

## A Framework for Fire Safety Management in School Facilities

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**Mohammad A. Hassanain**

Architectural Engineering Department, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia

**Mohammad Aljuhani**

Architectural Engineering Department, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia

**Mohammad B. Hamida**

Department of Management in the Built Environment, Delft University of Technology, Netherlands

**Mohammad H. Salaheldin**

Department of Civil Engineering, Ryerson University, Toronto, Canada

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### ABSTRACT

Schools are high-risk type of facilities in fire emergencies. This requires the implementation of safety measures, which comprise administrative and operational efforts to mitigate the occurrence of fire accidents. The review of literature indicated the lack of practical approaches that can be easily adopted for safety management in school facilities. This paper presents the development and implementation of a generic framework for fire safety management in school facilities. A literature review in the domain of fire safety in schools was performed to comprehend various knowledge areas in this context. A generic framework for fire safety management in school facilities was developed. The framework was implemented in a secondary school, located in the Eastern Province of Saudi Arabia, as a case study, to illustrate its applicability. An action plan was developed to improve the level of fire safety in the school facility, under review. The findings indicated that the framework provides a methodological and systematic approach for assessing the level of fire safety in schools, as well as determine the possible actions for improving the overall safety condition in such facilities. The paper provides a useful focus for practitioners and researchers concerned with fire safety in the educational workplace.

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### Corresponding Author Contact:

mohhas@kfupm.edu.sa

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### 1. Introduction

Schools are communal facilities, designed and operated to provide diverse educational services to students (Parnell et al., 2008). The spatial layout of these educational facilities aims to provide different types of spaces, to support teaching the different theoretical and practical sciences (Masly, 2008; Ariani and Mirdad, 2016; López-Chao et al., 2017). Thus, schools need to

be planned, designed and constructed to provide the required spaces that support the educational process, namely classrooms, laboratories, art rooms, libraries and other support spaces (Neufert and Neufert, 2012). Design professionals strive to provide these different types of spaces to accommodate a large number of users, within a specific time-frame during the day. Health and safety concerns are of prime significance to parents, teachers and school administrators, to ensure the provision of a

safe built-environment, conducive to learning and achievement of desired outcomes (Frerichs et al., 2016; DeVos, 2018; Campos, 2020). Therefore, schools need to implement a comprehensive management and control system to identify and mitigate the occurrence of all possible types of hazards (Lenzi et al., 2017).

Fires constitute a critical type of hazard in school facilities (Jonsson et al., 2016; Bhebe et al., 2019). Statistics indicated that a significant number of fatalities and injuries, around the world, have taken place in schools, due to fire accidents (Lambie et al., 2018). This is attributed to two risk factors, namely the availability of a large number of users in a confined space, and the readily available different types of combustibles, such as wooden furniture, combustible paper-based documents, class decorations, and chemicals used in science laboratories (Hassanain, 2006). Despite the presence of these factors, many schools suffer from poor enforcement of fire safety prevention measures (Moore and Lackney, 1993). This managerial shortcoming has led to catastrophic consequences, in many cases around the world (Danielsson and Sjöstedt-Landen, 2019). In Saudi Arabia, the statistics by the General Directorate of Civil Defense for the year 2020 (Civil Defense, 2020) indicated that a total 248 fire fighting operations were conducted on educational facilities, where the leading causes of these fires ranged from electrical circuit malfunction, pranks, open flames, misuse and handling of flammable liquids, and arson. The estimated losses were approximately SR 416,000 (US \$111,000). Additionally, in the United States, the issued statistics by the National Fire Protection Association for the year 2020 (NFPA, 2020) indicated that a total of 4,760 fire incidents have been reported in educational facilities, where the leading causes of these fires include intentional acts, cooking equipment, playing with heat sources, heating equipment, electrical distribution and lighting equipment, smoking materials and the use of torches, and burners. The estimated losses of these fires were approximately US \$28 million”.

This research aims to respond to this concern through developing and implementing a generic framework for the fire safety management in schools. The developed framework endeavours to identify the office and field processes that need to be conducted by the school administrators and facilities managers, to identify possible sources of hazards, and consequently eliminate these hazards. The developed framework contributes to the body of knowledge, through providing a useful focus for practitioners and researchers concerned with fire safety in the educational workplace.

## 2. Research Methodology

The activities listed below were performed to achieve the objectives of the research:

- Reviewing the literature and standards to comprehend various knowledge areas pertaining to fire safety in schools. Various literature sources have been consulted including the National Fire protection Association (NFPA 101, 2021), the International Fire Code (IFC, 2018) and the Saudi Building Code (SBC, 2018).
- Developing a generic framework for fire safety management in school facilities, to provide a practical guide to administrators and facilities managers, on the processes that

need to be conducted for preventing the risk of fire in schools. The framework comprises eight sequential processes, namely: (1) collect all records on school facilities, (2) identify possible sources of fire in school facilities, (3) identify the fire safety requirements in school facilities, (4) develop a fire safety inspection checklist for the school facilities, (5) review the collected records on school facilities, (6) conduct a fire safety inspection, (7) analyze and report the findings, and (8) recommend improvement action plan.

- Conducting a case study on a secondary school facility, located in the Eastern Province of Saudi Arabia, to demonstrate the implementation of the framework.
- Analyzing and reporting the findings of the case study.
- Developing an action plan of recommendations to improve the level of fire safety in the school facility, under review.

## 3. Literature Review

### 3.1 Nature of Combustibles in School Facilities

Schools are known to accommodate diverse types of combustibles, which can easily ignite and result in the rapid development of fire. These combustibles are present in a high level of concentration, as well as distributed in different locations within the school (Persson and Simonson, 1998). Since educational activities are mostly paper-based, paper is the most commonly found combustible material in schools (Hassanain and Iftikhar, 2015). Large amounts of paper are present in different locations within these facilities (Blomqvist and McNamee, 2009; DHS, 2007). Paper is present in different forms in schools, including curriculum documents, stored archives and display material (Wade et al., 2007). Chemicals used in science laboratories for demonstrating experimental activities are among the combustible materials that are present in large concentrations in schools (Hassanain, 2006). These chemicals are usually present in liquid, gaseous or even solid forms. They can be easily ignited, since their ignitability is directly influenced by the presence of heat sources and Oxygen (Schmanke, 1973). Furnishings are among the combustible elements in schools. School furniture is present in a high concentration in classrooms, laboratories and offices. The furniture is usually manufactured out of wooden, plastic and fabric material, which can ignite easily in the presence of heat sources, and cause a fire that can propagate easily throughout all the facilities (Hadjisophocleous and Chen, 2010).

### 3.2 Causes of Fire Accidents in School Facilities

There are several causes of fire ignition in schools. These include electrical, heating, smoking, and intentional causes (DHS, 2007). In addition, poor safety management and housekeeping practices are critical causes of fires in schools (Bhebe et al., 2019). Electrical fires may occur due to the overloading of the electrical plugs and connections. These conditions lead to the overheating of the electrical wiring, and consequently result in the occurrence of fire (Amuli, 2019). Moreover, the deterioration of the electrical wiring are contributory causes for fires in schools, as deteriorated wiring provides for electrical faults and overheating (Ilori et al., 2019). Further, heat generated from lighting fixtures, equipment and the other appliances in the building facilitates the ignition of the various combustible material, which are usually found in schools (Campbell, 2017). Other human-related causes of fire

accidents in schools include smoking and deliberate start of fires. Smoking in un-supervised locations could result in the development and propagation of fire (Hassanain, 2006). Intentional start of fires, being a serious act of vandalism, is a significant cause of fire in schools (Cooper, 2014). Despite the potential of these causes for school fires, poor safety management and housekeeping practices are also significant causes of fire in schools (McConnell et al., 1996). Such shortcomings can increase the risk potential for the occurrence of fire accidents in schools (Nakitto and Lett, 2010).

### 3.3 High potential Spaces for Fire Occurrence In Schools

School facilities accommodate many spaces that have a high-risk potential for fire ignition. These spaces include laboratories, libraries, classrooms and storage rooms, where they accommodate a high concentration of combustible material (Hadjisophocleous and Chen, 2010). Laboratories are considered to be the most risky spaces in schools, as they accommodate a high concentration of flammable materials, with the presence of heat sources (Schmanke, 1973). Further, lack of safety awareness, while conducting the science experiments and risky students' attitudes in the laboratories increase the risk of fire hazards in these spaces (Ilori et al., 2019). Libraries are among the high-risk spaces that have high potential for fire hazards in schools (DHS, 2007; Wade et al., 2007), since they accommodate high concentrations of paper load (Hadjisophocleous and Chen, 2010; Hassanain and Al-Ashwal, 2004). Classrooms are the mostly used type of space in schools, since they are the core workplace, in which students spend most of their time during the school day (Moore and Lackney, 1993). This density could be a high risk factor during fire emergencies, where students' response might be random and disorganized during these accidents (Bhebhe et al., 2019). Further, these spaces accommodate a high concentration of combustible materials, in terms of paper as well as furnishings (Ilori et al., 2019). Storage rooms are among the spaces of high risk in schools, because they are known to accommodate a large concentration of combustible materials (Hassanain, 2006). In cases of poor enforcement of safety prevention measures in storage rooms, fire accidents could take place easily (Gairín and Castro, 2011).

### 3.4 Fire Prevention Measures in School Facilities

There are a set of office and field processes that need to be implemented, as prevention measures, to ensure the provision of an appropriate level of safety in schools (Kurki et al., 2019). Records on the various aspects of school facilities need to be achieved and predictably updated. These records could comprise all the as-built drawings, as well as the school maintenance and inspection reports (Hassanain, 2006). Moreover, a clear hazard prevention plan for fire safety needs to be developed and implemented. The plan needs to ensure compliance with code requirements, for reducing the risk potential of fire ignition in all spaces of the school. The plan needs to indicate the time, resources and information needed for conducting all office and field processes pertaining to fire safety in the school (Vicario, 2012). The field inspection is an essential process that needs to be periodically implemented for assessing the conditions of fire safety in the school (Amuli, 2019), where a checklist can be utilized to

guide this process (Hassanain, 2006). The checklist would include all the elements that need to be assessed. The finding of the field inspection would provide for identifying the shortcomings, and developing and implementing prevention measures to improve the condition of fire safety (Gairín and Castro, 2011). A continuous enforcement and improvement of the fire safety measures should be always performed in school facilities, in order to maintain the implementation of an active preventive management (Bhebhe et al., 2019; Naranasamy and Abdullah, 2019).

## 4. Development of Framework to Assess Fire Safety in School Facilities

This paper presents a generic, systematic framework for fire safety management in school facilities. The framework provides the set of integrated knowledge areas that administrators and facilities managers would need to identify and assess the legislative requirements for fire prevention in schools (Bhebhe et al., 2019; Hassanain, 2006; Vicario, 2012; Lo, 1999). The developed framework depicts the set of office and field processes that need to be performed to safeguard against fire accidents in schools. The framework also considers the processes pertaining to analyzing and reporting the finding of fire risk assessment, as well as proposing an action plan of recommendations to improve the safety condition in schools (Hassanain and Al-Ashwal, 2004; Kurki et al., 2019; Hamida and Hassanain, 2019). The framework is developed to guide facilities managers on the tasks that need to be conducted to assess the condition of fire safety in any school facility. It comprises eight steps, namely: (1) collect all records on school facilities, (2) identify possible sources of fire in school facilities, (3) identify the fire safety requirements in school facilities, (4) develop a fire safety inspection checklist for the school facilities, (5) review the collected records on school facilities, (6) conduct a fire safety inspection, (7) analyze and report the findings, and (8) recommend improvement action plan. Figure 1 illustrates the developed framework for fire safety management in school facilities. The steps of the framework are described below:

- **Step 1 - Collect All the Records on the School Facilities:** This step is concerned with the collection of several necessary records to facilitate the ongoing processes of fire safety management in school facilities (Naranasamy and Abdullah, 2019). These records include the as-built drawings to analyze space defects that may impact upon the safety of users, as well the reports that document all previously implemented safety and maintenance works (Hassanain and Saif, 2006).
- **Step 2 - Identify the Possible Sources of Fire in Schools:** This step intends to identify the possible sources of fire in school facilities, so that prevention measures to mitigating their potential for causing fire could be developed (Kurki et al., 2019). The review of the relevant literature and standards, in the context of fire safety management in schools, indicated that these sources include smoking, overloaded electrical outlets, faulty wiring, poor housekeeping practices, use of non-standard extension cords,

and excessive storage of combustible materials (Hassanain, 2006).

- **Step 3 - Identify the Fire Safety Requirements in Schools:** This step serves to identify the fire safety requirements of school facilities from the published literature, building codes and standards (Hassanain and Iftikhar, 2015; Vicario, 2012). The purpose is to ensure the provision of these requirements, in an operational condition, due to their key role in mitigating all possible risks in the built-environment (Sanni-Anibire et al., 2020).
- **Step 4 - Develop a Fire Safety Inspection Checklist for Schools:** This step intends to develop an inspection checklist that can be utilized in the investigation and assessment processes of the fire safety requirements in school facilities. The checklist serves to summarize all the requirements in a tabular format (Hassanain et al., 2018). The preparation of the inspection checklist entails sorting all the identified requirements, under their respective categories (IFC, 2018). These categories include means of egress, fire protection systems, electrical systems, fire doors and housekeeping practices (Hamida and Hassanain, 2019). Table 1 presents the development of the fire safety inspection checklist for school facilities.
- **Step 5 - Review the Collected Records on School Facilities:** This is an office activity, which is conducted prior to the field inspection. It focuses on examining the compliance of the school facilities with the fire safety mandates, through reviewing the as-built drawings and previous records of safety and maintenance works (Kurki et al., 2019). The review of the as-built drawings aims at evaluating the adequacy of the means of egress in the original layout of the facility. The as-built drawings serve to indicate the distribution of the fire exits, maximum travel distances for reaching these exits, and the location of the assembly points. The as-built drawings will also serve to investigate the original distribution of all the fire protection systems, namely fire alarms, sprinkler heads, portable extinguishers and smoke detectors (IFC, 2018), in addition to the location of electrical and storage rooms, and fire apparatus access road (Hassanain, 2006). The previous records of safety and maintenance works serve to document the previously conducted fire drills, and performed maintenance and inspection activities of fire safety systems.
- **Step 6 - Conduct a Fire Safety Inspection:** This step intends to conduct a field fire safety inspection to assess the compliance of the school facilities with the identified requirements in the applicable codes and standards (Chang and Liang, 2009). In this process, the accessibility and clarity of all fire exits and assembly areas need to be inspected (Dunlap, 2016). The inspection includes the verification of the actual distribution of all fire protection systems. In this context, the operation mood of these systems needs to be investigated. The inspection would also focus on assessing the quality and condition of all fire doors (IFC, 2018). In

addition, the inspection entails assessing all safety measures in the laboratories, and electrical and storage rooms, in light of the housekeeping practices and the interventions by the end users (Hassanain, 2006). Other targets for inspection include the clarity of the school address, accessibility of the fire hydrant, and availability of the evacuation plans (Vicario, 2012). The developed checklist, as illustrated in Table 1, provides a listing of the fire prevention measures for inspection.

- **Step 7 - Analyze and Report the Findings:** This step focuses on analyzing the outcomes of the document investigation, and the findings of the field inspection (Kurki et al., 2019). The findings will be tabulated and reported, as per the sequence of the available elements in the developed fire safety inspection checklist (Hamida and Hassanain, 2019).
- **Step 8 - Recommend improvement action plan:** This step intends to develop an action plan of recommendations to improve the level of fire safety in the school under review (Dunlap, 2016), based on the findings of the document investigation and field inspection (Lindell, 1997).

## 5. Case Study Building

The selected building for the case study is a secondary school, attended by students of grades 7 to 9. It is located in the Eastern Province of Saudi Arabia. The school is a one-story building, with a gross area of 7,225 m<sup>2</sup>. The school building accommodates 30 classrooms, 13 administrative offices, 4 faculty rooms, 5 science laboratories, 3 exhibition halls, a library and a playground. The school accommodates other spaces designated for support services, namely storage rooms, electrical rooms, mechanical rooms, washrooms and a first aid room. Figure 2 illustrates the floor plan of the case study building.

The layout of the school building is configured as two main compartments. The gross areas of both compartments are 3,300 m<sup>2</sup> and 3,925 m<sup>2</sup>, respectively. Each compartment is designed to have its own circulation corridors, fire exits and spaces for support services. The maximum number of users is 400, including 350 students and 50 staff (teachers, administrative and operations personnel). According to the International Fire Code, the case study building is classified as group “E” occupancy (IFC, 2018), since it is an educational facility, which is used by more than 6 users, who are under the 12th grade of study. The as-built drawings and maintenance reports of the building were collected and reviewed, to investigate the compliance of the school with the fire safety mandates. The review served to identify the details of the performed maintenance and inspection activities of fire safety systems. Subsequently, a walkthrough inspection was conducted throughout the school, in order to assess the provision and up-keep of fire safety requirements. Both activities, document review and walkthrough inspection, were guided by the developed fire safety inspection checklist, as illustrated in Table 1.

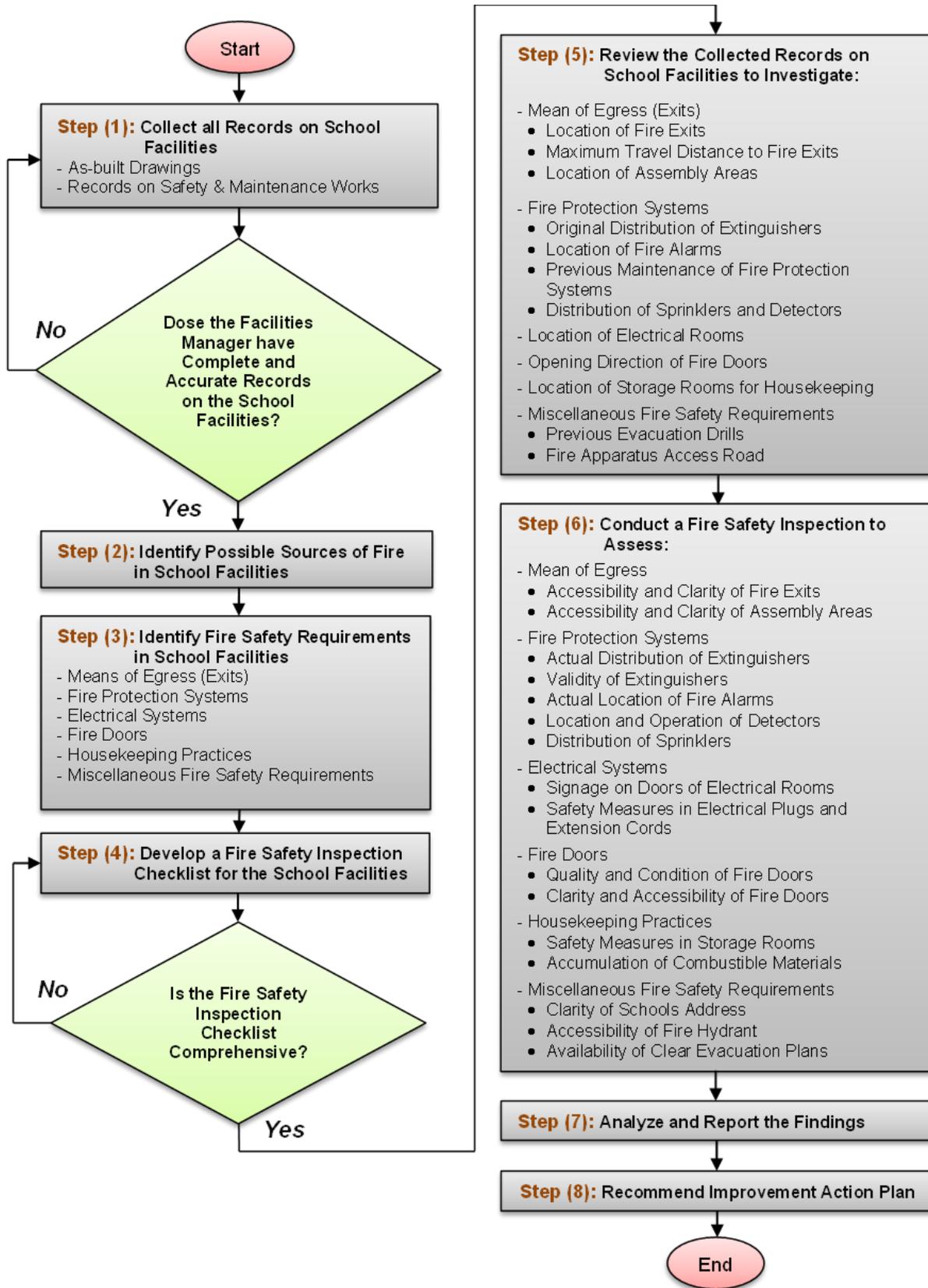


Figure 1. Framework for fire safety management in school facilities

Table 1. School fire safety inspection checklist

I. Means of Egress		Yes	No
1.	Number of fire exits satisfies the occupancy as per the code (not less than 2)	✓	
2.	Travel distance for reaching the fire exits is not more than 22m		✓
3.	Assembly areas are assigned and clearly demonstrated	✓	
4.	Fire exits are continually accessible to the assembly areas	✓	
5.	Exit signs are illuminated and available in the corridors per each 30 m	✓	
6.	Fire exits are illuminated throughout their avenues	✓	
7.	The phrase "PUSH TO EXIT" is attached in the doors of the fire exits	✓	
II. Fire Protection Systems		Yes	No
8.	Fire extinguishers are provided throughout the school, with a travel distance that is not exceeding 22 m from any point in the building	✓	
9.	Fire extinguishers are provided in each laboratory space	✓	
10.	Fire extinguishers are installed in clear locations in the building		✓
11.	Fire extinguishers are renewed annually	✓	
12.	Fire alarm systems are provided throughout the compartments of the building	✓	
13.	Fire alarms are inspected periodically and kept in an operational mood	✓	
14.	Smoke detectors are provided throughout the building spaces	✓	
15.	Smoke detectors are inspected periodically and kept in an operational mood	✓	
16.	Fire sprinkler heads are installed in all spaces of the building	✓	
III. Electrical Systems		Yes	No
17.	Electrical rooms are clearly distinguished in the building by posting the expression "ELECTRICAL ROOM" on their doors	✓	
18.	Power taps are connected directly with permanent receptacles	✓	
19.	Flexible power taps are not be extended through doors, partitions, ceilings or floors	✓	
20.	Electrical plugs are not overloaded throughout the building spaces	✓	
21.	Electrical extension cords are not overloaded by further appliances	✓	
IV. Fire Doors		Yes	No
22.	Fire doors are manufactured of fire rated materials	✓	
23.	Fire doors are not deteriorated or damaged	✓	
24.	The swing of the fire door is in the exit direction	✓	
25.	The capacity of the fire doors is not reduced or obstructed by any physical elements		✓
V. Housekeeping Practices		Yes	No
26.	Storage rooms are identified in the building	✓	
27.	Storage rooms are not accessible to the students	✓	
28.	Combustible chemicals are stored in shelves away from any source of hazard	✓	
29.	Storage rooms of laboratory spaces are not overloaded by combustibles	✓	
VI. Miscellaneous Fire Safety Requirements		Yes	No
30.	Fire drills are conducted and recorded periodically		✓
31.	Accessible fire apparatus road and fire hydrant are provided and clearly assigned		✓
32.	School address number is clearly posted on the school building	✓	
33.	Clear evacuation plans are provided throughout the building corridors	✓	

## 6. Findings and Discussion

Upon reviewing the school documents and conducting the walkthrough inspection throughout the school, the following are the outcomes of the case study:

### 6.1 Means of Egress

The floor plan of the case study building was divided into two compartments, as illustrated in Figure 2. The review of the

collected records of the building indicated that, there are 10 fire exits, which are distributed throughout the floor plan. The first compartment had four fire exits, and the second compartment had six fire exits. An analysis of the maximum travel distance for reaching the fire exit in each compartment was performed, as demonstrated in Figure 2. The analysis revealed that the maximum travel distance for reaching the fire exit in the first compartment was equal to the maximal allowable distance, which is 22 meters. However, the analysis of the maximum travel distance in the second compartment indicated that the travel distance exceeded the allowable distance by 13 meters. The

document review as well as the walkthrough inspection pointed out to the provision of two assembly areas, outside the school building. Further, the walkthrough inspection indicated that all fire exits were clearly marked, illuminated as well as accessible to the assembly areas.

### 6.2 Fire Protection Systems

The review of the building records revealed that the school building was designed and constructed, in compliance with the mandates of the International Fire Code (IFC, 2018). The provided fire protection systems included fire alarms, smoke detectors, sprinkler heads, and portable extinguishers. The walkthrough inspection indicated that the portable extinguishers were provided per each 20 meters in the corridors of both compartments. Further, two to three portable extinguishers were provided in each laboratory. However, some of the portable extinguishers in the laboratories were not installed in their recommended positions, as per the requirements of the fire code. Overall, the walkthrough inspection as well as the review of the building records indicated that all fire extinguishers are renewed

periodically. The walkthrough inspection indicated that the fire alarms, smoke detectors and sprinkler heads were provided and maintained throughout the building in an operative mood.

### 6.3 Electrical Systems

The building records indicated the provision of six electrical rooms. The walkthrough inspection revealed that these electrical rooms were not accessible to the end users, including teachers and students, for safety and security purposes. Further, the phrase “ELECTRICAL ROOM” was posted on the doors of all electrical rooms. Furthermore, the conducted walkthrough inspection indicated that all appliances were directly connected to the plugs, where extension cords were banned throughout the school building. In addition, the electrical plugs were not loaded beyond their capacities. These findings indicated that the enforcement of the safety measures over the electrical systems in the school building was adequate.

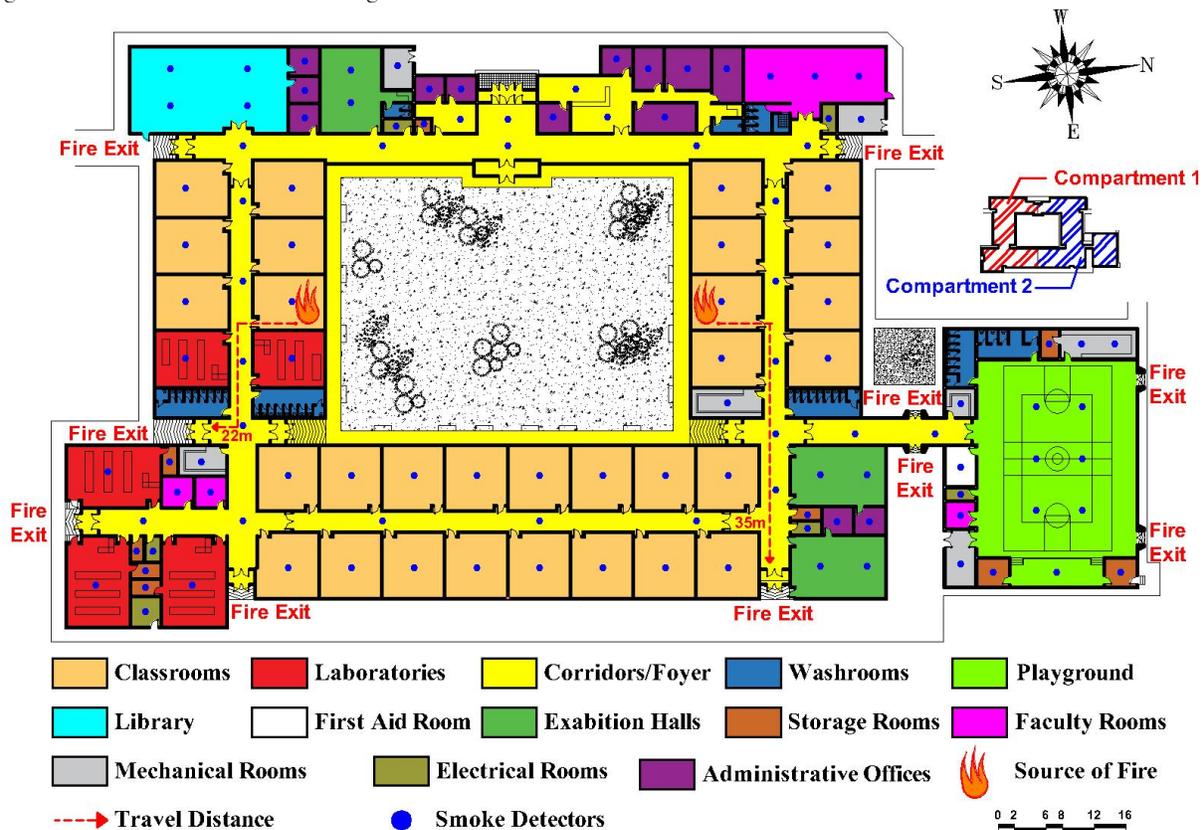


Figure 2. Floor plan of the case study building

### 6.4 Fire Doors

Both, the review of the building records and the walkthrough tour indicated that all fire doors were swinging in the direction of exit, and manufactured out of fire rated materials. The inspection revealed that these fire doors were maintained in an acceptable condition, to perform their function in the case of fire emergencies. Further, the capacities of the fire doors were

maintained as planned, since all physical obstructions were banned throughout the fire exits.

### 6.5 Housekeeping Practices

The building records indicated that there were nine designated storage rooms, throughout the school building. The walkthrough inspection indicated that these storage rooms were

not accessible to the students, especially those provided in the science laboratories. The inspection of the laboratories' storage rooms indicated that adequate housekeeping practices were maintained. Chemicals were safely stored in special shelves in the laboratories. The storage rooms were not over stocked with chemicals.

### 6.6 Miscellaneous Fire Safety Requirements

The review of the building records indicated the absence of previous fire drills. The walkthrough inspection indicated that the apparatus road was blocked by the school gate. Further, it was observed that the fire hydrants were not clearly visible and accessible from the road. On the other hand, the school address number was clearly posted on the school fence. Additionally, clear evacuation plans were sufficiently posted in different locations of the case study building.

## 7. Conclusions and Recommendations

Schools are among the high-risk facilities for fire hazard, due to the presence of various types of combustible materials and sources of fire ignition. These facilities are used by a large number of users within a specific time during the day, which increases the magnitude of risk to these users. Despite the harmful potential of these hazards, active enforcement of fire safety measures could be inadequate in many schools. This may be attributed to the absence of managerial frameworks that can be applied by the school administrators. This paper aimed at presenting the development and implementation of a generic fire safety management framework in school facilities. The development of the framework was guided by the knowledge obtained from the literature review. The framework was implemented in a secondary school building, as a case study, which is located in the Eastern Province of Saudi Arabia. The case study indicated that the framework provided a methodological approach for fire safety management in school facilities. The implementation of the framework served to identify all the shortcomings in the case study building. These shortcomings included: (1) exceeding the allowable travel distance for reaching the fire exit in one compartment, (2) placement of the fire extinguishers in invisible locations at the science laboratories, (3) lack of implementing fire drills on periodic basis, (4) blockage of the apparatus road by the school gate, and (5) placement of the fire hydrants in visible and accessible locations in the street.

The implementation of the framework served to develop an action plan of recommendations, for the purpose of improving the fire safety condition in the case study building. These recommendations include:

- An additional fire exit needs to be provided in the second compartment of the building, to satisfy the code requirements.
- The portable fire extinguishers need to be mounted on the walls in all science laboratories.
- Fire drills need to be planned and conducted periodically.
- Awareness programs about the significance of fire safety in schools should be conducted periodically.
- The apparatus road should be accessible.

- The fire hydrants need to be visible and accessible from the street.

This paper presented the development of a practical guide for administrators and facilities managers, on the processes involved in the fire safety management in school facilities. The paper provides a future research avenue for researchers concerned with fire safety management in the educational workplace.

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