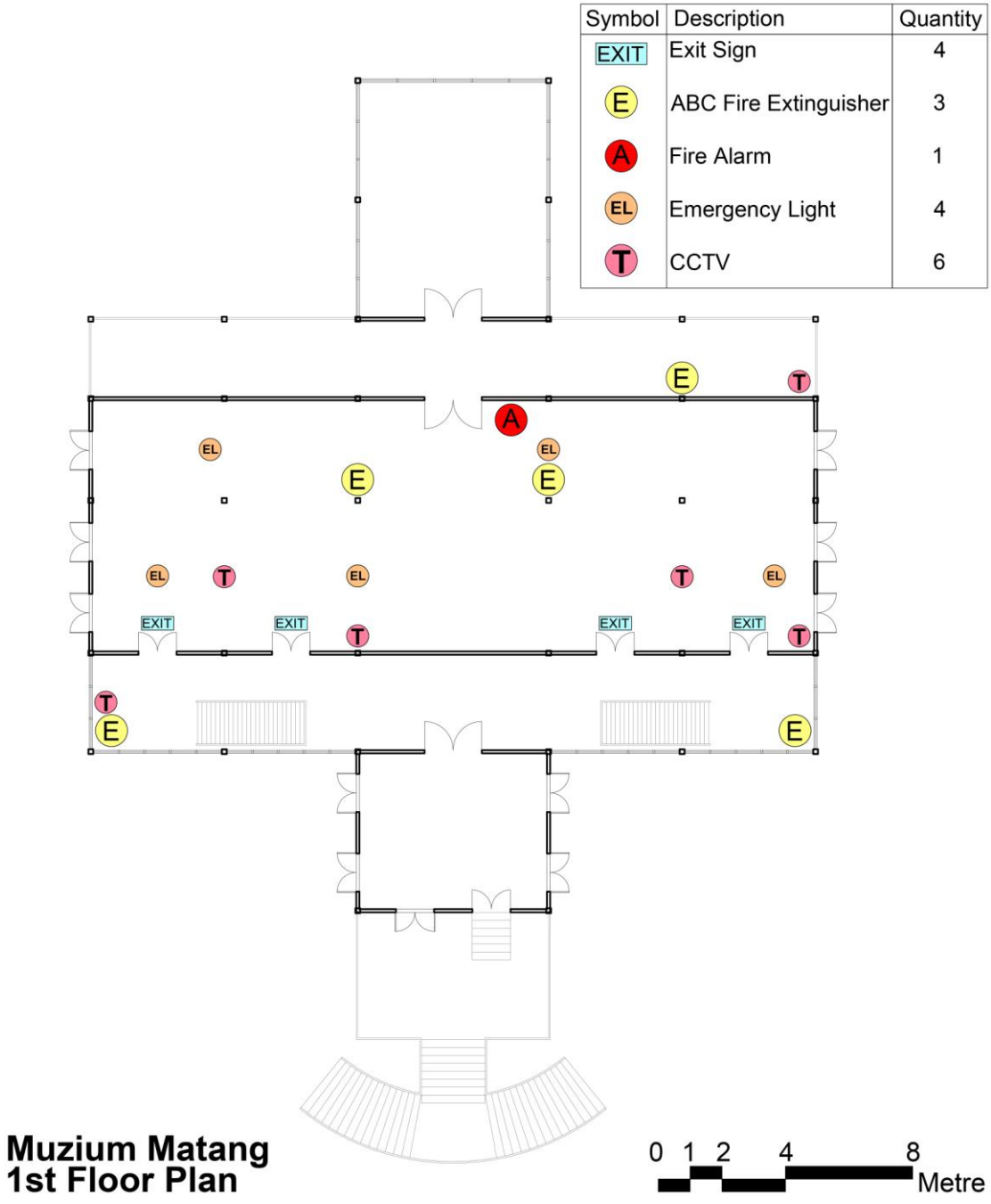


Figure 8. Location of Fire Safety Measures in Muzium Matang (First Floor)

Survey Findings

Upon the completion of the survey, several similarities and differences in terms of method of fire safety implementation were identified in each of the four buildings. These methods include the usage of detection system and suppression system as well as method of escape. The locations for each of the recorded fire equipment are shown in Figure 4 to 8 whereas the summary of the fire safety measures between all four buildings is shown in Table 5.

Table 5. Summary of fire safety measures between heritage timber building

Heritage Timber Building	*Detector System*	*Suppression System*	*Means of Escape*
Istana Ampang Tinggi	Smoke detector	ABC fire extinguisher	Emergency light
Rumah Tradisional	None	ABC fire extinguisher	Emergency light
Muzium Matang	CCTV	ABC fire extinguisher CO^2 fire extinguisher	Emergency light Exit sign
Muzium Kota Kuala Kedah	CCTV	ABC fire extinguisher	None

One of the similar methods which can be identified in all of the four buildings is the usage of ABC Powder fire extinguisher as their main fire suppression system. However, due to the small size of the building, only one ABC Powder fire extinguisher is provided each for Istana Ampang Tinggi and Rumah Tradisional Negeri Sembilan whereas Muzium Kota Kuala Kedah is equipped with two ABC Powder fire extinguishers. Since Muzium Matang consists of two separate floors and larger floor area, it is equipped with six ABC Powder fire extinguishers, one on the ground floor and five on the first floor. In addition, two CO^2 fire extinguishers were also equipped on the ground floor of Muzium Matang as shown in Figure 8. This is most likely due to the presence of the control panel used for the alarm system next to the registration counter. While ABC Powder fire extinguishers are commonly used in most situations, CO^2 fire extinguishers are deemed as an appropriate type of extinguisher when dealing with electrical fire since it is harmless to electrical equipment.

Figure 9. ABC Powder fire extinguishers

Figure 10. CO^2 fire extinguishers

As for the detection system, only Istana Ampang Tinggi incorporates the usage of a photoelectric smoke detector inside the building as shown in Figure 11. Even though Rumah Tradisional Negeri Sembilan is situated just right next to it, no fire detection system can be found within the building. Similarly, both Muzium Matang and Muzium Kuala Kedah also did not incorporate any fire detection system but relies solely on the usage of closed-circuit television (CCTV) system to monitor the building condition which can be seen in Figure 12. The system is closely monitored 24 hours a day by the security guard on duty. However, the smoke detector system is considered as a more viable option since it can detect the presence of smoke particles faster which may not be visible or easy to be seen through the camera.

Figure 11. Photoelectric Smoke detector

Figure 12. CCTV camera (right)

With the exception of Muzium Kota Kuala Kedah, each of the heritage timber buildings is equipped with LED emergency lights as shown in Figure 13. These lights will help the occupants to navigate through the exits or escape routes during the evacuation process of the building in the event of loss of primary power. The positioning of each light are spread out throughout the whole building to provide the minimum level of coverage to each area of the building.

Figure 13. LED Emergency Light

From the observation, each of the selected buildings is generally equipped with an appropriate amount of active fire protection system. However, the selection of equipment of each building is different when compared to one another. This is due to the difference in terms of the size of the building as well as the content inside the building. Since Istana Ampang Tinggi and Rumah Tradisional Negeri Sembilan are smaller than the other two buildings, the implementation of active fire protection system is slightly minimal and less complicated. In addition, there is hardly any content or valuable item on display inside both of these buildings. Thus, the main focus of the building's fire safety is only to evacuate the occupants and prevent further damage towards the building from the outside.

Figure 14. Interior View of Istana Ampang Tinggi

In comparison, Muzium Kota Kuala Kedah and Muzium Matang are bigger in terms of size especially Muzium Matang which comprises of two floors. Unlike the two buildings from Negeri Sembilan, both of these buildings contain precious artefacts as well as various kinds of display items. Thus, this would also raise security concerns aside from fire safety related matters. The usage of CCTV system is considered as the most viable option since it can act as both the surveillance system as well as fire detection system at the same time. However, the main concern is that the system relies on a human presence in order to monitor the status of the building.

Figure 15. Security guard on duty at Muzium Kota Kuala Kedah

Conclusions

The findings of the study had identified several existing fire safety measures available for heritage timber buildings in Malaysia but due to the limited functionality of these systems, these buildings are still considered exposed to the threats of fire. In addition, these measures may not fully comply with each of the six conservation principles listed previously. Several other considerations have yet to be

taken into account such as the cost of equipment and methods of installation of each system. Further investigation should be conducted on how these considerations may also greatly influence the necessity of the system as well how the system can be integrated appropriately into the building. More examples are needed in order to come out with the ideal method or guideline that can be implemented and follow through by other heritage timber buildings in Malaysia. With a proper understanding on the requirements of fire safety measures and a systematic approach towards its implementation process, these issues can be appropriately solved.

Acknowledgement

This research was funded under Fundamental Research Grant Scheme from Ministry of Higher Education Malaysia (FRGS15-192-0433).

References

Confederation of Fire Protection Associations Europe. (2013). *Managing Fire Protection of Historic Buildings*.

Department of Standards Malaysia. (2001). Part 9: Fire Resistance of Timber Structures. In *MS 544: Code of Practice for Structural Use of Timber*.

Gerard, R., & Barber, D. (2013). Fire Safety Challenges of Tall Wood Buildings. *Arup North America*, (December), 131. http://doi.org/10.1007/978-1-4614-8142-3

Historic Scotland. (2005). Fire safety Creating an Awareness of Fire Threat.

Kidd, S. (2001). *Fire Risk Management in Heritage Buildings*. *Technical Advice Note* (Vol. 22). Scotland: Historic Scotland.

Kidd, S. (2010). *Fire Safety Management in Traditional Buildings Part 1*. *Guide for Practitioners*. Edinburgh: Historic Scotland.

Lowden, L., & Hull, T. (2013). Flammability behaviour of wood and a review of the methods for its reduction. *Fire Science Reviews*, *2*(1), 4. http://doi.org/10.1186/2193-0414-2-4

National Fire Protection Association. (2015). *NFPA 914: Code for Fire Protection of Historic Structures*.

National Heritage Act 2005. (2006).

Nurul Hamiruddin Salleh, & A. Ghafar Ahmad. (2009). Fire Safety Management in Heritage Buildings : the Current Scenario in Malaysia. *22nd CIPA Symposium*.

Siemens Switzerland Ltd. (2015). Fire protection in historical buildings and museums.

U.S. Department of Housing and Urban Development. (2007). The Effects of Fire on Structural Systems. Retrieved July 24, 2016, from http://www.ashireporter.org/HomeInspection/Articles/The-Effects-of-Fire-on-Structural-Systems/1154

Urquhart, D. (2007). *Conversion of Traditional Buildings*. *Guide for Practitioners* (Vol. 6). Edinburgh: Historic Scotland. Retrieved from www.historic-scotland.gov.uk/publicationsresults.html

Zainab Arman Ali. (2005). Properties of Malaysian Fired Clay Bricks and Their.