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Evaluation the Degree of Compatibility with Fire Safety international codes in the Islamic University Buildings

تقييم مدى توافق مباني الجامعة الإسلامية مع الأكواد العالمية للأمن والسلامة من الحريق

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أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Evaluation the Degree of Compatibility with Fire Safety international codes in the Islamic University Buildings

تقييم مدى توافق مباني الجامعة الإسلامية مع الأكواد العالمية للأمن والسلامة من الحريق

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نتيجة الحكم على أطروحة ماجستير

بناءً على موافقة شئون البحث العلمي والدراسات العليا بالجامعة الإسلامية بغزة على تشكيل لجنة الحكم على أطروحة الباحثة/ نسرين غالب حسن المصري لنيل درجة الماجستير في كلية *الهندسة* قسم الهندسة المدنية- إدارة المشروعات الهندسية وموضوعها:

تقييم مدى توافق مباني الجامعة الاسلامية مع الأكواد العالمية للأمن والسلامة من الحريق

Evaluation the Degree of Compatibility with Fire Safety International Codes in the Islamic University Buildings

وبعد المناقشة التي تمت اليوم الاثنين 23 رجب 1437هـ، الموافق 2016/04/30م الساعة الواحدة والنصف ظهراً، اجتمعت لجنة الحكم على الأطروحة والمكونة من:

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واللجنة إذ تمنحها هذه الدرجة فإنها توصيها بتقوى الله ولزوم طاعته وأن تسخر علمها في خدمة دينها ووطنها.

والله ولي التوفيق ،،،

نائب الرئيس لشئون البحث العلمي والدراسات العليا

أ.د. عبدالرؤوف علي المناعمة

ABSTRACT

Purpose: The assessment of existing structures is becoming more and more important for social and economic reasons, while most codes deal explicitly only with design situations of new structures. The main objective of this thesis is to evaluate the current status of Islamic University buildings with degree of compatibility to international fire protection codes. In order to reach the main objective, a lot of secondary objectives were taken in consideration. The secondary objectives include identification of the international fire codes used in risk indexes and selection of three codes for fire safety. Then, they have been compared with each other and merged to choose the best fire safety factors.

Design/methodology/approach: A fire safety ranking system is presented to quantify the level of fire safety in new and existing buildings. This risk assessment methodology is used to determine the relative importance ranking of the fire safety factors. Basically, this methodology can be classified into two sequential phases. The first phase consists of selection of most important factors or attributes affecting the fire safety, followed by arrangement of these factors and determination of their relative importance.

Nineteen factors that affect fire safety in educational facilities were selected based on the literature review. They were represented in evaluation framework used to assessment some educational buildings at the Islamic University. Three buildings have been chosen. First, Scientific Laboratory Building , Second Information Technology building in addition to the Educational staff and administration building.

Findings: the degree of computability of the building. 83% for Scientific Laboratory Building, 82.46% for Educational staff and administration building and 82.46% for Information technology building.

Recommendation: Concentrating on making evaluation to construction, vertical opening, automatic sprinkled, travel distance, corridor separation, and fire alarm because they represent 65% of the total effects besides separating the building floors into compartment or zones.

Keywords: Gaza, Islamic university, exiting building, fire safety, fire protection systems.

Abstract in Arabic

الملخص

الغرض : أصبحت عملية تقييم المباني أمر ضروري من الناحية الاقتصادية والاجتماعية ولكن على الرغم من أهمية عملية التقييم للمباني القائمة الا أن معظم الأكواد تهتم بإجراء عملية التقييم على المباني الجديدة فقط لذلك كان الهدف الرئيسي من هذه الدراسة هو تقييم الوضع الراهن للمباني القائمة في الجامعة الإسلامية ومدى توافقها مع عوامل الأمن والسلامة من الحريق ومقارنتها مع المعايير الدولية للوقاية من الحرائق, وللوصول إلى هذه الأهداف الرئيسية تم اتخاذ العديد من الأهداف الثانوية في الاعتبار وهي تتمثل في:دراسة الأكواد الدولية المتعلقة بالحريق ثم اختيارثلاثة أكواد فيما بينها والمقارنة بينهم بالاضافة الى عمل دمج بين الأكواد المختارة للوصول الى أفضل عوامل لتقييم الأمن والسلامة من الحريق.

منهجية البحث :تم استخدام نظام تقييم قدرة أنظمة الحماية من الحريق لتحديد مستوى السلامة من الحريق في المباني الجديدة والقائمة وهذه الطريقة استخدمت للوقوف على الأهمية النسبية لتقييم مواصفات أنظمة الحماية من الحريق وهذه الطريقة يتم تقسيمها الى مرحلتين اساسيتين :المرحلة الأولى تتضمن أكثر المواصفات أهمية والتي تلعب دورا فعالا في تحديد قدرة الأنظمة للحماية من الحريق,بعد ذلك يتم ترتيب هذه المواصفات تنازليا من الأعلى أهمية الى الأدنى ومن ثم تحديد الأهمية النسبية لها.

تم اختيار تسعة عشر عاملا بناءً على تأثيرهم على السلامة من الحريق في المنشآت التعليمية اعتمادا على الأبحاث النظرية السابقة في هذا المجال وممثلة في النموذج الذي تم استخدامه لتقييم بعض المباني التعليمية في الجامعة الإسلامية.

تم اختبار ثلاثة مباني كممثل عن مباني الجامعة (مبنى المختبرات العلمية كنموذج لأنه يحتوي على مختبرات ومخازن للمواد الكيميائية، وقد تم اختيار مبنى تكنولوجيا المعلومات باعتباره نموذج لمبنى تدريسي في الجامعة بالإضافة إلى مبنى الإدارة كمثال على المباني الإدارية في الجامعة).

النتائج: تم التوصل الى أن درجة التوافق للمباني في الجامعة الإسلامية تقدر على النجو التالي: 83% لمبنى المختبرات العلمية و82.46% لمبنى الإدارة و82.46% لمبنى تكنولوجيا المعلومات.

التوصيات: ومن خلال نتائج هذه الدراسة، فإننا نوصي بما يلي :التأكد بأن النظام الإنشائي للمبنى قادر على مقاومة الحريق,التركيز على عمل تقييم لمقاومة الانشاء والفتحات الرأسية ورشاشات المياه التلقائية ومسافات الإرتحال وفصل جدران الممرات وأجهزة الإنذار عن الحريق وذلك لأنهم يمثلوا 65% من إجمالي التأثير ,بالإضافة الى السيطرة على الحريق واحتوائه والحد من انتشاره وذلك من خلال : فصل طوابق المبنى نطاقات حريق من أجل منع انتشار الحريق، تركيب نظام إنذار الحريق التلقائي ، تزويد الممرات بالإضاءة في حالات الطوارئ وفي حالة انقطاع الطاقة الكهربائية..

كلمات مفتاحية: غزة ، الجامعة الإسلامية ، المباني القائمة ،الأمن والسلامة من الحريق ،أنظمة الحماية من الحريق.

Epigraph Page

بسم الله الرحمن الرحيم

(الرحمن، علم القرآن ، خلق الإنسان ،علمه البيان)

(الرحمن 1-4)

Dedication

To the soul that has lived in my own soul and has given its life again; to the name That is deeply connected with my name and gives me the real conception of happiness, to my soulmate, **Khaled**.

To the heart that beats to give life to my heart, to the woman who cuddled me and brought me up embracing my pains, to my beloved **mother**

To the source of eternal giving and granting, to the person whose hair became gray and whose skin was wrinkled to raise me up, to my **father**

To the couple who are not my actual parents but their blood is in my children blood, to **Khaled's parents**

To the little hands, to the little laughter, to the meaning of life, to my children

To the bodies and souls that defend our land by victimizing themselves, to the souls of our **martyrs**

To all the people who supported me in all times, to my **sister**, **brothers and friends**

To all of you, I dedicate the extract of my diligent and endeavour since you are the ones who should be dedicated

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List of Abbreviations

NFPA	National Fire Protection Association
ICC	International Code Council
U.L.	Underwriter's Laboratories
IUG	Islamic University of Gaza
SFPE	The Society of Fire Protection Engineers
AHJ	Authority Having Jurisdiction
BOCA	Building Officials Code Administrators International
BCNYC	Building current New York State Code
IBC	International Building Code
HVAC	Heating,ventalaition and conditioning system
CFD	Chicago Fire Department
LSE	Life Safety Evaluation

Chapter 1
Introduction

This chapter gives an introductory overview of the study which has been made beside reasons for choosing research, research hypothesis underlying the research building structure and identify the problem, the main objective, secondary goals and the importance of research.

1.1 Background

The fast advances in modern civilization have made the humankind more dependent on using buildings and infrastructure, increasing by that the probability of exposure to various risks and hazards. This has emphasized the importance of maintaining high safety standards in buildings to prevent or reduce casualties, injuries and losses that may occur due to incidents. One of the main threats to human safety is fires. Every year significant life loss and tremendous martial damage occur due to fires happening around the world.

According to History of Fire and Fire Codes, fire has been a vital part of humankind's existence and survival since its inception. Years of experience, incidents, tragedies, and education has helped evolve how people handle, control, prevent, contain and provide safe conditions with fire. Agencies such as the National Fire Protection Association (NFPA), the International Code Council (ICC), and Underwriter's Laboratories (U.L.), as well as many others have been monumental in the development of codes and regulations that limit the devastating effect that fire creates. Throughout history there have been building regulations for preventing fire and restricting its spread. Over the years, these regulations have evolved into the codes and standards developed by committees concerned with safety. (Cote, Arthur and et al., 2008).

1.2 Problem Statement:

For a large part of the existing buildings and infrastructure the design life has been reached or will be reached in the near future. These structures need to be reassessed in order to investigate whether the safety requirements are met. So the assessment of existing structures is becoming important for social and economic reasons, though most codes deal explicitly only with design situations of new structures. In general, the safety assessment of an existing structure differs from that of a new one in a number of aspects the main differences are: Increasing safety levels usually involves more costs for an existing structure than for structures that are still in the design phase, the remaining lifetime of an existing building is often less than the standard reference period of 50 or 100 years that applies to new structures, (Steenburgen, Raphael and et al., 2010).

The research problem is the difficulty of reaching the optimal method to select the safety factors that affect measuring the level of compatibility of existing buildings in the Islamic University of Gaza corresponding to international standard fire safety codes, where the fire was erupted in its building as a result two wars which represented by: December 2008 war, the university was bombed in six air strikes by the Israeli Air Force as part of the Gaza War also in August 2014, due to the 2014 Israel–Gaza conflict, Israeli forces have destroyed the Islamic University of Gaza by firing multiple missiles into the building and A large part of the university has been destroyed. Many buildings has been renovated and reconstructed after war, so it is necessary to re-assess the situation of the university buildings and its ability to fire resistance.

1.3 Research aim, objectives and hypotheses

➢ **Aim:**

The aim of this research is creating an evaluation framework to measure the compatibility of the existing buildings in Islamic university of Gaza with the requirements of international fire protection codes.

➢ **Research objectives**

- To identify the international fire safety codes which used in risk indexes and Select codes to study and compare between them.
- To Study the alternative methods which make the existing building agree with international codes.
- To Analysis and Identify the factors that leading to reduce the compatibility of building with fire protection standers.
- To Applicate an evaluation framework to some educational buildings in the Islamic University- Gaza and determine the extent of the compatibility of the proposed check list through the application on the buildings.

1.4 Research hypothesis:

Research hypothesis revolves around the degree of compatibility of Islamic University buildings with standard fire codes.

H0: the degree of compatibility of Islamic University buildings $\geq$ 50 %.

H1: the degree of compatibility of Islamic University buildings < 50 %.

1.5 Justification:

On one hand, fire protection is the study and practice of mitigating the unwanted effects of potentially destructive fires.

It involves the study of the behavior, compartmentalization, suppression and investigation of fire and its related emergencies, as well as the research and development, production, testing and application of mitigating systems. Buildings must be constructed in accordance with the version of the building code that is in effect when an application for a building permit is made.

Building inspectors check on compliance of a building under construction with the building code. Once construction is complete, a building must be maintained in accordance with the current fire code, which is enforced by the fire prevention officers of a local fire department. To provide an adequate level of fire safety in buildings and other structures consideration needs to be given to a whole range of connected design and use aspects, (National Fire Protection Association, 2011).

Now a day fire prevention is a function of many fire departments. The goal of fire prevention is to educate the public to take precautions to prevent potentially harmful fires, and be educated about surviving them. It is a proactive method of reducing emergencies and the damage caused by them, http://www.slideshare.net/kaverinarang/fire-protection .

An important aspect of fire prevention is concerned with facility executives, which can improve the fire safety of buildings by understanding both how and why individual systems work, and how and why systems work together. “The most important thing to help improve fire safety is to understand how all the systems in building work: The alarms, the means of egress and passive building systems like fire doors and walls and dampers”, (Jelenewicz and Windle, 2006).

If a fire does occur it is essential that occupants become aware of it as soon as possible and have awareness of the actions they need to take to move to a place of safety. “What if the fire is below? What if they need to evacuate up? Any time you change security measures, you need to see how it affects life safety," (Jelenewicz and Windle, 2006). Also using the contingency plan lead to cover events that seem unlikely but are still possible, ideally if a fire starting in one part of a building can be contained and the hazard becomes controllable, "Emergency contingency planning covers unforeseen circumstances, such as flood or wind or fire," (Domagala and Windle, 2006). "Or it can be as simple as a key piece of equipment breaking down. You need contingency planning so when something happens you can do the right thing at the right time."

On another hand Evaluating and upgrading existing structures becomes more and more important, these structures need to be reassessed in order to find out whether the safety requirements are met. Not only for new structures but also for the existing stock Eurocodes are starting point for the assessment of the safety.Finally, by making a study for fire safety protection and making evaluation for the buildings inside and out, we can know what construction components provide for fire and life safety and what components hinder it? What are the limitations of these systems? Then we can make sure that the building is designed for all the hazards it faces, and can deal with the any hazards change, (Steenbergen, Raphael and et al., 2010).

1.6 Scope and boundary of research

This study will focus only on three buildings at the Islamic University of Gaza to evaluate the current status of the buildings and determine the degree of compliance with the proposed framework for fire protection.

1.7 Summary of the study methodology

To fulfill research objectives the following tasks were done:

- It was initiated to identify the problem, establish aim, objectives, hypothesis, and develop research plan/strategy by deciding on the research approach and deciding on the research technique.
- Intensive literature review was conducted to review the previous studies made in this field. It was performed by reading and note-taking from different sources which was helped in having better understanding of the issue and a wider view by making use of the experience of previous researchers from different communities.
- Based on the extensive literature reviews, a check list was designed, a checklist is a type of informational job aid used to reduce failure by compensating for potential

limits of human memory and attention. It helps to ensure consistency and completeness in carrying out a task.

- Analytical study of the proposed situation (application security and safety codes in the building):
  - Stage one: The researcher has an analytical study of the proposed status guaranty the application of all the design parameters which ensure the security and safety factors within the buildings which have been studied in the theoretical literature reviews.
  - Stage two: Then, an assessment of the compatibility of the fire safety codes with three main buildings in the Islamic University have done.
- Recommendations were suggested through the conclusion of the research.

1.8 Organization of the study

This research study was organized into the following five chapters:

Chapter 1 (Introduction): In this chapter, an attempt at giving an introductory overview of the study has been made. Reasons for choosing research and research hypothesis underlying the research building structure and identify the problem, the main objective, secondary goals and the importance of research.

Chapter 2 (Literature review): Chapter 2 discussed the concept fire safety engineering and the risks that threaten the facilities also it explained the fire safety management and their factors which are affected by it, besides the study of fire codes and the analysis of some fire risk indexes models to conclude the factors that will be used in evaluating the buildings.

Chapter 3 (Research methodology): Chapter 3 included the detailed research methodology, fire safety factors evaluation check list design, and the various quantitative analytical methods applied were simply described.

Chapter 4 (Results and discussions): The findings are analyzed and discussed in chapter four, where results were presented, discussed and linked to the previous studies.

Chapter 5 (Conclusion and recommendations): According to the final results, conclusion and recommendations of the research is Discussed in chapter five.

References

Chapter 2

Literature Review

The literature review is aimed to establish a theoretical understanding of the concept of fire safety engineering and the risks that threaten the facilities also it explained the fire safety management and their factors which are affected by it, besides the study of fire codes and the analysis of some fire risk indexes models to conclude the factors that will be used in evaluating the buildings.

2.1 Understanding of Fire Theory Concept

Fire or combustion is the process of burning. It is a chemical reaction initiated by presence of heat energy in which a substance combines with oxygen in the air and the process is accompanied by emission of energy in the form of heat, light and sound. It is known that the continuation of fire needs continuous supply of heat, fuel and oxygen in the buildings. Therefore we must concentrate on these three factors. The supply of oxygen is common and continuous from the atmosphere; Fire Accident is an unplanned or unexpected event in the building environment. The second factor of fire causes, or sources of ignition in buildings are of two types, the first one is human error type fire, and the second one is appliances type fire. The human error type's fires are children playing with matches, rubbish burning, smoking and intentional fire. The appliances types' fires are electrical appliances, gas appliances, other fuel appliances, acetylene and liquefied gas, solid fuel appliances and other specified causes fire. The survey and study reveals that human error types fire are the main causes of fire in the buildings. (Lennon, Tom, et al., 2003).

The modern materialized society all activities depends on fuel consumption and energy utilization based, most of the energy utilization processes are fire based. This fire based activities has become the main source of fire accident in buildings for most of the time. The third factor of fuel supply based on the nature, quantity and the arrangement of fire load or the combustible materials, which is stored in side of the building, (Voelkert, 2009).

2.1.1 Basic elements of fire

Four elements must be present in order for fire to exist. These elements are heat, fuel, oxygen and chain reaction. While not everything is known about the combustion process, it is generally accepted that fire is a chemical reaction. This reaction is dependent upon a material rapidly oxidizing, or uniting with oxygen so rapidly that it produces heat and flame. Until the advent of newer fire extinguishing agents, fire was thought of as a triangle with the three sides represented by heat, fuel, and oxygen.

If any one of the three sides were to be taken away, the fire would cease to exist. Studies of modern fire extinguishing agents have revealed a fourth element - a self-propagating chain reaction in the combustion process. As a result, the basic elements of fire are represented by the fire tetrahedron: heat, fuel, oxygen and chain reaction, (Voelkert, 2009).

According to (The Occupational Safety and Health Administration (OSHA)) These 3 elements make up what is commonly called the **"Fire Triangle":**

- **Oxygen:** Oxygen is usually readily available. It makes up 21% of the air we breathe.
- **Fuel:** Solid combustibles like paper, furniture, clothing and plastics. Flammable liquids like petrol, oils, kerosene, paints, solvents and cooking oils / fats, Flammable gases like natural gas, LPG, acetylene.
- **Heat:** The heat given off by the oxidation reaction sustains the fire once it is established. But first, a heat source is required to produce ignition sources include: Heating and cooking appliances, Faulty electrical equipment, Cigarettes, lighters and matches, Friction.

The theory of fire extinguishment is based on removing any one or more of the four elements in the fire tetrahedron to suppress the fire.

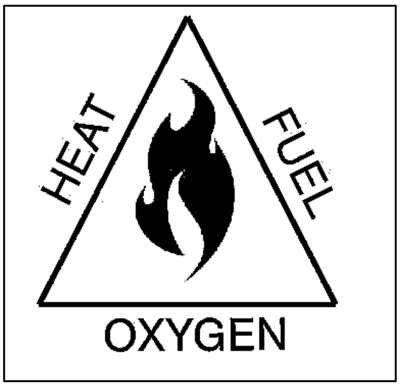

Fig (2.1): Fire Tetrahedron, *(http://fire-training.com.au/)*

Response to any fire scenario, regardless of the form of the response, should have these three basic priorities listed by importance:

a. Life Safety and Personal Protection: The most important thing to accomplish in any fire incident is to protect life and avoid injury, Property, product, processes and material can be replaced and rebuilt. Human life and health is most precious and cannot be replaced. If nothing else is accomplished in a fire incident other than the complete safety of all persons involved, then the first and most important goal in a response to fire has been accomplished.

b. Incident Stabilization: Once the first priority has been accomplished, the second goal is to stabilize the incident – keep it from growing or getting worse. By stabilizing the incident and not allowing it to change, grow in intensity or grow in size, the incident cannot threaten more lives and property, even if the area or property involved becomes a total loss.

c. Property conservation**:** Only after item (a) and item (b) have been established, the focus may turn to extinguishing the fire quickly with the least amount of damage to the property involved. The role of portable extinguishers and pre-engineered systems in response to a fire incident has the same priorities listed above. Together with a fire plan, alarm notification, evacuation, quick and safe response, portable extinguishers and pre-engineered systems may be key factors in the outcome of any fire incident, (http://www.mfs.sa.gov.au/site/community_safety/theories_of_fire_fire_extinguishment.jsp).

2.1.2 Fire extinguishment:

According to (Voelkert, 2009) Fire extinguishment needs many steps:

a. Removing the heat

In order to remove the heat, something must be applied to the fire to absorb the heat or act as a heat exchanger. Water is not the only agent used to accomplish this, but it is the most common.

b. Removing the fuel

Under many circumstances, it is not practical to attempt to remove the fuel from the fire. When dealing with flammable liquid fires, valves can be shut off and storage vessels pumped to safe areas to help eliminate the supply of fuel to the fire. Flammable gas fires are completely extinguished by shutting off the fuel supply.

c. Remove the oxygen

Oxygen as it exists in our atmosphere (21%) is sufficient to support combustion in most fire situations. Removal of the air or oxygen can be accomplished by separating it from the fuel source or by displacing it with an inert gas. Examples of separation would be foam on a flammable liquid fire, a wet blanket on a trash fire, or a tight fitting lid on a skillet fire. Agents such as CO_2, nitrogen, and steam are used to displace the oxygen.

d. Interrupt the chain reaction

Modern extinguishing agents, such as dry chemical and halons, have proven to be effective on various fires even though these agents do not remove heat, fuel, or oxygen. Dry chemical and halogenated agents are thought to suspend or bond with "free radicals" that are created in the combustion process and thus prevent them from continuing the chain reaction.

e. Combustion

Generally speaking, for any material to burn, it must be heated to the point that it releases vapors that may be ignited. The temperature at which a material (solid, liquid or gas) will be capable of being ignited varies greatly from one material to another. Another factor to be considered, particularly in the case of solids, is the physical size and shape of the material. The more surface area subjected to heat and resulting vaporization, the more easily ignitable it becomes. As an example it is very difficult to light a large log in a fire place with a single match, but very small pieces of wood, having more combined surface area exposed to heat, can be easily ignited.

f. Heat transfer

Heat may be transferred from one object to another or one material to another by any one of three methods.

- Conductive heat - the transfer of heat through a solid as an example, a pan on an electric burner is heated by direct contact with the hot burner.
- Convective heat - transfer of heat through a circulating fluid or gas (such as air), as an example, the hot coils of a heater will warm the air that contacts it causing the air to rise and circulate and then heating (or warming) other objects in the room.

- Radiant heat - transfer of heat without direct contact or heating a fluid or air between the objects as an example, the sun heats the earth without direct contact with the earth and without heating the space between the earth and the sun.

2.1.3 Classification of Fires

a) Class A: Fires involving carbonaceous solids, such as wood, cloth, paper, rubber and plastics. Class A does not include flammable metals (see Class D).
b) Class B: Fires involving flammable and combustible liquids.
c) Class C: Fires involving combustible gases.
d) Class D: Fires involving certain combustible metals, including potassium, sodium, & magnesium. Specialist advice should be sought.
e) Class E: Electrical Hazards.
f) Class F: Fires involving cooking oils and fats, (http://www.mfs.sa.gov.au/site/community_safety/theories_of_fire_fire_extinguishment.jsp).

2.1.4 Causes and prevention of fire:

2.1.4.1 Accidental fires

The term accidental fire refers to all fires other than those which have been deliberately or maliciously started. There are a wide range of causes of fires within the workplace. These will to a certain extent reflect the use to which the workplace is put. It is also useful to consider causes of fires in vehicles as in many organizations a workplace may be a vehicle, such as in the case of a long distance lorry driver working for a haulage company, Using the current statistics available it can be seen that the common causes of major accidental fires in the workplace fall under the broad headings of:

- Electrical appliances and installations.
- Cookers, associated cooking equipment and installations.
- Naked lights and flames.
- Heaters and heating systems.
- Chemical and LPG (hazardous materials).
- Smokers and smokers' materials.
- Waste and waste management systems.
- Other significant causes, (Furness and Martin, 2008).

2.1.4.2 Causes of fire relating to construction and maintenance

Many of the causes of fire detailed above can relate to work involving construction and maintenance operations.

Equally the preventive measures that may be adopted to minimize the risk of a fire occurring in construction and maintenance operations may be equally valid across many sectors of industry. A large proportion of fires started within the construction sector fall under the following key headings:

- Arson
- Electrical
- Hot work
- Flammable and combustible substances as arson is dealt with in a section on its own within this section the first area to be addressed will be electrical causes of fire, (Furness and Martin, 2008).

2.1.5 Strategies to Safeguard Occupants Exposed to a Fire

Occupant fire safety requires more than just a fire alarm bell and exit stairs to the outside. To be reliable and effective, the system must include:

- means to alert occupants and make them promptly take appropriate action,
- means to communicate with them in a meaningful manner,
- means to protect occupants who cannot evacuate at the same speed or who may require assistance,
- exits that are sufficiently large and as smoke free as possible, and
- Means to defend certain occupants in place should that strategy be used, (Richardson, 2002).

2.2 Safety and Fire Protection Engineering

2.2.1 Fire safety engineering

Before setting the ground work for the complete subject of fire safety engineering and its influence on the overall planning, design and construction of building structures, it is necessary to attempt to define what is meant by fire safety engineering. There is as yet no absolute definition, although the following may be found acceptable:

Fire safety engineering can be defined as the application of scientific and engineering principles to the effects of fire in order to reduce the loss of life and damage to property by quantifying the risks and hazards involved and provide an optimal solution to the application of preventive or protective measures. The concepts of fire safety engineering may be applied to any situation where fire is a potential hazard, *http://www.kuleuven.be*

The largest area of risk from fire damage is low-rise domestic housing which generally does not require sophisticated design methods as it is not a structural collapse which tends to be the problem, but the spread of smoke and toxic gases, and the resultant inability of the occupants to escape, (Malhotra, 1987).

Fire protection engineering is the application of science and engineering principles to protect people and their environment from destructive fire and includes: analysis of fire hazards, mitigation of fire damage by proper design, construction, arrangement, and use of buildings, materials, structures, industrial processes, and transportation systems, the design, installation and maintenance of fire detection and suppression and communication systems, post/fire investigation and analysis, (Groningen, 2006).

2.2.1.1 Design Concerns in Elements of Fire Safety Engineering

Elements within the discipline of fire safety engineering can be readily identified which relate both to life and property safety. These areas are not mutually exclusive as an action which increases life safety may also increase property safety. The key areas can be identified as follows: (Purkiss, 2007):

a. Control of ignition

This can be done by controlling the flammability of materials within the structure, by maintenance of the structure fabric and finishes, or by fire safety management in, say, imposing a ban on smoking or naked flames.

b. Control of means of escape

This can be forced either by the imposition of statutory requirements on provision of suitable escape facilities or by the education of occupants.

c. Detection

This covers the installation of methods whereby the fire may be detected, preferably at the earliest possible stage.

d. Control of the spread of fire

Here, concern is the spread of the fire, either within the building or to adjacent properties. This control may either be effected by in-built features (such as compartmentation) or control of distance between buildings or by mechanical means (such as venting, smoke screens or sprinklers).

e. Prevention of structure collapse

This covers the imposition of load-bearing capacity and integrity on the structure as a whole or in part during a fire. Each of these can now be considered in greater depth.

2.2.1.2 Fire protection (preventive and protective measures)

Fire protection of buildings, the preventive and protective measures that will protect persons in the event of a fire, fall into two broad categories referred as passive and active protection. (Muckett and Furness, 2007):

a) Passive fire protection

Passive fire protection is based on the principle of containment; the compartments of the building are constructed so that if a fire should occur, it will be restricted to one area. For example, fire doors should prevent the spread of smoke and flames from lobbies, stairwells and lift shafts, another example of passive fire protection is the design of escape routes, which should not incorporate combustible wall, ceiling or floor linings. Fire dampers should be installed in ducts where they pass through compartment walls, and holes in such walls around cables and other services should be fire stopped.

Doors and shutters in compartment walls should be able to withstand the effects of fire for the same period of time as the walls themselves.

b) Active fire protection

Active fire protection systems may detect or extinguish a fire, with a water sprinkler or inert gas flooding installation performing both functions. An automatic fire detection installation will detect heat or combustion products of a fire in its early stages and raise the alarm. Such systems should be monitored remotely when the building is not occupied to allow the fi re brigade to be summoned without delay, thus reducing the damage. A sprinkler installation will release water from the heads nearest the flames with flow switches raising the alarm in a similar way to a conventional detection system. Active systems also include those that assist in compartmenting the fire such as fire door release mechanisms, fire shutters and mechanical damping systems. In addition other systems may be actively used for smoke extraction, neither passive nor active fire protection measures can be installed and then forgotten; they require regular inspection and maintenance. Service contracts should be established with accredited contractors for installed equipment but the fire safety manager should also ensure that regular inspections are made of escape routes, fire doors and housekeeping standards and that suitable records of such inspections are kept.

2.2.2 Consideration that prevent compliance with a performance requirement:

• Compliance too costly (cannot be considered equivalent to deemed-to-satisfy, unless tested to deemed-to-satisfy and testing is too expensive).

• Building Appeals Board or other approval body has previously approved a similar application.

• Method proposed has been used before.

• Supporting argument of compliance with other regulatory required items (stair has handrail, therefore riser height can be increased).

• Regulation not required in other States or Territories.

• Approval by expert judgement when Building Appeals Board/council or other approval body might not approve (access for people with disabilities, thermal insulation).

• Appropriate maintenance specified for the essential safety measures that relate to the alternative solution, (Hutchins and Murdy, et al., 2008).

2.3 Fire Protection Systems

The National Fire Protection Association (NFPA) published fire codes that architects, engineers, and building officials use every day. However, only the most common NFPA codes are well known. Fire protection is a very complex subject, and so are all the codes that address it.

Even in its better known prescriptive mode, fire protection engineering is often misunderstood or misapplied. Adding performance- based design has made fire protection all the more challenging to grasp. In 2000, The Society of Fire Protection

Engineers (SFPE) and NFPA jointly published the benchmark for understanding performance-based fire protection design: The SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings. SFPE has also published many articles on performance-based fire protection design in Fire Protection Engineering magazine. These sources are indispensable for understanding performance-based fire protection design, (Hutchins, Murdy and et al., 2008).

2.3.1 Functions of Fire Protection Systems

2.3.1.1 Preventing and Protecting Against Fire

Having an adequate level of protection against fire is important in meeting facility goals. However, preventing as many fires as possible is just as important, if not more so. Preventing fires is accomplished through a facility's fire prevention programs.

The fire prevention measures based on engineered systems must be implemented in the project design stage. In this respect, fire prevention and fire protection measures closely overlap. Sometimes no distinction is drawn between them. Engineered fire prevention measures can include"

- Separation distances between hazards and exposures;
- Combustion safeguards on fuel fired equipment;
- Systems for liquid containment, drainage or run off;
- Provisions for bonding and grounding to control static;
- Explosion-proof electrical and heating equipment in hazardous areas; and
- Process safety control systems, (Lataille, 2003).

2.3.1.2 Reasons for Installing Fire Protection Systems

Fire protection systems can be installed for many different reasons. Most often, fire protection systems are expected to meet a combination of purposes. Designing a fire protection system requires knowing the purposes it must serve.

Requirements to install fire protection systems usually stem from mandatory codes, but the systems installed to meet these codes will not necessarily meet all the owner's goals unless this is most fire protection systems are installed for several of the above reasons. One of the challenges of designing fire protection systems is to achieve several purposes as effectively as possible, another challenge is to anticipate likely future occupancy changes in the original fire protection design basis, (Jones, 2015).

2.3.1.3 Protecting Assets

According to (Lataille, 2003), Asset protection is a very important function of fire protection systems. Assets that fire protection systems can be intended to protect include: Property: Conventional sprinkler systems protect buildings. In rack sprinkler systems keep fire from spreading through rack storage. Sprinkler systems limit property damage, but they cannot totally eliminate it. Directional water spray systems protect special hazards, like oil-filled transformers. Protecting a transformer does not save it from damage, but keeps it from damaging nearby buildings and structures, including other transformers.

a. Life: Controlling fire sufficiently to protect a building can also keep fire from harming people. Since people are also harmed by the smoke fire generates, smoke control systems are used to allow time for people to evacuate before smoke concentrations reach dangerous levels.

b. The basis for protecting life is in ensuring fast egress from buildings. This involves:

- Provision of adequate exit capacity;
- Maximum allowed distances for egress travel paths;
- Minimum allowed widths of egress travel paths;
- Reliably illuminated and marked exits;
- Maximum allowed length of dead ends; and
- Protected exits to public ways.

c. Mission continuity: After a fire, lost property can be replaced and damaged buildings can be repaired. But business lost to competitors while operations are down cannot always be recovered. Competitive industries sometimes provide more fire protection than required for protection of life and property to decrease possible downtime that may occur after a fire.

d. Environment: Risk management principles often dictate protecting lives and high value property. Unoccupied buildings of relatively low value may not normally require protection. However, this changes if a fire in such buildings could have an adverse effect on the environment. This could be due to the contents of the building or to its location near a waterway or watershed area.

2.3.2 Prescriptive Fire Protection Design

2.3.2.1 Desirability of Prescriptive Design

Despite the advent of performance-based design, much fire protection design is still prescriptive. An important advantage of prescriptive design is that it requires little analysis, and therefore (presumably) little time or knowledge to apply. Implementing prescriptive design is very much like following a recipe. Another advantage of prescriptive design is that it can cover a broad range of conditions. This is appropriate given the diversity of facilities being protected and the wide-ranging properties of fire. Through its inherent safety factors, prescriptive design can sometimes be more flexible than custom performance-based design. Many other factors have kept prescriptive design in common use. Prescriptive design is a "known." It is what has worked in the past. It matches other designs at existing facilities, (Rothenberger, Marcus, and et al., 2012).

Authority Having Jurisdiction (AHJ), are comfortable with prescriptive design and readily accept it. One disadvantage of prescriptive design is that the safety factors can be so high as to render the design unduly expensive. A second disadvantage is that a prescriptive design might not result in the most effective way of protecting a particular facility. It neither accommodates a facility's specialized needs nor coordinates with other systems in the facility. The fire protection engineer's struggle with the efficacy of prescriptive design has helped support the trend toward performance-based design. Prescriptive design is desirable so long as the advantages outweigh the disadvantages. For many facilities, prescriptive design can be fast and inexpensive. Its inherent safety factors can also provide sufficient flexibility for future changes. This type of design still serves light manufacturing facilities very well.

The more specialized the building, and the more its architecture departs from assumed norms, the higher the chance that performance- based design can better serve that building's fire protection needs, (Lataille, 2003).

2.3.2.2 Prescriptive Codes

Most prescriptive fire protection design is dictated through prescriptive codes. In the U.S., the prescriptive codes most often used in fire protection are the National Fire Protection Association (NFPA) codes and regional building codes. The regional building codes adopt many NFPA codes by reference. Some other countries also adopt NFPA codes, and some have their own comparable codes.

Prescriptive codes are both easy to apply and easy to misapply. The codes are straightforward, but the situations to which they apply might not be. In addition, several codes may apply simultaneously .Using some codes and leaving others out might compromise a design, Table 2.1 shows the main advantages and dis advantages for the prescriptive codes.

Probably the most familiar code that prescribes fire protection design is NFPA 13, Standard for the Installation of Sprinkler Systems. All major U.S. building and fire codes adopt NFPA 13 by reference. Just about everyone involved in building projects is familiar with this code, (travares, 2008).

2.3.2.3 Inherent Risk

In contrast to using performance-based design, using prescriptive design does not require selecting an acceptable level of risk. For this and other reasons, many people believe that using prescriptive design totally eliminates any fire risk. This is not true. All prescriptive designs encompass an unstated, and usually uncertain, level of risk. All prescriptive codes encompass this risk within the code requirements, (Hocquet, 2013).

Quantifying the risk in prescriptive designs is difficult, because applying the same fire protection recipe to different facilities results in as many levels of risk. Paradoxically, the risk inherent in prescriptive design can be estimated by using performance-based analysis. Having an idea of the level of risk involved in a prescriptive design is very important. For one thing, it allays the misperception of lack of risk. Secondly, it provides a base for valid comparison to performance-based alternatives that may be considered, Table 2.2 shows the main advantages and disadvantages of the performance code, (travares, 2008).

Prescriptive codes are still being written. Understanding the level of risk incorporated during code-writing could help make these codes more effective. For a discussion of the issue of risk in codes, see "The Importance of Risk Perceptions in Building and Fire Safety Codes," Fire Protection engineering magazine, (Wolski, 2001).

Understanding the risk inherent in prescriptive design also paves the way for accepting performance-based design, where the level of risk is specified as a basis for the design.

Table (2.1): the main advantages and disadvantages for the prescriptive codes, (travares, 2008).

Advantages	Disadvantages
Direct analysis, i.e., direct interpretation of the requirements	Specific recommendations which sometimes are not clear
Fire safety engineer's with more specific qualifications and/or skills (such as evacuation modeler; CFD modeler etc.) are not required	The codes structure is complex
	It is more difficult to develop safe design with reduced costs, and there is no flexibility in terms of requirements completion
	They are not much open to technological innovations or alternative solutions

Table (2.2): the main advantages and disadvantages of the performance code, (travares, 2008).

Advantages	Disadvantages
The establishment of the fire safety objectives is clearly defined and the fire safety engineer has the freedom to define the criteria and methodology to achieve them	It is difficult to define the quantitative criteria (i.e., performance criteria)
They are flexible for introducing innovative solutions	Training might need to necessary, especially during the fire phases of implementation
Harmonic to the international codes	It is difficult to analyze and evaluate the "equivalent project"
They enable the development of fire design with the reduction of the costs	There are difficulties in validating the methodologies used when define the quantitative criteria
Introduction of new technologies in the fire safety market	

2.4 Principles of Fire Risk Assessment in Building

2.4.1 Overview

The term fire risk assessment refers to assessing risks to both people and property as a consequence of unwanted fires. In a simple risk assessment the probability of a certain unwanted fire scenario is considered and the consequence of that scenario is explored. In a comprehensive risk assessment all probable unwanted fire scenarios and their consequences are considered, a fire scenario involves the projection of a set of fire events, all of which are linked together by whether the fire protection measures succeed or fail. The probability of a fire scenario is dependent on the individual probabilities of success or failure of fire protection measures.

The risk to the occupants depends not only on the probability of the fire scenario that can lead to harm to the occupants, but also the level of harm to the occupants as a result of the consequence of that scenario. The consequence of a fire scenario can be assessed by using time-dependent modelling of fire and smoke spread, occupant evacuation and fire department response, (Yung, 2006).

2.4.2 What is Fire Risk Assessment

Fire risk assessment is the assessment of the risks to the people and property as a result of unwanted fires. It employs the same basic principles of risk assessment that are used in many other fields. A simple risk assessment considers the probability of the occurrence of a certain unwanted fire scenario and the consequence of that scenario.

A comprehensive risk assessment considers all probable unwanted fire scenarios and their consequences.

A fire risk assessment is an organized and methodical look at your premises, the activities carried on there and the likelihood that a fire could start and cause harm to those in and around the premises. The aims of the fire risk assessment are:

- To identify the fire hazards.
- To reduce the risk of those hazards causing harm to as low as reasonably practicable.
- To decide what physical fire precautions and management arrangements are necessary to ensure the safety of people in your premises if a fire does start, *(http://www.firesafe.org.uk/fire-risk-assessment/).*

➢ Hazard: anything that has the potential to cause harm.

➢ Risk: the chance of that harm occurring. If your organization employs five or more people, or your premises are licensed or an alterations notice requiring it is in force, then the significant findings of the fire risk assessment, the actions to be taken as a result of the assessment and details of anyone especially at risk must be recorded.

You will probably find it helpful to keep a record of the significant findings of your fire risk assessment even if you are not required to do so, (Yung, 2006).

- Your fire risk assessment should demonstrate that, as far as is reasonable, you have considered the needs of all relevant persons, including disabled people. According to (Department for Communities and Local Government, 2006) there are five steps you need to take to carry out a fire risk assessment:

- STEP 1 : Identification of fire hazards

Look carefully at how people could be harmed. When you work in a place every day it is easy to overlook some hazards. The following are typical examples of fire hazards you may identify. Remember ignition sources are sources of heat that can become hot enough to ignite material found in the premises .Anything that burns is a source of fuel for a fire. This applies to contents, fixtures and fittings, building structure and to wall and ceiling linings. How ignition sources, sources of fuel and sources of oxygen (usually present in the air around us) contribute to the spread of fire should be identified, (Fire Risk Assessment Guidance, 2013).

- STEP 2 : Identify people at risk

For each hazard you identify, you must consider who might be harmed; it will help you identify the best way of managing the risk. The type of persons at risk can vary greatly from premises to premises. In some premises, such as a factory, the workforce may be predominantly physically fit. In other premises such as in a shop or public office, there may be a very different range of people at risk such as infants, other young children, elderly or disabled people, *(www.nifrs.org.)*.

- STEP 3: Evaluation of risk and assessment of adequacy of existing fire safety measures.

The chances of fire starting will be low if there are few ignition sources and if combustible materials are kept away from them. In general, fire is likely to start in one of three ways:

- Accidentally, such as when smoking materials are not properly extinguished.
- By act or omission, such as when electrical equipment is not properly maintained or when waste is allowed to accumulate near to a heat source.
- Deliberately, such as intentional setting fire to external storage or rubbish bins, *(www.nifrs.org.)*.

- STEP 4 : Record Fire Risk Assessment Information

  Having carried out a fire risk assessment for the premises, the findings must, in some circumstances be recorded, including any action taken or action still to be taken.

Fire safety legislation requires information to be recorded where five or more employees are employed (whether they are on site or not) or the premises are subject to licensing or registration or an 'Alterations Notice' has been issued requiring this. The assessment record should be retained and made available, on request, to the enforcing authority, (Fire Risk Assessment Guidance, 2013).

2.4.3 Fire Scenarios

A fire scenario is a sequential set of fire events that are linked together by the success or failure of certain fire protection measures. A fire event is an occurrence that is related to fire initiation, or fire growth, or smoke spread, or occupant evacuation, or fire department response. For example, a fire event can be: a fire develops into a post-flashover fire, or the occupants cannot evacuate quickly enough and are trapped in the building, or the fire department responds in time and rescues the trapped occupants. A fire protection measure is a measure that can be a fire protection system, such as sprinklers and alarms; or a fire protection action, such as occupant evacuation training and drills. A simple example of a fire scenario is the following set of events that are linked together by the failure of fire protection measures: a fire develops into a post-flashover fire, the alarm system does not activate and the occupants receive no warning signals and are trapped in the building. Another simple example is the following set of events that are linked together by the success of fire protection measures: a fire does not develop into a post-flashover fire, the alarm system activates, and the occupants receive the warning signals and evacuate the building. In real-world fires, fire scenarios are much more complex and the possible number of fire scenarios can be many. A set of fire scenarios can be constructed based on the well-known event-tree concept, where events are linked together like the branches of a tree, (Custer and Meacham, 1997). Figure 2.2 shows a simple event tree where an initiating event can lead to different events depending on the success or failure of the fire protection measures at the branch points. For example, Event A terminates in Event C if the fire protection measure for that event succeeds, whereas Event A continues with Event B to others if the fire protection measure fails.

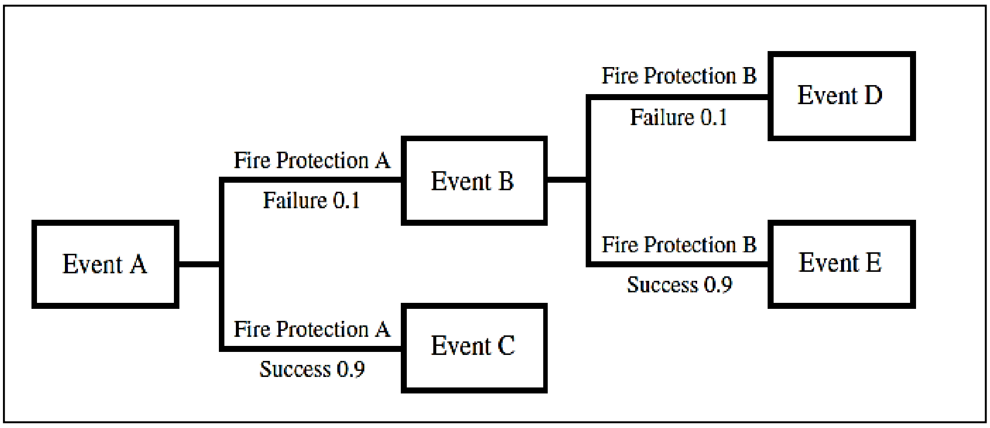

Fig (2.2): a simple event tree, (Custer and Meacham, 1997)

A particular set of events that are linked together forms one fire scenario. For example, the set of Event A and Event C forms one scenario. A set of all possible combinations of the linked events forms a complete set of all possible fire scenarios. For example, the combinations of A–C, A–B–D and A–B–E form a complete set of three fire scenarios. Figure 2.2 also shows the probability of success or failure of these two fire protection measures at the two branch points. The probabilities of failure at the two branch points are assumed, for this example, to be the same, at 10% or 0.1. Based on this, Scenario A–C has a probability of 0.9. Scenario A–B–E has a probability of 0.09, obtained by multiplying the probability of A–B (0.1) and that of B–E (0.9). Similarly, Scenario A–B–D has a probability of 0.01. The combined probability of all three fire scenarios is one. The important thing to note here is that the probabilities of success or failure of fire protection measures affect the probabilities of all fire scenarios. The lower the probabilities of failure of fire protection measures, the lower the probabilities of all those fire scenarios that will lead to an undesirable outcome. For example, if Event D is not the desired end point, then lower probabilities of failure of fire protection measures will lead to a lower probability of the undesirable fire Scenario A–B–D. If the probabilities of failure of the two fire protection measures are reduced to 0.01, the probability of the undesirable Scenario A–B–D is reduced to 0.0001, (Yung and Wiley, 2008).

2.4.4 Fire Protection Measures as Fire Barriers

For fire risk assessments in buildings, the event tree can be constructed based on the following five major fire events. They are considered major events because each is related to a major phase of fire development and hazard: fire ignition, fire growth, smoke spread, failure of occupants to evacuate, and failure of fire department to respond According to (Yung and Benichou, 2003):

- Fire ignition is the initiating event, such as cigarette ignition of a couch in a living room or a mattress in a bedroom. Fire protection measures include fire prevention education, or the use of fire-retarded material in furniture, which would help to reduce the probability of occurrence of this event and the consequential risks.
- Fire growth is the second event, which includes various types of fire growths, from fires developing into smoldering fires to fires developing into post-flashover fires. Fire protection measures include sprinklers, compartmentation and door self-closers, which would help to contain these fires and reduce their consequential risks.

  The reduction in risk depends on the reliability and effectiveness of these fire control systems.
- Smoke spread to critical egress routes and other locations in a building is the third event. Fire protection measures include door self-closers, smoke control, and stairwell pressurization, which would help to contain the smoke and reduce its consequential risks.

  The reduction in risk depends on the reliability and effectiveness of these smoke control systems.
- Failure of occupants to evacuate as a result of the spread of fire and smoke to egress routes is the fourth event. Fire protection measures include smoke alarms, voice communication, protected egress routes, refuge areas, and evacuation training and drills, which would help to provide early warnings to occupants, safe egress routes, quick occupant response and evacuation to either exit the building or to seek temporary protection in refuge areas.

  The reduction in risk depends on the reliability and effectiveness of these early warning and evacuation systems and the implementation of regular occupant training and evacuation drills.

- Failure of fire department to respond in time to rescue any trapped occupants and control the fire is the fifth event. Protection measures include early fire department notification and adequate fire department resources. The reduction in risk depends on the reliability of early notification and adequacy of fire department resources.

2.4.5 Qualitative Fire Risk Assessment

Qualitative fire risk assessment is based on subjective judgment of not only the probability of a fire hazard or fire scenario occurring, but also the consequence of such a fire hazard or fire scenario. The term fire hazard generally describes any fire situation which is dangerous and which may have potentially serious consequences. Qualitative fire risk assessment is usually employed in order to obtain a quick assessment of the potential fire risks in a building and to consider various fire protection measures to minimize these risks. In general qualitative fire risk assessments may be performed in two ways: (Young, 2008)

- A checklist is used to go through the potential fire hazards, the fire protection measures to be considered and the subjective assessment of their fire risks;
- An event tree is used to go through the potential fire scenarios and the fire protection measures to be considered and the subjective assessment of their fire risks.

The outcome in both cases, is a list of potential fire hazards, or fire scenarios, the fire protection measures to be considered and their assessed, fire risks. In this context assessed risks are described in qualitative rather than quantitative terms.

2.4.6 Risk Matrix in qualitative fire risk assessment

Fire risk is measured, by the product of the probability of occurrence of a fire scenario and the consequence of that scenario. In qualitative fire risk assessments, there are no numerical values for the probability or consequence that can be used to obtain the product. Instead, the product is assessed using a simple two-dimensional risk matrix, with one axis representing the level of the probability of occurrence and the other representing the severity of the consequence, (*http://www.cgerisk.com/knowledge-base/risk-assessment/risk-matrices*).

The degree of risk is assessed based on how high the probability is and how severe the consequence is. An example of a risk matrix is shown in Figure (2.3). In this risk matrix, the value of the probability is divided into five levels and the severity of the consequence is divided into five categories. The higher the probability and the higher the consequence in the matrix, the higher is the assessed risk (similar to the product of two values).

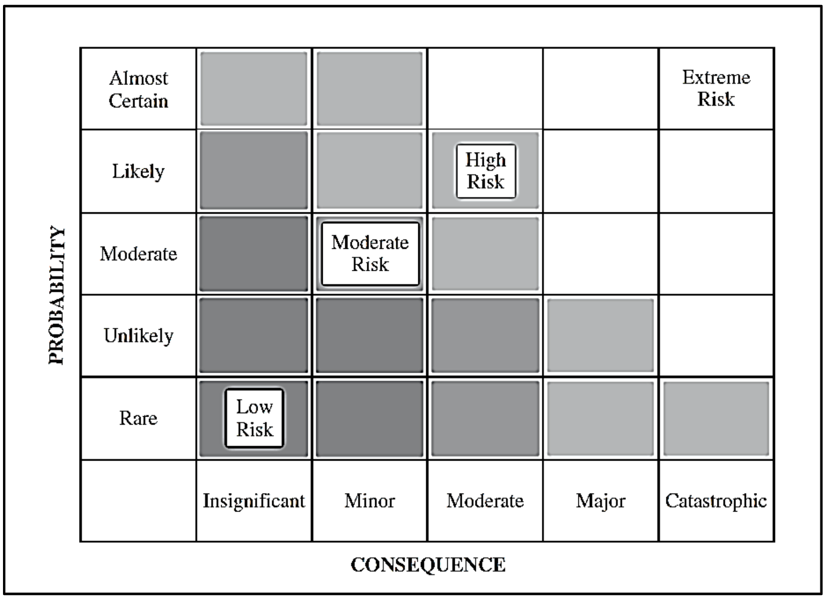

Fig (2.3): Risk matrix diagram, (Young, 2008).

For example, the combination of an 'Almost certain' probability and a 'catastrophic' consequence is assessed as an 'extreme' risk; whereas the combination of a 'rare' probability and an 'insignificant' consequence is assessed as a 'low' risk. In between these two extremes, the risk is assessed as either 'moderate' or 'high', depending on the combination of the probability and the consequence. In qualitative fire risk assessments, as was described earlier, various terms are used to describe the values of the probability, the consequence and the assessed risk. It should be noted that there are no standards on how to name these terms. Usually, these terms are developed for specific applications. For example, the definitions of the terms used in Table 2.3, Table 2.4 and Table 2.5, were developed mainly for occupational health and safety risk assessments in Australia and New Zealand.

Table (2.3): the consequence and risk levels, (Young, 2008).

Probability Level	**Definition**
Almost certain	Is expected to occur in most circumstances
Likely	Will probably Might occur at some time
Moderate	occur in most circumstances
Unlikely	Could occur at some time
Rare	May occur only in exceptional circumstances

Consequence Level	Definition
Catastrophic	Death, toxic release off-site with detrimental effect, huge financial loss
Major	Extensive injuries, loss of production capability, off-site release with no detrimental effects, major financial loss
Moderate	Medical treatment required, on-site release contained with outside assistance, high financial loss
Minor	First aid treatment, on-site release immediately contained, medium financial loss
Insignificant	No injuries, low financial loss
Risk Level	**Definition**
Extreme	Immediate action required
High	Senior management action required
Moderate	Management responsibility specified
Low	Managed by routine procedures

Table (2.4): the definitions of the severity levels, (Yung, 2006).

Probability Level	Description	Frequency (median time to event)
Anticipated	Incidents that might occur several times during the lifetime of the building.	>10−2/yr (<100 yr)
Unlikely	Events that are not anticipated to occur during the lifetime of the facility.	10−4/yr < f < 10−2/yr (100–10 000 yr)
Extremely unlikely	Events that will probably not occur during the life cycle of the building.	10−6/yr < f < 10−4/yr (10000–1 000 000 yr)
Beyond extremely unlikely	All other accidents	<10−6/yr (>1 000 000 yr)
Consequence Level	**Impact on populace**	**Impact on property/operations**
High	Sudden fatalities, acute injuries, immediately life threatening situations, permanent disabilities	- Damage > $X million, Building destroyed, surrounding property damaged
Moderate	Serious injuries, permanent disabilities, hospitalization required	- $Y < damage < $X million Major equipment destroyed, minor impact on surroundings
Low	Minor injuries, no permanent disabilities, no hospitalization	- Damage < $Y million, Reparable damage to building, significant operational downtime, no impact on surroundings
Negligible	Negligible injuries	- Minor repairs to building required, minimal operational downtime

Table (2.5): Definitions of probability and consequence levels as NFPA551, (Yung, 2006).

Probability Level	Definition
Frequent	Likely to occur frequently
Probable	Will occur several times during systemlife
Occasional	Unlikely to occur in a given system operation
Remote	So improbable, may be assumed this hazard will not be experienced
Improbable	Probability of occurrence not distinguishable from zero.
Consequence Level	**Definition**
Catastrophic	The fire will produce death or multiple deaths or injuries. The impact on operations will be disastrous, resulting in long-term or permanent closing. The facility would cease to operate immediately after the fire occurred.
Critical	Personal injury and possibly deaths may be involved. The loss will have a high impact on the facility, which may have to suspend operations. Significant monetary investments may be necessary to restore to full operations.
Marginal	Minor injury may be involved. The loss will have impact on the facility, which may have to suspend some operations briefly. Some monetary investments may be necessary to restore the facility to full operations.
Negligible	The impact of loss will be so minor that it would have no discernible effect on the facility or its operations

Consequence of a fire occurrence by suppressing or controlling the fire or by allowing the occupants to evacuate more quickly, (Yung, 2006).

2.4.7 Checklist Method in qualitative fire risk assessment

The checklist method (NFPA 551, 2007) employs the creation of a checklist of potential fire hazards and the consideration of fire protection. Measures, either in place or to be added, to arrive at a subjective judgment of the fire risks. The creation of a checklist of potential fire hazards allows a systematic check of potential fire hazards that are in place. The listing of fire protection measures alongside with the potential fire hazards allows a quick check of any safety deficiencies and any need to provide additional fire protection measures to minimize the risk, The checklist method, therefore, is an enumeration of potential fire hazards, fire protection measures, either in place or to be added, and the subjective judgment of the residual fire risks. It is used to identify any deficiencies and any corrective measures needed to minimize the fire risks.

2.4.8 Event-Tree Method

An event tree is another way to identify potential fire hazards, judge their probabilities and consequences and arrive at risk ratings. Different from the checklist method, an event tree shows more than a list of potential fire hazards and fire protection measures for the judgment of the probabilities, consequences and eventually the risk ratings. The event-tree method constructs an event-tree subsequent to the initiation of a fire hazard, an example for a fire hazard in an assumed apartment building is shown in Figure 2.4, (Foord G., et al., 2015). In Figure 2.4, the branching to different events depends on the success or failure of the fire protection measures in place. This example looks at one fire hazard in an assumed apartment building and the consideration of a number of additional fire protection measures to minimize the risk. The same event tree can be constructed for more hazards and more fire protection measures. A complete fire risk assessment would involve the identification of all potential fire hazards and the consideration of various fire protection measures to minimize the risk.

A typical apartment building usually has some fire protection measures, such as fire resistant construction and fire alarms. Additional fire protection measures would lower the risk further, in this example the three additional fire protection measures are: (1) no smoking material (such as cigarettes) in the apartments, (2) sprinklers, and (3) regular evacuation drills. Each of the three fire protection measures has an impact on either the probability of fire occurrence or the consequence of a fire occurrence.

For example, the measure of ‘no smoking material in the apartment’ would have an impact on lowering the probability of fire occurrence; whereas the measures of ‘sprinklers’ and ‘regular evacuation drills’ would have an impact on lowering the consequence of a fire occurrence by suppressing or controlling the fire or by allowing the occupants to evacuate more quickly.

As is in the discussion of the checklist method, the event tree in Figure 2.4 is only an example to show how an event tree can be used for qualitative fire risk assessment. The descriptions allow more transparent discussions and agreements among stakeholders, in an event tree, each fire scenario has a probability value depending on the success or failure of the fire protection measures associated with that scenario.

For this example, the level of probability is again divided into the same four levels. The definitions are assumed to be based on the number of successes and failures of the fire protection measures associated with the scenario, with a further assumption that the probability of failure of each fire protection measure is a much smaller value than that of the probability of success, (Foord G., et al., 2015).

2.5 Quantitative Fire Risk Assessment

According to (Yung, 2006): The term quantitative fire risk assessment refers to an assessment involving numerical quantifications not only of the probability a fire hazard, or fire scenario occurring, but also the consequences of that fire hazard or fire scenario. By multiplying the numerical values of probability and consequence each fire scenario is given a numerical fire risk value. By accumulating the sum of the risk values from all probable fire scenarios.

We can obtain an overall fire risk value. The overall fire risk value can be used for comparisons with those of alternative or code-compliant fire safety designs.

In general there are two ways to perform systematic quantitative fire risk assessments as follows:

- By using a checklist to go through a list of potential fire hazards and the quantitative assessment of their fire risks;
- By using an event tree to go through a set of potential fire scenarios and the quantitative assessment of their fire risks.

In both these methods, the values for the probability and consequence parameters are obtained from statistical data, if they are available, or from subjective judgment, if such data are not available.

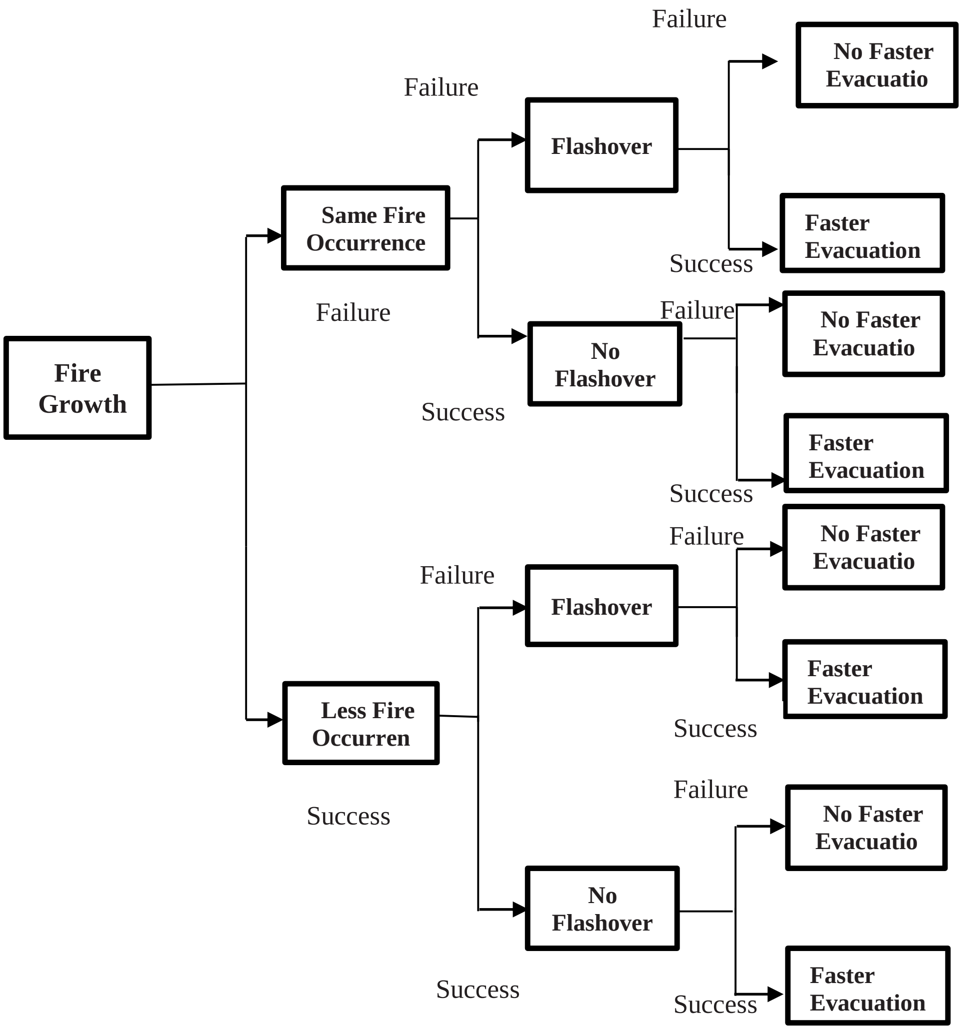

Fig (2.4): an example of an event tree, (Foord G., et al., 2015).

2.5.1 Risk Indexing in quantitative fire risk assessment

Risk indexing involves the use of a set of well-defined risk parameters that have been developed for a specific application. The parameters can be both risk parameters (contributing to risk) and safety parameters (contributing to safety). The value of each parameter can be selected, based on its characteristics, from well-defined tables that have been developed by experts specifically for this application. The assessed values (index) can be used for comparison with those of mandatory requirements, or for comparison with those of alternative fire protection measures. In risk indexing methods, there are no separation of probability and consequence, (NFPA 101A, 2004). Each parameter is given an assessed value and the summation of all these values are used for comparisons for compliance or equivalency.

One such representative risk indexing method is the one developed by NFPA (National Fire Protection Association) for health care facilities, (NFPA 101A, 2004).

In the NFPA method, worksheets are used to evaluate whether a facility can meet the basic safety requirements in four areas: (1) containment, (2) extinguishment, (3) people movement and (4) general safety. Table (2.6) has a list of 13 safety parameters which are to be evaluated under these four safety areas. The value for each of these 13 safety parameters is actually worked out in a separate worksheet. Their values are then entered into Table (2.6) the sum of all values in one column (one safety area) represents the valuated total value for that safety area. For example, the sum of all values in the column for S1 represents the evaluated total value for containment safety. The total value in each safety area is then compared with the required value for that safety area. The facility is considered safe if the evaluated total values meet the required values in all four areas. For more details of this method, consult the reference, (NFPA 101A, 2004).

Other risk indexing methods are similar in concept, but with different sets of parameters and tables for different applications. They can be found in the SFPE (Society of Fire Protection Engineers hand book), (Watts, 2002).

2.5.2 Checklist Method in quantitative fire risk assessment

The checklist method employs the creation of a checklist of potential fire hazards and the consideration of fire protection measures, either in place or to be added, to arrive at an assessment of the fire risks. The creation of a checklist of potential Fire hazards allows a systematic check of potential fire hazards that are in place. The listing of fire protection measures alongside with the potential fire hazards allows a quick check of any safety deficiencies and any need to provide additional fire protection measures to minimize the risk. The checklist method, therefore, is an enumeration of potential fire hazards, fire protection measures, either in place or to be added, and the assessment of the residual fire risks. It is used to identify any deficiencies and any corrective measures needed to minimize the fire risks.

Table (2.6): check list example, (Yung, 2006).

Parameter	**Containment safety (S1)**	**Extinguishment safety (S2)**	**People movement Safety (S3)**	**General Safety (S4)**
1. Construction	-	-	NA	-
2. Segregation of Hazards	-	NA	-	-
3. Vertical Openings	-	NA	-	-
4. Automatic Sprinklers	-	-	/2=	-
5.Doors to corridor	-	NA	-	-
6. Fire Alarm	NA	-	NA	-
7. Smoke Detection	NA	-	-	-
8. Interior Finish	-	NA	-	-
9. Interior finish (rooms	-	NA	NA	-
10. Smoke Control	NA	NA	-	-
11. Corridor/Room Separation	-	NA	NA	-
12. Occupant Emergency Program	NA	NA	-	-
13. Zone dimensions	NA	NA	-	-
Total	S1 =	S2 =	S3 =	S4 =

2.6 Fire Risk Indices Explained

Fire risk indices originated in the insurance industry approximately 100 years ago and have been successfully used for a variety of applications, including as a means to ascertain compliance with codes. In general, fire risk indices assign numerical values to selected fire safety parameters, based on professional judgement, experience or prevailing regulations. The parameters selected for a fire risk index represent both positive and negative fire safety features. The assigned values for each parameter are then combined in various ways to achieve a single value (or a few values) representing risk in a particular building. That value can be compared to other values, calculated utilizing different fire safety features for the same building and using the same methodology, to achieve a relative ranking of risk for different designs or materials in a building. For example, by calculating the risk for a code-complying design and using that as a benchmark, the calculated risk using other designs, materials and systems can be compared to that benchmark to determine if the code-intended level of safety has been achieved using the risk index as a basis.

Some examples of where risk indices have been used include:

- Insurance Rating Schedules
- Fire and Explosion Indices
- Fire Safety Evaluation Systems (NFPA 101A).

Fire risk indexing is a more flexible and inclusive technique for evaluating alternative fire safety configurations in buildings. A fire risk index is a tabular tool for analyzing and scoring hazards and other risk parameters that describe various building features or systems related to fire safety. Numerical values assigned to these parameters are arithmetically manipulated to create a single mathematical expression for the overall level of fire safety provided by the building. Like the codes, existing fire risk index systems focus on modern construction techniques. While these indexing systems can be useful tools for rehabilitation projects, they do not include the range of alternatives that are appropriate for buildings of historic significance, (National Center for Preservation Technology and Training).

2.7 Summary

In this chapter, the basic concepts of fire risk assessment were introduced. Fire risk assessment is the assessment of the risks to the people and property as a result of unwanted fires. A simple risk assessment considers the probability of the occurrence of a certain unwanted fire scenario and the consequence of that scenario. A comprehensive risk assessment considers all probable unwanted fire scenarios and their consequences. A fire scenario is a set of fire events that are linked together by the success or failure of fire protection measures. There are basically five major hazardous events that must occur before a fire can cause, Qualitative fire risk assessment is an assessment based on subjective judgment of both the probability of occurrence of a fire hazard, or fire Scenario, and the consequence of that fire hazard, or fire scenario. There are in general two ways to conduct qualitative fire risk assessments:

(1) Use a checklist to go through the potential fire hazards, the fire protection measures to be considered, and the subjective assessment of their fire risks; (2) use an event tree

to go through the potential fire scenarios and the fire protection measures to be considered and the subjective assessment of their fire risks. In both cases, the outcome is a list of potential fire hazards, or fire scenarios, the fire protection measures to be considered and their assessed fire risks.

Quantitative fire risk assessment is an assessment involving numerical quantifications of both the probability of occurrence of a fire hazard, or fire scenario, and the consequence of that fire hazard or fire scenario. The multiplication of the numerical values of probability and consequence gives each fire scenario a numerical fire risk value. There are in general two ways of conducting systematic quantitative fire risk assessments: (1) using a checklist to go through a list of potential fire hazards and the quantitative assessment of their fire risks; (2) using an event tree to go through a set of the potential fire scenarios and the quantitative assessment of their fire risks.

Within the checklist method, there are specific methods that have been developed by various organizations for their own use. One particular one is called the *risk indexing* method which uses well-defined schedules, or tables, to rate the risks. In both the checklist and event-tree methods, the outcome is a list of potential fire hazards, or fire scenarios, and their assessed fire risk values.

Chapter 3
Methodology

This chapter discusses the methodology which was used in this research. The research methodology was chosen to satisfy the research aim and objectives which help to accomplish this research study. This chapter included information about the research design, codes chosen, sample building, data collection technique, checklist design and development, final content of the checklist, and analytical methods of data.

3.1 Research design

The research design is the general plan for how and what data should be collected and how the results should be analyzed. The chosen research design will influence the type and the quality of the collected data, (Ghauri and Grønhaug, 2010). The research technique was chosen as a checklist research to measure objectives, the purpose of Checklist is to facilitate building owners/occupiers to carry out routine inspections on fire safety provisions of their own buildings, and to rectify minor irregularities identified. This would enhance their awareness on fire safety, and is the most effective and immediate means to protect their lives and properties.

First stage: Theme identification (Problem definition)

It was initiated to identify the problem, establish aim, objectives, hypothesis and key research checklist questions, and develop research plan/strategy by deciding on the research approach and deciding on the research technique.

Second stage: Literature Review

- As part of this study a literature review was performed including collecting existing knowledge on the subject of evaluation of fire safety factors, reading and note-taking from different sources such as:

  - Refereed academic research journals.
  - Refereed conferences.
  - Dissertations/theses.
  - Reports/occasional papers/ white papers.
  - Government publications.
  - Books.

- Intensive literature review was conducted to review the previous studies made in this field. It was performed by reading and note-taking from different sources also it was helped in having better understanding of the issue and a wider view by making use of the experience of previous researchers from different communities.
- Based on the extensive literature reviews, a check list was designed, a checklist is a type of informational job aid used to reduce failure by compensating for potential limits of human memory and attention. It helps to ensure consistency and completeness in carrying out a task.
- The literature review is aimed to establish a theoretical understanding of the concept of fire safety engineering and the risks that threaten the facilities also it explained the fire safety management and their factors which are affected by it, besides the study of fire codes and the analysis of some fire risk indexes models to conclude the factors that will be used in evaluating the buildings.

Third stage: To identify international fire codes used in risk indexes

The study aims to identify the risk indexing and clarify areas of application and usage also, to identify alternative and adjustable methods for evaluation fire safety.

Fourth stage: Codes selection and identification

Select three codes for fire safety (NFPA, IBC and CHICAGO) then make a comparison between them and then merge them to choose the best fire safety factors.

Fifth stage: Proposition for an evaluation framework based on the requirements of the codes

The study aims to identify the international codes and knowledge of the standards and requirements required to provide appropriate protection for all buildings.

Sixth stage: Checklist design and development

Checklist have been widely used for descriptive and analytical surveys in order to find out facts, on what is happening, where, how many or how much (Naoum, 2007). The check list can also assist you in ensuring that the critical fire safety elements and equipment are inspected periodically through this stage, the following points have been identified: types of evaluation, the checklist format and the sequence of factors.

Seventh stage: The application of evaluation framework to some educational buildings in the IUG

The assessment has done on three buildings at the Islamic University to evaluate the current status of the buildings and determine the degree of compliance with the proposed model for fire protection.

Eighth stage: Results

Showing the final results obtained through the theoretical and applied study to the research beside evaluation results from assessment the degree of compatibility, besides making a comparison between current study and previous studies in Egypt and Saudi Arabia.

Ninth stage: Conclusion and Recommendations

The final phase of the research included the conclusions and recommendations.

3.2 Research location

The research was carried out in Gaza governorate, in Islamic university.

3.3 Check list design and development

- Identification of international fire codes used in risk indexes (NFPA, IBC or BOCA and CHICAGO).
- Comparison of Codes, at the time of the design and construction.
- Distribution of evaluation factors between fire safety codes.
- Proposed model for measuring the Compatibility of buildings.

3.3.1 Identification of international fire codes used in risk indexes

3.3.1.1 NFPA, Fire Safety Evaluation System (FSES)

NFPA 101, Life Safety Code, is one of the most widely used voluntary codes for identifying a minimum level of fire safety. The Fire Safety Evaluation System (FSES) provides a multi attribute approach to determining equivalencies to the Code's requirements for certain occupancies. The technique was developed in the late 1970s at the Center for Fire Research, National Bureau of Standards (presently the Building and Fire Research Laboratory, National Institute of Standards and Technology). It has been adapted to new editions of the Life Safety Code and is presently published in NFPA 101A, Alternate Approaches to Life Safety.

The original FSES was developed for health-care facilities as a uniform method of evaluating fire safety to help regulators assess compliance with federal requirements. FSES users would be able to determine what measures would provide a level of safety equivalent to that required by the Life Safety Code. The FSES was also designed to give the user information efficiently and with minimal effort. NFPA 101A now includes an FSES not only for health-care occupancies, but for correctional facilities, board and care homes, and business occupancies, as well, (Watts and John, 1997).

3.3.1.2 Fire Safety Parameters

The FSES for business occupancies allows users to compute a relative level of safety provided by safeguards that are arranged differently than they are in NFPA 101. In the FSES, each of 12 fire safety parameters is assigned a Set of applicable values that correspond to facility conditions that may be present to different degrees. These conditions and their values appear as Table 3.1 of NFPA 101A.

The analysis in this study involves examining the range, or spread, of each safety parameter. The spread of a safety parameter from minimum to maximum value is assumed to be a measure of its importance. The greater the spread, the more impact the parameter has on the resulting fire safety score; thus, the greater it's imputed importance, (Watts and John, 1997).

Table 3.1 lists the 12 fire safety parameters for business occupancies in the left-hand column. The second and third columns of Table 3.1 specify the minimum and maximum values for each parameter, and the last column is the spread between the minimum and maximum values.

Table (3.1): the spread between the minimum and maximum values of factors, (Watts and John, 1997).

Parameter	**Min**	**Max**	**Spread**
1. Construction	-12	2	14
2. Segregation of Hazards	-7	0	7
3. Vertical Openings	-10	1	11
4. Automatic Sprinklers	0	12	12
5. Fire Alarm	-2	4	6
6. Smoke Detection	0	4	4
7. Interior Finish	-3	2	5

8. Smoke Control	0	4	4
9. Exit Access	-2	3	5
10. Exit System	-6	5	11
11. Corridor/Room Separation	6	4	10
12. Occupant Emergency Program	-3	2	5
Total	-51	43	94

Table (3.2): Ranked fire safety parameter, (Watts and John, 1997).

Parameter	**Spread**	**Percent**
1. Construction	14	15%
4. Automatic Sprinklers	12	13%
10. Exit System	11	12%
3. Vertical Openings	11	12%
11. Corridor/Room Separation	10	11%
2. Segregation of Hazards	7	7%
5. Fire Alarm	6	6%
7. Interior Finish	5	5%
9. Exit Access	5	5%
12. Occupant Emergency Program	5	5%
6. Smoke Detection	4	4%
8. Smoke Control	4	4%
Total	94	100%

In the FSES for business occupancies, eight parameters are used to calculate a building's fire control score, and ten parameters are used to calculate its egress score. Values for all 12 parameters are added together to produce a score for general fire safety. Only the general fire safety scores are considered in this analysis, (Watts and John, 1997).

Table (3.1) indicates that the lowest possible general fire safety score for any business occupancy is –51 points. Similarly, the highest possible score is +43 points. The spread of possible scores is the difference between the highest and lowest possible scores, or 94 points.

3.3.1.3 Analysis of Parameter Importance

The spread from a parameter's minimum to maximum value indicates the potential magnitude of its effect on the general fire safety score. Thus, the spread of a parameter's values may be taken as a relative measure of the Importance of the parameter to life safety. In Table (3.2), the fire safety parameters are ranked according to the size of the spread from minimum to maximum value, as calculated in Table (3.1) the first column in Table (3.2) is the parameter's rank according to its spread, as shown in Column 3.

The last column in Table (3.2) is the percentage of a parameter's spread out of the total spread of points (94) in the general fire safety scoring. Table (3.2) shows two distinct sets of fire safety parameters in terms of their value spread. The first five parameters in Table (3.2) account for 63% of the 94 possible points, while the last seven parameters account for only 37%, (Watts and John, 1997).

The parameters that seen in these two groups may not be as intuitively important or unimportant to a fire protection engineer as their spread ranking implies. For example, one might intuitively believe that fire detection (parameter 6, rank 9) and interior finish (parameter 7, rank 8) would be more important to life safety in business occupancies than corridor/room separation (parameter 11, rank 4),Fig 3.1 Illustrates the ranked fire safety parameters.

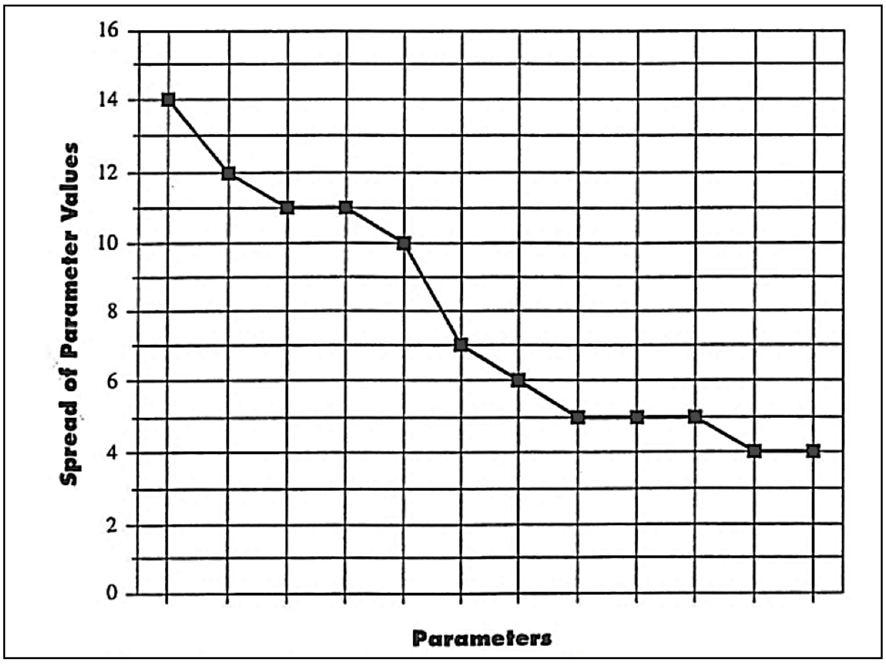

Fig (3.1): Graphical plot of the rank, (Watts and John, 1997).

3.3.1.4 International Building Code, IBC

The International Building Code (IBC) is a model building code developed by the International Code Council (ICC). It has been adopted throughout most of the United States. A large portion of the International Building Code deals with fire prevention. It differs from the related International Fire Code in that the IBC addresses fire prevention in regard to construction and design and the fire code addresses fire prevention in regard to the operation of a completed and occupied building. For example, the building code sets criteria for the number, size and location of exits in the design of a building while the fire code requires the exits of a completed and occupied building to be unblocked. The building code also deals with access for the disabled and structural stability (including earthquakes), (International Building Code, 2009).

3.3.1.5 Fire Safety Evaluation system:

The evaluation shall be comprised of three categories:

- **Fire safety**, means of egress and general safety fire safety. Included within the fire safety category are the structural fire resistance, automatic fire detection, and fire alarm and fire suppression system features of the facility.
- **Means of egress**. Included within the means of egress category are the configuration, characteristics and support features for means of egress in the facility.
- **General safety**. Included within the general safety category are the fire safety parameters and the means of egress parameters.

3.3.1.6 Evaluation process:

The evaluation process specified herein shall be followed in its entirety to evaluate existing Buildings. Table 3.3 shall be utilized for tabulating the results of the evaluation. References to other sections of this code indicate that compliance with those sections is required in order to gain credit in the evaluation herein outlined:

Table (3.3): Tabulating the results of the evaluation for IBC.

Safety Of Parameters	Fire Safety (Fs)	Means Of Egress (Me)	General Safety(Gs)
3412.6.1 Building Height 3412.6.2 Building Area 3412.6.3 Compartmentation			
3412.6.4 Tenant and Dwelling Unit Separation 3412.6.5 Corridor Walls 3412.6.6 Vertical Openings			
3412.6.7 HVAC Systems 3412.6.8 Automatic Fire Detection 3412.6.9 Fire Alarm Systems			
3412.6.10 Smoke Control 3412.6.11 Means of Egress Capacity 3412.6.12 Dead Ends	**** **** ****		
3412.6.13 Maximum Exit Access Travel Distance 3412.6.14 Elevator Controls 3412.6.15 Means of Egress Emergency Lighting	**** ****		
3412.6.16 Mixed Occupancies 3412.6.17 Automatic Sprinklers 3412.6.18 Standpipes 3412.6.19 Incidental Accessories Occupancy		**** +2 =	

3.3.1.7 Analysis of parameter importance:

Next table (3.4) indicates to the arrangement of fire safety factors for (BOCA) and its effect, where it appears that the more influential factor is the vertical openings with 22.1%, while the least one is Means of Egress with 0.3%.

Table (3.4): the arrangement of fire safety factors for (BOCA).

Ranking	Parameters		Min Value	Max Value	Spread	Percent%
1	6	Vertical openings	-58	14	72	22.1%
2	2	Building Area	-22	18	40	12.3
3	13	Maximum Exit Access Travel	-20	20	40	12.3
4	1	Building Height	-20	10	30	9.2
5	17	Automatic Sprinklers	-12	12	24	7.4
6	3	Compartmentation	0	20	20	6.1
7	7	HVAC Systems	-15	5	20	6.1
8	9	Fire Alarm System	-10	5	15	4.6

9	8	Automatic Fire Detection	-4	8	12	3.7
10	5	Corridor Walls	-5	5	10	3.1
11	16	Mixed Occupancies	-5	5	10	3.1
12	4	Tenant and Dwelling Unit Separation	-4	4	8	2.5
13	14	Elevator Control	-4	4	8	2.5
14	10	Smoke Control	0	4	4	1.2
15	12	Dead ends	-2	2	4	1.2
16	15	Means of Egress Emergency Lighting	0	4	4	1.2
17	18	Incidental Use	-4	0	4	1.2
18	11	Means of Egress	-1	1	1	0.3

3.3.1.8 Influence Type for fire safety factors:

Safety factors are divided in BOCA evaluation system in terms of impact to three groups based on possible values for factors from positive or negative side, that is the factors which affect with negative include 1.5% from all, however the factors affect with positive 8.5%, while others include 90% from all affect for building safety.

3.3.1.9 Distribution of Parameter importance:

By analyzing the possible weights for fire safety factors values, we conclude that the first seven factors with 38.8% from all factors affect with 75.5% while 61.2% from all factors affect with 24.5% for public safety.

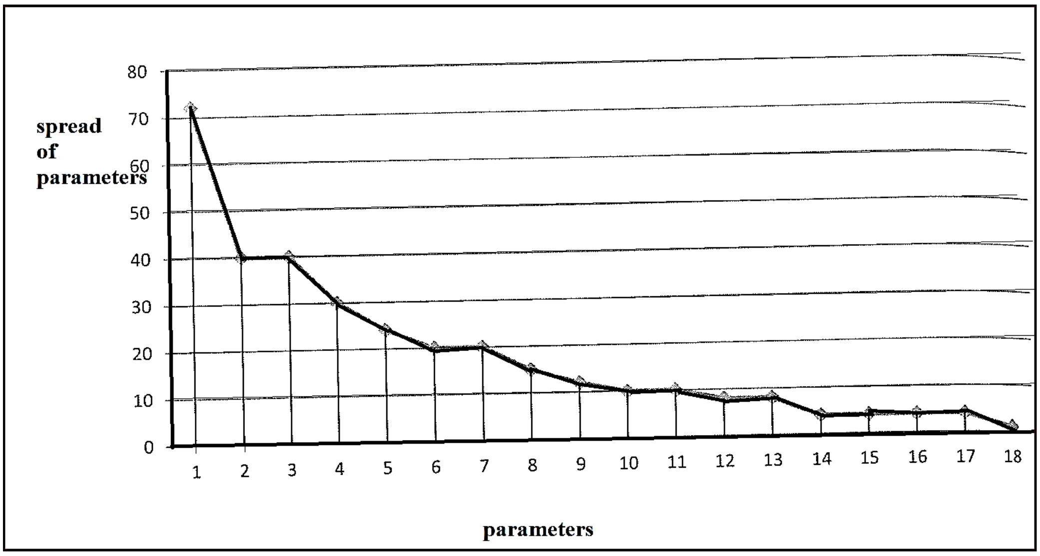

Fig (3.2): the linear distribution of FSES, IBC.

As shown in the Fig (3.2), the linear distribution of the impact of safety coefficients similar to FSES evaluation system, Note that the horizontal coordinate indicates safety factors while the vertical coordinate refers to the potential for parameter spread value.

3.3.1.10 Code of Chicago City:

1. Chicago Fire Department (CFD) provides fire suppression and emergency medical services to the city of Chicago, Illinois, United States, under the jurisdiction of the Mayor of Chicago. The Chicago Fire Department is the third largest municipal fire department in the United States after the New York City Fire Department and Cal Fire, as measured by sworn personnel. It is also one of the oldest major organized fire departments in the nation.

2. The Life Safety Evaluation (LSE) of a building must measure three major areas of safety which are as follows:

a. Fire Safety: This is a measure of the ability to contain a fire within the place of fire origin by passive means such as fire barriers, and to extinguish the fire through active means via either automatic sprinklers and/or manual fire department intervention. Fire safety is also determined by the fire endurance characteristics of the barriers, the structural stability of the building frame, the fire environment, the ability to detect and alarm a fire condition and the nature of the Response to that alarm.

b. Means of Egress: This is a measure of the ability of building occupants to escape to a safe location within or outside of the building, in case of a fire. It is determined by the ability to detect and announce a fire condition, the character and availability of the emergency escape egress system and/or area of refuge, and the ability to communicate with the building occupants during and after a fire.

c. General Safety: This is a measure of the overall fire safety level of the building. Building elements, systems or devices included in the evaluation must be properly designed, functional, properly maintained, and in compliance with the Chicago Building Code (CBC) in force at the time the building was built. to gain credit for a parameter, any new installation must be properly permitted and comply with the applicable provisions of the current CBC, (Kaderbek, et al., 2005).

3. The parameters below in Table (3.5) are applicable to both residential and commercial buildings that are not fully sprinklered in accordance with the CBC. For the purposes of the LSE, “commercial” is defined as any occupancy which is not Class A, Residential. If a building contains any non-transient residential units, the building must be inspected and evaluated as a residential building using the residential parameters. (Kaderbek, et al., 2005).

Table (3.5): parameters that applicable to both residential and commercial buildings.

Safety Parameters	Min value	Max value	Spread	Percent
10.1 Building Height	0	4	4	1.5%
10.2 Construction Type	12	16	28	10.2%
10.3.1 or10.3.2 Compartment Area	-10	8	18	6.6%
10.4.1Dwelling Unit separations or 10.4.2 Tenant Separations	-5	5	10	3.6%
10.5.1 or 10.5.2 Corridor Partitions/Walls	-5	2	7	2.55%
10.6 Vertical Openings	-13	1	14	5.1%
10.7 HVAC Systems	0	5	5	1.8%
10.8.1 or 10.8.2 Smoke Detection	0	10	10	3.6%
10.9 Communications	0	16	16	5.83%
10.10 Smoke Control	-5	10	15	5.5%
10.11.1 or 10.11.2 Exit Capacity	-40	10	50	18.24%
10.12.1 or 10.12.2 Dead End Corridors	-15	5	20	7.3%
10.13.1 or 10.13.2Maximum Exit Travel	-15	10	25	9.12%
10.14 Elevator Controls	-7	3	10	3.6%
10.15 Emergency Lighting	-10	2	12	4.37%
10.161 or 10.16.2 Mixed Occupancies	-10	0	10	3.6%
10.17 Automatic Sprinklers	0	12	12	4.37%
10.18 Auxiliary Uses	-10	0	10	3.6%
TOTAL	**-179**	**119**	**276**	**100%**

4. Previous table indicates to the arrangement of fire safety factors for (CBC) and its effect, where it appears that the more influential factor is the Exit Capacity with18.24%, while the least one is Building height with 1.5 %.

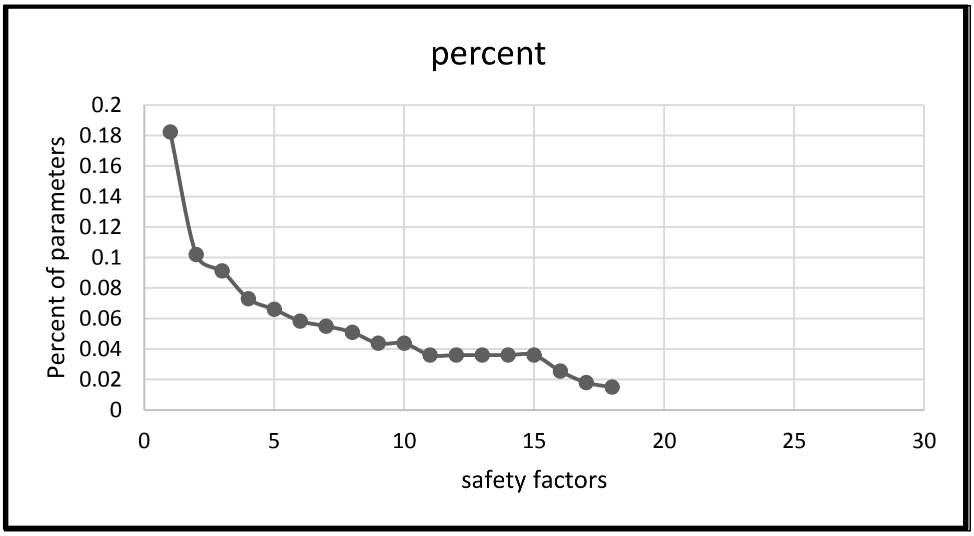

Fig (3.3): the linear distribution of IBC.

As shown in the graph Fig 3.3, the linear distribution of the impact of safety coefficients similar to FSES and BIC evaluation system, Note that the horizontal coordinate indicates safety factors while the vertical coordinate refers to the percent for parameter spread value, (*By Researcher preparation after studying*, Kaderbek, et al., 2005).

3.3.2 Comparison of Codes, at the time of the design and construction:

According to (Raymond and Jensen, 2005) there are a lot of differences between factors in codes, this comparison isullarate it:

1. **General Differences**

The requirements of the 1965 edition of Building Officials and Code Administrators (BOCA) are more performance oriented than prescriptive in many areas of the document. The current Building Code of the City of New York (BCNYC) is more prescriptive in its requirements. The requirements of National Fire Protection Association (NFPA) 101, Code for the Safety to Life, is focused on maintaining the integrity of egress elements and control of fire growth and spread to allow for occupant egress. Therefore, there are limited requirements for fire resistance of typical building elements as would be found in a typical building code.

2. Occupancy Separations

The current BCNYC included detailed requirements for treating mixed occupancy buildings which were not found in the other codes compared in this report. The Chicago Building Code did contain a specific requirement for a 4 h separation between buildings and below-grade public space (i.e., subways). There is no requirement of this nature in either the BCNYC or New York State Building Codes. NFPA 101 permits the provision of fire sprinklers in lieu of 1 h fire rated construction for separations of occupancies having different hazard levels.

3. Construction

The current BCNYC and New York State Building Codes allowed Type IA or Type IB construction for the World Trade Center (WTC) buildings. The current Chicago Building Code would have required Type IA construction. The Chicago Building Code would require 4 h fire resistance ratings for structural elements such as columns and bearing walls versus 3 h fire resistance required by the BCNYC or the New York State Building Code. The BOCA Building Code allowed Type IA or Type IB construction for the World Trade Center buildings. Fire resistance rating requirements in the BOCA Building Code are almost identical to the current New York City Building Code. One are of deviation is that the then current New York City building Code required 1 h fire rated tenant separations versus ¾ h fire rated tenant separations in BOCA. NFPA 101 does not contain construction requirements for the types of occupancies that were included in the WTC Buildings.

4. Fire and smoke dampers

The smoke dampers. Smoke dampers were required at the main supply and return ducts. The other codes reviewed in this report did not have any requirements for fire and smoke dampers.

5. Fire stopping and through penetration protection

The current BCNYC included comprehensive requirements identifying when and where fire stopping was required. The current New York State Building Code addressed the issue in less detail and the Chicago Building Code had no requirements.

NFPA 101 has limited requirements for fire stopping (exterior and interior partitions at floor levels and unoccupied attic spaces) and does allow a trade off in this area for sprinklered concealed spaces.

6. Interior finish and smoke development ratings

The requirements for flame spread of interior finish are similar amongst the codes reviewed in this report. The current BCNYC is more detailed in specifying requirements based on use of spaces and is the only code of those reviewed in this report that included requirements for maximum smoke development ratings for interior finish.

7. Means of egress

The current BCNYC provided detailed requirements for the design of the various elements of the egress system. This includes detailed occupant loading criteria based on use, egress element widths, continuity of egress path, and criteria for horizontal egress. The current New York State Building Code and Chicago Building Code did not have detailed requirements for the means of egress. The current BCNYC requirements for egress were consistent with the BOCA Building Code and NFPA 101 with minimal differences in technical requirements. The travel distance requirement of the then current BCNYC (200 ft) is less restrictive than BOCA (150 ft) but consistent with the requirement of NFPA 101. Requirements for illumination of egress elements are most restrictive in the then current BCNYC (5 foot candle intensity) versus BOCA (3 foot candle intensity) and NFPA 101 (1 foot candle intensity), (Raymond and Jensen, 2005).

8. Fire suppression systems

The fire sprinkler requirements of the current BCNYC and New York State Building Codes were driven by lack of means for exterior ventilation. The current Chicago Building Code had no requirements for fire sprinkler protection. BOCA and NFPA 101 sprinkler requirements are driven by occupancy and area of that occupancy. Office occupancies did not require sprinkler protection by BOCA or NFPA 101. The then current BCNYC had specific design criteria within the code if a system was to be provided.

9. Stand pipes and water supply

The current BCNYC and BOCA required standpipes and had detailed design and installation criteria incorporated in the code. The New York State Building Code required standpipes, but did not include design or installation criteria in the code. The current Chicago Building Code was silent on the subject. NFPA 101 would not have required standpipes.

10. Fire alarm, detection, and signaling systems

The current New York State Building Code, BOCA and NFPA 101 required a fire alarm system in high rise office buildings. The BOCA requirement was triggered by height (75 ft) and the NFPA 101 requirement was driven by occupant load (greater than 200 people). The current BCNYC and NFPA 101 had comprehensive requirements for installation of smoke detectors in heating, ventilating, and air conditioning equipment. The current BCNYC also had requirements for a firefighter communication system with permanent telephones to provide communication between pump rooms, building entrance floor, gravity tank rooms, and at each floor near the main standpipe.

11. Elevators and escalators

The current BCNYC contained the most comprehensive requirements for elevators among the codes reviewed in this report. Requirements also included application of elevators if areas of refuge were provided in buildings. Areas of refuge above the 11th floor were required to be served by at least one elevator. Emergency controls for fire department use were also required.

12. Smoke and heat venting

The current BCNYC was the only code of the codes reviewed in this study that required smoke and heat venting of elevator, dumbwaiter, and other closed shafts including stairway enclosures. NFPA 101 required automatic smoke and heat venting for underground structures with occupant loads exceeding 1,000 people, (Raymond and Jensen, 2005).

3.3.3 Distribution of evaluation factors between fire safety codes

- Table 3.6 was prepared by (*researcher after studying evaluation theory for each code*).

Table (3.6): Distribution of evaluation factors between fire safety codes.

Safety Parameters		Evaluation system for NFPA	Evaluation system for BIC-BOCA	Evaluation system for Chicago
1.	Construction Building Height Building Area	✓	✓	✓
2.	Vertical Openings	✓	✓	✓
3.	Compartment		✓	✓
4.	Dwelling Unit Separations or Tenant Separations		✓	✓
5.	Corridor Partitions/Walls	✓	✓	✓
6.	Segregation of Hazards/incidental use	✓	✓	
7.	HVAC Systems		✓	✓
8.	Smoke Detection	✓	✓	✓
9.	Corridor Walls	✓	✓	
10.	Smoke Control	✓	✓	✓
11.	Exit System	✓	✓	✓
12.	Exit Access Dead End Corridors travel distance	✓	✓	✓
13.	Means of Egress Emergency Lighting	✓	✓	✓
14.	Elevator Controls		✓	✓
15.	Fire Alarm	✓	✓	✓
16.	Mixed Occupancies		✓	✓
17.	Automatic Sprinklers	✓	✓	✓

Safety Parameters		Evaluation system for NFPA	Evaluation system for BIC-BOCA	Evaluation system for Chicago
18.	Interior Finishes	✓		
19.	Occupant Emergency program	✓		
20.	Communications			✓
21.	Auxiliary uses			✓

As a result of studying safety coefficients has been reached to merge between the most important elements in the codes, where the study which carried out by (Watts,1997) to the possibility of make integration between fire safety evaluation systems for the non-identical in type and number of factors through the making normalization to the spread of probability value which move through it from minimum value to maximum value, so that nineteen coefficient have been resulted to measure the compatibility of the buildings with evaluation systems factors.

Normal spread (N.S) = (Spread value / Total Spread value) *Number of parameters in each code.

Table (3.7): The Percentage Weight for the Spread of IBC and NFPA Systems.

BOCA Parameters		**S**	**N.S**	**FESE Parameters**		**S**	**N.S**	**AVR**
1	Building Height	30	1.66	1	Construction	14	1.79	1.72
2	Building Area	40	2.21					1.1
3	Compartmentation	20	1.1					0.55
4	Tentent and Dwelling unit separations	8	0.44					0.22
5	Corridor Walls	10	0.55	11	Corridor/Room Separation	10	1.28	0.92
6	Vertical openings	72	3.98	3	Vertical Openings	11	1.4	2.69

7	HVAC Systems	20	1.1					0.55
8	Automatic Fire Detection	12	0.66	6	Smoke Detection	4	0.51	0.59
9	Fire Alarm System	15	0.83	5	Fire Alarm	6	0.77	0.8
10	Smoke control	4	0.22	8	Smoke Control	4	0.51	0.37
11	Means of Egress	1	0.06	10	Exit System	11	1.4	0.73
12	Dead ends	4	0.22	9	Exit Access	5	0.64	0.43
13	Maximum Exit Access Travel Distance	40	2.21	9	Exit Access			1.1
14	Elevator Control	8	0.44					0.22
15	Means of Egress Emergency Lighting	4	0.22					0.11
16	Mixed Occupancies	10	0.55					0.28
17	Automatic Sprinklers	24	1.33	4	Automatic Sprinklers	12	1.53	1.43
18	Incidental Use	4	0.22	2	Segregation of Hazards	7	0.89	0.56
				7	Interior Finish	5	0.64	0.32
				12	Occupant Emergency Program	5	0.64	0.32
	Totals	326	18			94	12	15

Example for percentage weight calculation:

For Construction: = (AVR / Total AVR)*100% = (1.72/15) *100%=11.49%

3.3.4 The proposed model for measuring the compatibility of buildings

Existing occupancy:

Number of stories:

Year building was constructed:

Area per floor:

Type of construction:

Table (3.8): Code Compliance Review Check List

Safety Parameters		Code reference for safety factors	Compatibility state		Parameter weight
			Ok	**Not ok**	
1.	Construction • Building Height • Building Area	IBC 503			18.85%
2.	Vertical Openings (atriums) • Automatic sprinkler protection • Fire alarm system. • Interior Finish	IBC 404 NFPA 8.6.7			17.92%
3.	Compartmentation • Smoke Barrier Penetration	IBC 3412.6.3			3.68%
4.	Unit Separations	IBC 709.3			1.47%
5.	Corridor Partitions/Walls • Corridor width • Dead Ends	IBC 1017 NFPA 7.1.3.1 NFPA18.3.6.2. 2,IBC 1017.3			6.11%
6.	Segregation of hazards/incidental use	NFPA 13.3.2			3.7%
7.	HVAC Systems	IBC 716 IBC 3412.6.7			3.68%

Safety Parameters		Code reference for safety factors	Compatibility state		Parameter weight
			Ok	Not ok	
8.	Fire Detection	IBC 909 NFPA 9.6 33.3.3.4.8			3.91%
9.	Maximum Exit Access travel distance	IBC 3103.4			7.36%
10.	Smoke Control	IBC 716.2			2.44%
11.	Exit System(<u>Means of Egress)</u> • Exit signs • Illumination level. • Areas of refuge • Interior Stairs	IBC 1001 NFPA 3.3.1 NFPA 3.3.18			4.85%
12.	Dead End /Exit access	IBC 3412.6.12 NFPA 12.2.5 NFPA 13.2.5			2.87%
13.	Emergency Lighting	IBC 3412.6 NFPA 33.3.2.9			0.74%
14.	Elevator Controls	IBC 708.14			1.47%
15.	Fire Alarm	IBC 907 NFPA 38.3.4.1			5.33%
16.	Mixed Occupancies • Non separated occupancies • Separated occupancies	IBC 508.3.2 NFPA 6.1.14.3 NFPA 6.1.14.4 IBC 508.3.3			1.84%
17.	Automatic Sprinklers	IBC 903 NFPA 12.3.5.2, NFPA 12.3.5.3			9.52%
18.	Interior Finishes • Wall and ceiling Rooms • Wall and ceiling/exit access • Floors	IBC 801 NFPA 10.2.1 NFPA33.3.3.3			2.13%
19.	Occupant Emergency program	NFPA 38.4.2			2.13%
	Total compatibility percent				%

3.4 Evaluation the Degree of Compliance with fire safety factors System Code Requirements

Note: Most of requirements was taken from NFPA as standards because it has minimum and the simplest view for requirements.

A. Construction.

NFPA (8.5.1) Construction types are classified in accordance with the definitions of NFPA 220, Standard on Types of Building Construction, NFPA220: Non-combustible Material: *NFPA 220 (4.1.5.1*)* the material that complies with any of the following shall be considered a non-combustible material:

The material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors, when subjected to fire or heat, Examples of such materials include steel, concrete, masonry and glass.

Table (3.9): construction requirements, NFPA.

Fire Resistance Ratings for Type I through Type V Construction (hr)										
	Type I		**Type II**			**Type III**		**Type IV**	**Type V**	
	442	**332**	**222**	**111**	**000**	**211**	**200**	**2HH**	**111**	**000**
Exterior bearing Walls										
supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	2	2	2	1	0
Supporting one floor only	4	3	2	1	0	2	2	2	1	0
Supporting a roof only	4	3	1	1	0	2	2	2	1	0
Interior Bearing Walls										
supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	2	1	0
Supporting one floor only	3	2	2	1	0	1	0	1	1	0
Supporting a roof only	3	2	1	1	0	1	0	1	1	0

Columns supporting more than one floor, columns, or other bearing walls	4	3	2	1	0	1	0	H	1	0
Supporting one floor only	3	2	2	1	0	1	0	H	1	0
Supporting a roof only	3	2	1	1	0	1	0	H	1	0
Beams, girders, Trusses, and Arches supporting more than one floor, columns, or othe bearing walls	4	3	2	1	0	1	0	H	1	0
Supporting one floor only	2	2	2	1	0	1	0	H	1	0
Supporting a roof only	2	2	1	1	0	1	0	H	1	0

B. Mixed Occupancy.

A multiple occupancy where the occupancies are intermingled, IBC 3412.6.16 Mixed occupancies. Where a building has two or more occupancies that are not in the same occupancy classification, for business occupancy 2 hours fire barrier must be between mixed occupancy.

Table (3.10): Required separation of occupancies, NFPA.

Occupancy	Apartment Buildings	Board & Care Small	Board & Care Large	Mercantile	Mercantile, Mall	Mercantile, Bulk Retail	Business	Industrial General Purpose	Industrial Special-Purpose	Industrial High	Storage, Law & Ordinary hazard	Storage High
Assembly ≤ 300	2	2	2	2	2	3	1	2	2	3	2	3
Assembly >300 to ≤1000	2	2	2	2	2	3	2	2	2	3	2	3
Assembly >1000	2	2	2	2	2	3	2	3	2	3	3	3
Educational	2	2	2	2	2	3	2	3	3	3	3	3
Business								2	2	2	2	2

C. Compartmentation

NFPA (8.2.1.1) Zoning must divide the building into units that consist of one or more complete fire/smoke zones. A fire/smoke zone is a portion of a building that is separated from all other portions of the building by vertical or horizontal fire barriers(Tests reported by the Gypsum Association in the Fire Resistance Design Manual indicate that two layers of 16-mm (5⁄8-in.), fire-rated, Type X gypsum wallboard, applied at right angles to the underside of nominal 50 mm ,250 mm (nominal 2 in. 10 in.) wood joists and spaced 610 mm (24 in.) on centers, with the face layer of the gypsum board offset by 610 mm (24 in.) from the base layer joints, will provide 1-hour fire resistance protection for the wood framing**.)** having at least a 1-hour fire resistance rating or vertical smoke barriers conforming to the requirements of Section 8.5 (NFPA 101), or a combination of both. Any vertical openings (shafts, stairs) involved also must provide 1-hour separation.

D. Smoke Control

NFPA (3.3.35.2*) *Smoke Compartment:* A space within a building enclosed by smoke barriers on all sides, including the top and bottom.

NFPA (9.5.13.1) the active smoke control value should be used when an engineered smoke control system complying with NFPA92, Standard for Smoke Control Systems, is installed and the building is protected throughout by an approved, supervised automatic sprinkler system in accordance with Section 9.7 (NFPA *101*).

NFPA (9.5.13.2) The passive smoke control with auto-closing doors value should be used when the building is subdivided into compartments by smoke partitions having a 1-hour fire resistance rating complying with Section 8.4 (NFPA101), and all doors located within the smoke partition are designed to close automatically upon the activation of the fire alarm system or the fire sprinkler system per NFPA 72, It is imprecise to refer to a ‘‘1-hour smoke barrier.’’

Table (3.11): smoke control.

Type of Assembly		**Required Assembly Rating (hours)**	**Minimum Fire Window Assembly Rating (hours)**
Interior walls	Fire walls	All	Npa
	Fire barriers	> 1 1	Npa ¾
	Smoke barriers	1	¾
	Fire partitions	1 ½	3/4 1/3
Exterior walls		> 1 1	1 1/ 2 ¾
Party wall		All	NP

Table (3.12): Minimum Equivalent thickness of concrete fire rating wall, (Sturgeon, 2011).

Minimum required equivalent thicknesses for masonry and concrete (mm)							
Hours	**0.5**	**0.75**	**1**	**1.5**	**2**	**3**	**4**
Solid Brick (>80%)	63	76	90	108	128	152	178
Cored Brick (<80%)	50	60	72	86	102	122	142
Concrete Block	44	59	73	95	113	142	167

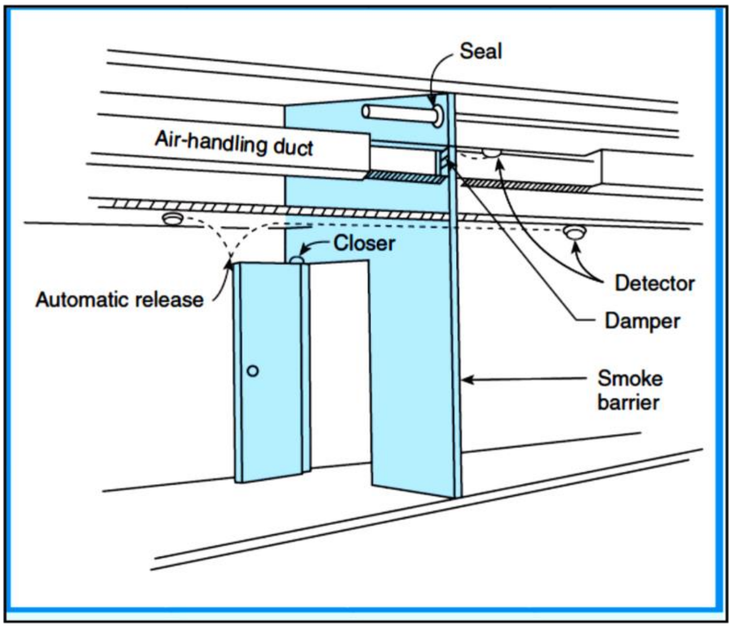

Fig (3.4): smoke barrier, NFPA.

E. Segregation of Hazards.

The assignment of charges for unsegregated hazardous areas is a four-step process. The charges against non-segregated areas are determined by four steps:

- Step 1: Identify the hazardous areas

- Step 2: Determine the level of hazard the levels of hazard are classified into two levels of structurally endangering and non-structurally endangering.

- Step 3: Determine the fire protection provided after the above two steps, the fire protection to be provided has to be determined. (NFPA 101 A) as showed in Table (3.12), Table (3.13), Hazardous Area Protection, (NFPA)

Table (3.13): Hazardous Area Descriptions, Protection and Separation.

Hazardous Area Descriptions Protection/Separation	Hours
Boiler and fuel-fired heater rooms	1 hour
Central/bulk laundries larger than 100 ft^2 ($9.3m^3$)	1 hour
Laboratories employing flammable or combustible materials in quantities less	See 18.3,6.3,3.11
than those that would be considered a several hazard	
Laboratories that use hazardous materials that would be classified as a sever	1 hour
Hazard in accordance with NFPA 99. Standard for health care Facilities	
Paint shops employing hazardous substances and materials in quantities less	1 hour
than those that would be classified as a sever hazard	
Physical plant maintenance shops	1 hour
Rooms with soiled linen in volume exceeding 64 gal (242 L)	1 hour
Storage rooms larger than 50 ft^2 ($4.6m^2$) but not exceeding 100 ft^2 (9.3 m^2) 18.3,6.3,3.11	See
and storing combustible material	
Storage rooms larger than 100 ft^2 (9.3 m^2) and storing combustible material	1 hour
Rooms with collected trash in volume exceeding 64 gal (242 L)	1 hour

Table (3.14): Incidental accessory occupancies, (NFPA).

ROOM OR AREA	SEPARATION AND/OR PROTECTION
Furnace room where any piece of equipment's is over 400000 Btu per hour input	1 hour or provide automatic fire-extinguishing system
Rooms with boilers where the largest piece of equipment is over 15 psi and horsepower	1 hour or provide automatic fire-extinguishing system
Refrigerant machinery room	1 hour or provide automatic sprinkler system
Hydrogen cutoff rooms. Not classified as Group H	1 hour in Group B, F, M, S and U occupancies ; 2 hours in Group A, E, I and R occupancies
Incinerator rooms	2 hours and automatic sprinkler system
Paint shops. Not classified as Group H. located in occupancies other than Group F	2 hours; or 1 hour and provide automatic fire-extinguishing system
Laboratories and vocational shops. Not classified as Group H. located in a Group E or 1-2 occupancy	1 hour or provide automatic fire-extinguishing system
Laundry rooms over 100 square feet	1 hour or provide automatic fire-extinguishing system
Group 1-3 cells equipped with padded surfaces	1 hour
Group 1-2 waste and linen collection rooms	1 hour

Waste and linen collection rooms over 100 square feet	1 hour or provide automatic fire-extinguishing system
Stationary storage battery systems having a liquid electrolyte capacity of more than 50 gallons, or a lithium-ion capacity of 1000 pounds used for facility standby power, emergency power or uninterrupted power supplies	1 hour in Group B, F, M, S and U occupancies ; 2 hours in Group A, E, I and R occupancies
Rooms containing fire pumps in non-high-rise buildings	2 hours; 1 hour and provide automatic sprinkler system throughout the building
Rooms containing fire pumps in high-rise buildings	2 hours

F. Vertical openings

These values apply to vertical openings and penetrations including exit stairways, ramps, and any other vertical exits, pipe shafts, ventilation shafts, duct penetrations, and laundry and incinerator chutes. Openings through floors shall be enclosed with fire barrier walls, shall be continuous from floor to floor, or floor to roof, and shall be protected as appropriate for the fire resistance, NFPA (8.6.5*) Required Fire Resistance Rating. The fire resistance rating for the enclosure of floor openings shall be not less than as follows (see 7.1.3.2.1 for enclosure of exits):

(1) Enclosures connecting four stories or more in new construction, 2-hour fire barriers

(2) Other enclosures in new construction,1-hour fire barriers, Existing vertical openings, regardless of the number of stories they connect, require protection by 1⁄2-hour fire resistance–rated enclosures.

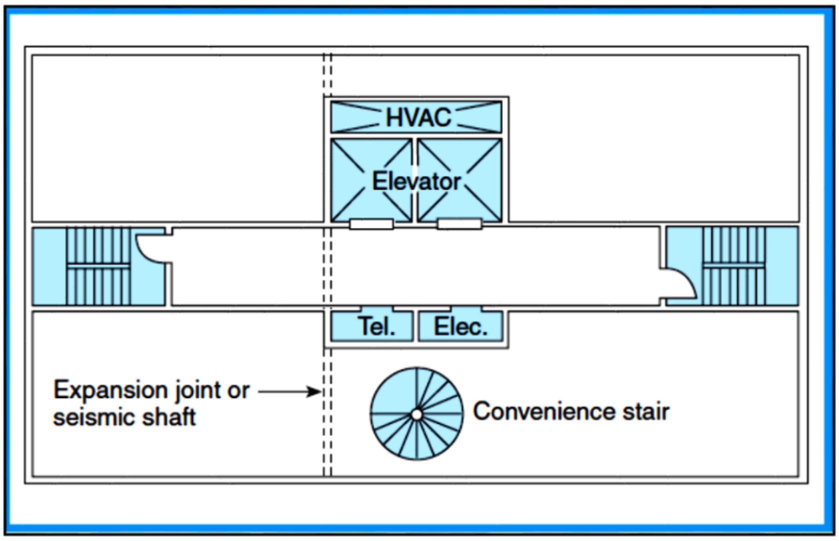

Fig (3.5): Vertical openings, NFPA.

Table (3.15): Minimum Fire Protection Rating for Opening Protectives, (NFPA).

Component	Walls and Partitions (hr)	Fire Door Assemblies (hr)	Fire Window Assemblies (hr)
Elevator hoist ways	2	1½	NP
	1	1	NP
Vertical shafts (including stairways, exits, and refuse chutes)	2	1½	NP
	1	1	NP
	½	⅓	NP
	3	3	NP
Fire barriers	2	1½	NP
	1	¾	¾
	½	⅓	⅓
Horizontal exits	2	1½	NP
Horizontal exits served by bridges between building	2	¾	¾
Exit access corridors	1	⅓	¾
	½	⅓	⅓
Smoke barriers	1	⅓	¾
Smoke partition	½	⅓	⅓

G. HVAC systems, (NFPA90B).

Evaluate the ability of the HVAC system to resist the movement of smoke and fire beyond the point of origin.

Air Dispersion Systems shall:

(1) Be installed entirely in exposed locations.

(2) Be utilized in systems under positive pressure.

(3) Not pass through or penetrate fire-resistant-rated construction.

(4) Be listed and labelled in compliance with UL 2518.

H. Interior Finish

NFPA (8.5.7.1) Classification of interior finish is based on the flame spread rating of the interior finish tested in accordance with ASTM E 84, Standard Test Method for Surface Burning Characteristics of Building Materials, The requirements apply to wall and ceiling finish materials as described in Table (3.15), (NFPA 101).

8.5.7.4 Any interior finish having a flame spread of 75 or less that is protected by automatic sprinklers is evaluated as having a flame spread not exceeding 25. Any interior finish having a flame spread of more than 75 but not more than 200 that is protected by automatic sprinklers is evaluated as having a flame spread not exceeding 75.

Table (3.16): Requirement of interior finish, NFPA.

Occupancy	**Exits**	**Exit Access Corridors**	**Other Spaces**
Mercantile Existing Class A or Class B stores	A or B	A or B	Ceilings - A or B; walls -A, B, or C
Class C stores	A, B, or C	A, B, or C	A, B, or C
Business and Ambulatory	A or B	A or B	A, B, or C
Health Care – New	I or II		NA
Business and Ambulatory	A or B	A or B	A, B, or C
Health Care -Existing			
Industrial	A or B	A, B, or C	A, B, or C
Storage	I or II	I or II	NA
	A or B	A, B, or C	A, B, or C
	I or II		NA

I. Fire Detection

IBC (907.6.3.2) High-rise buildings. In high-rise buildings, a separate zone by floor shall be provided for each of the following types of alarm-initiating devices where provided:

1. Smoke detectors.
2. Heat detectors.
3. Sprinkler water flow devices.
4. Manual fire alarm boxes.
5. Other approved types of automatic fire detection devices or suppression systems.

Table (3.17): fire detection.

Feature	No Suppression or Detection System Option 1	Complete Automatic Fire Detection Option 2	Automatic Sprinkler Protection in Selected areas Option 3	Automatic Sprinkler Protection Throughout per NFPA 13 (with exception Option 4
Exit Access				
Travel distance from apartment door	100 ft (30 m)	150 ft (45 m)	150 ft (45 m)	200 ft (61 m)
to exit				
Travel distance within apartment	75 ft (23 m)	125 ft (38 m)	75 ft (23 m)	125 ft (38 m)
Smoke barrier required (See 31.3.7.)	R	R	R	NR
Maximum single path corridor	35 ft (10.7 m)	35 ft (10.7 m)	35 ft (10.7 m)	35 ft (10.7 m)
distance				
Maximum dead end	50 ft (15 m)	50 ft (15 m)	50 ft (15 m)	50 ft (15 m)
Corridor fire resistance				
Walls	½ hr	½ hr	½ hr	½ hr
Doors (fire protection rating)	20 min. or 1¾ in	20 min. or 1¾ in	Smoke resisting	Smoke resisting
	(44 mm) thick	(44 mm) thick		
Interior Finish				
Lobbies and corridors	A or B	A or B	A or B	A, B, or C
Other spaces	A, B, or C	A, B, or C	A, B, or C	A, B, or C
Floors in corridors	I or II	I or II	NR	NR
Exits				
Wall fire resistance				
1–3 stories	1 hr	1 hr	1 hr	1 hr
>3 stories	2 hr	2 hr	2 hr	1 hr
Smokeproof enclosures				
Not high-rise	NR	NR	NR	NR
High-rise	R	R	R	NR
Door fire resistance				
1–3 stories	1 hr	1 hr	1 hr	1 hr
>3 stories	1½ hr	1½ hr	1½ hr	1 hr
Interior finish				
Walls and ceilings	A or B	A or B	A or B	A, B, or C
Floors	I or II	I or II	I or II	NR

J. Fire Alarm.

NFPA (9.6.1) The provisions of Section 9.6 cover the basic functions of a complete fire alarm system, including fire detection, alarm, and communications. These systems are primarily intended to provide the indication and warning of abnormal conditions, the summoning of appropriate aid, and the control of occupancy facilities to enhance protection of life.

K. Automatic Sprinklers

NFPA (8.5.4.1) where an automatic sprinkler is installed for either total or partial building coverage, the system shall be in accordance with the requirements of NFPA13, Standard for the Installation of Sprinkler Systems.

NFPA (8.5.4.2) to receive credit for protection, the sprinkler system must be equipped with an automatic alarm initiating device that activates the building manual fire alarm system or otherwise sounds an alarm sufficiently audible to be heard in all occupied areas.

L. Travel Distance to Exits.

NFPA (38.2.6) *Travel distance***:** is that length of travel to an exterior exit door.

NFPA (38.2.6.1) in buildings protected throughout by an approved, supervised automatic sprinkler system in accordance with 9.7.1.1(1), the travel distance shall not exceed 91 m (300 ft.).

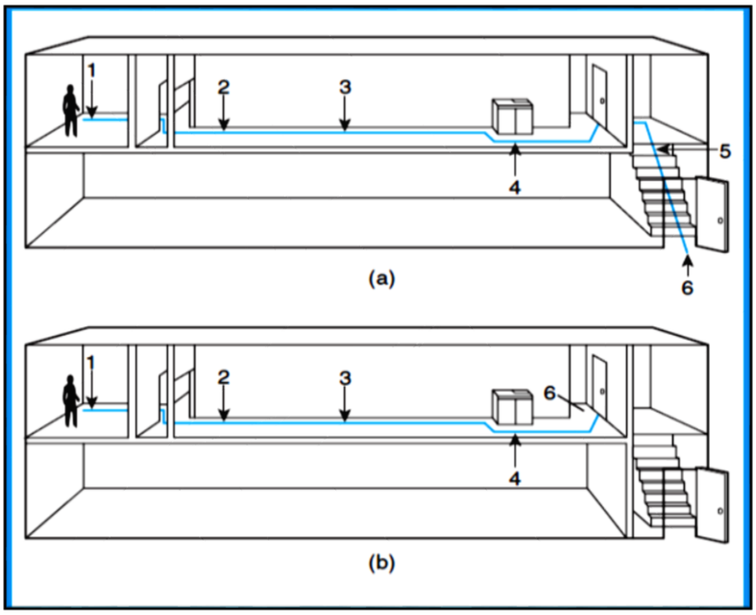

Fig (3.6): Travel distance, NFPA

M. Exit Access (Dead End)

NFPA (8.5.9.1) the charge for dead-end access is made where any corridor affords access in only one direction to a required exit. A dead end can exist where there is no path of travel from an occupied space but can also exist where an occupant enters a corridor thinking there is an exit at the end and, finding none, is forced to retrace his or her path to reach a choice of exits.

8.5.9.3 The 50 ft. (15 m) dead-end limit is applicable to existing buildings or new fully sprinklered buildings. A value of 20 ft. (6.1 m) should be used for other new buildings.

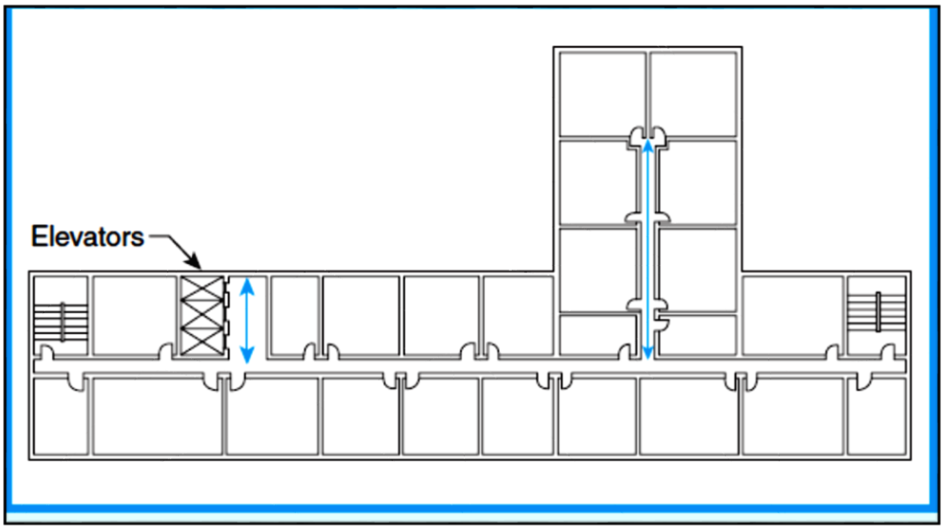

Fig (3.7): Dead Ends, NFPA.

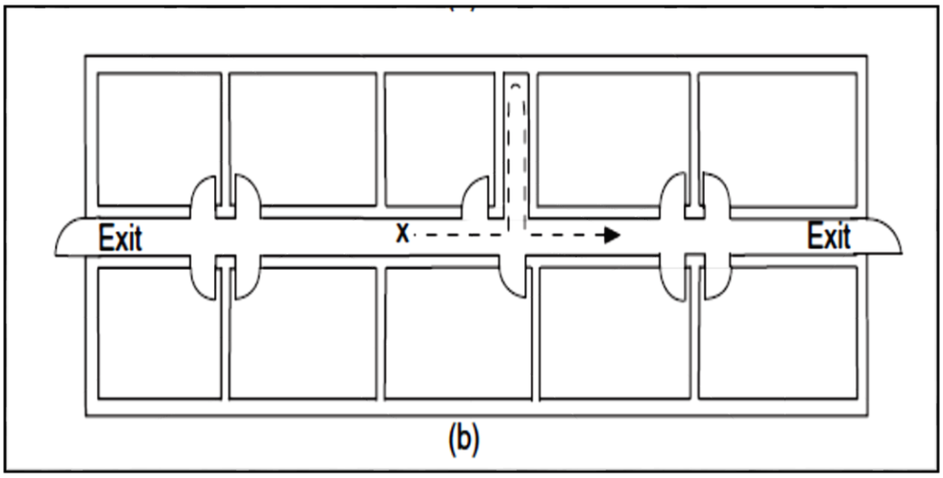

Fig (3.8): Dead Ends, NFPA.

Table (3.18): Dead End Limit, (NFPA).

Type of Occupancy	Common Path Limit				Dead-End Limit				Travel Distance Limit			
	Unsprinklered		Sprinklered		Unsprinklered		Sprinklered		Unsprinklered		Sprinklered	
	ft.	m	ft.	m	ft.	m	ft.	m	ft.	m	ft.	M
Assembly												
New	20/75	6.1/23a	20/75	6.1/23a	20	6.1	20	6.1	200	61	250	76
Existing	20/75	6.1/23a	20/75	6.1/23a	20	6.1	20	6.1	200	61	250	76
Educational												
New	75	23	100	30	20	6.1	50	15	150	45	200	61
Existing	75	23	100	30	20	6.1	50	15	150	45	200	61
Business												
New	75	23	100	30	20	6.1	50	15	200	61	300	91
Existing	75	23	100	30	50	15	50	15	200	61	300	91

N. Egress Route.

NFPA (8.5.10.1) Egress routes are the paths of travel from any point within a room to the public way using any types and arrangements described in Sections 38.2 or 39.2 (NFPA *101*).

i. NFPA (38.2.3) Capacity of Means of Egress.

Occupant Load Factor: The occupant load in any building or portion therefor shall be not less than the number of persons determined by dividing the floor area assigned to that use by the occupant load factor for that use as specified in Table 7.3.1.2 **(**Classrooms 1.9m² per person net, Shops, laboratories, vocational rooms 4.6 m² per person, Bench-type seating 1 person/455mm , Exits shall be provided for the waiting spaces on the basis of one person for each 0.28 m² (3 ft²) of waiting space area.

Table (3.19): Occupant load factor.

Use	**(ft² per person)**	**(m² per person)**
Assembly Use		
Concentrated use, without fixed seating	7 net	0.65 net
Less concentrated use, without fixed seating	15 net	1.4 net
Bench-type seating	1 person/18 linear in.	1 person/455 linear mm
Fixed seating	Number of fixed seats	Number of fixed seats

Waiting spaces	See 12.1.7.2 and 13.1.7.2.	See 12.1.7.2 and 13.1.7.2.
Kitchens	100	9.3
Library stack areas	100	9.3
Library reading rooms	50 net	4.6 net
Swimming pools	50 (water surface)	4.6 (water surface)
Swimming pool decks	30	2.8
Exercise rooms with equipment	50	1.6
Exercise rooms without equipment	15	1.4
Stages	15 net	1.4 net
Lighting and access catwalks, galleries, gridirons	100 net	9.3 net
Casinos and similar gaming areas	11	1
Skating rinks	50	4.6
Educational Use		
Classrooms	20 net	1.9 net
Shops, laboratories, vocational rooms	50 net	4.6 net
Business Use (other than below)	100	9.3
Air traffic control tower observation levels	40	3.7

Table (3.20): Stairway capacity factor.

Area	**Stairways width per person**	
	in.	mm
Board and care	0.4	10
Health care, sprinklered	0.3	7.6
Health care, nonsprinklered	0.6	15
High hazard contents	0.7	18
All others	0.3	7.6

ii. NFPA (7.3.4) Minimum Width.

7.3.4.1 The width of any means of egress, not less than 915 mm (36 in).

iii. NFPA (38.2.4) Number of Exits.

NFPA (38.2.4.1) Exits shall comply with the following except as otherwise permitted by 38.2.4.2 through 38.2.4.6:

- The number of means of egress shall be in accordance with Section 7.4., The number of means of egress from any story or portion thereof, other than for existing buildings as permitted in Chapter 12 through Chapter 42, shall be as follows:

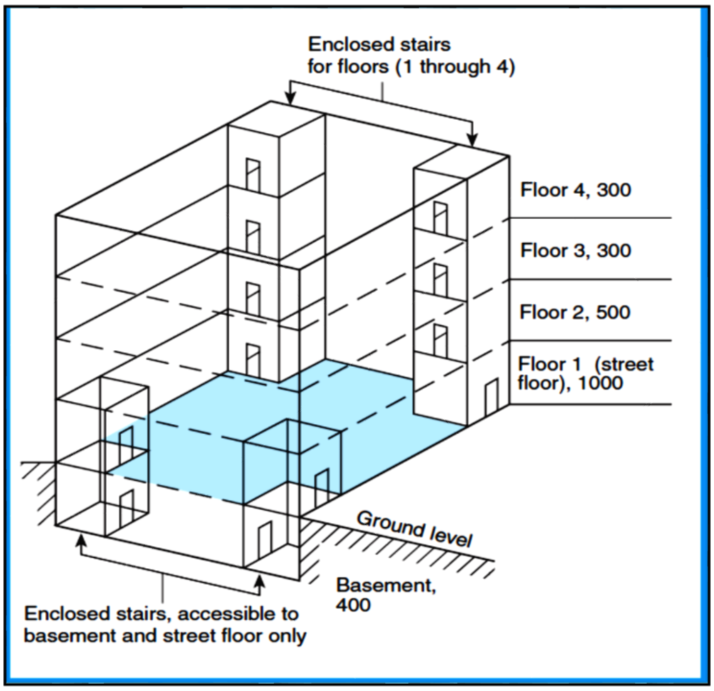

Fig (3.9): Exit Capacity for each floor, NFPA.

(1) Occupant load more than 500 but not more than 1000—not less than 3.

(2) Occupant load more than 1000—not less than 4.

(3) Not less than two separate exits shall be provided on every story.

(4) Not less than two separate exits shall be accessible from every part of every story.

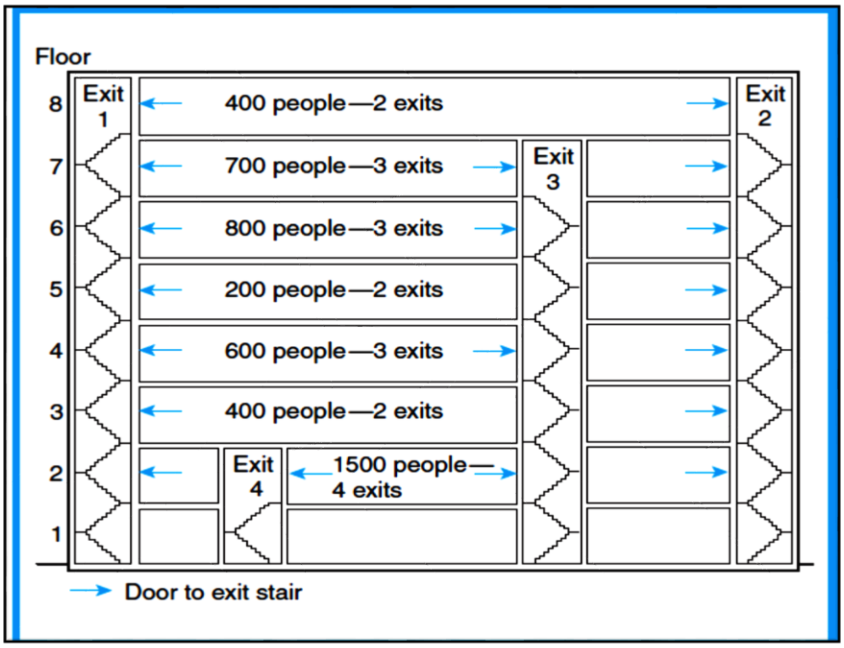

Fig (3.10): Minimum number of means of Egress, NFPA.

iv. Stairway Marking.

NFPA (7.2.2.5.4.1) Stairs serving five or more stories shall be provided with special signage within the enclosure at each floor landing. The signage shall indicate the floor level, the terminus of the top and bottom of the stair enclosure, and the identification of the stair enclosure. The signage also shall state the floor level of, and the direction to, exit discharge.

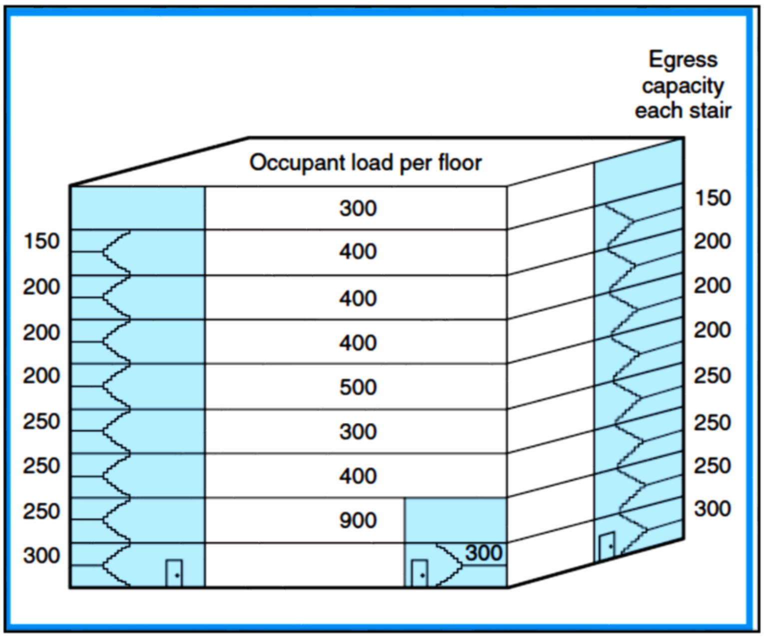

Fig (3.11): Capacity of exit stairs, NFPA.

v. Illumination of Means of Egress.

NFPA (7.8.1.3*) the floors and other walking surfaces within an exit and within the portions of the exit access and exit discharge designated in 7.8.1.1 shall be illuminated as follows:

(1) During conditions of stair use, the minimum illumination for new stairs shall be at least 108 lux (10 ft-candle), measured at the walking surfaces.

(2) The minimum illumination for floors and walking surfaces, other than new stairs, shall be to values of at least 10.8 lux (1 ft-candle), measured at the floor.

O. Emergency Illumination of Means of Egress

NFPA (7.9.2.2*) The emergency lighting system shall be arranged to provide the required illumination automatically in the event of any interruption of normal lighting due to any of the following:

(1) Failure of a public utility or other outside electrical power supply.

(2) Opening of a circuit breaker or fuse.

(3) Manual act(s), including accidental opening of a switch controlling normal lighting facilities.

NFPA (7.9.2.1*) Emergency illumination shall be provided for not less than 1(1⁄2) hours in the event of failure of normal lighting.

P. Occupant Emergency Program.

This is on fire safety management and should be considered carefully. It is suggested to keep a 'fire safety manual' in the new British Standard on Fire Safety Engineering Provisions that should be part of the emergency preplan include the following:

- Measures for alerting employees.
- Identification and posting of exit access routes.
- Establishment of group assembly areas for occupants once they have evacuated the building.
- Procedures for determining that all employees have safely evacuated 21.7.2.2 Fire Safety Plan.
- By taking a training course.

A written fire safety plan shall provide for the following:

(1) Use of alarms.

(2) Transmission of alarm to fire department.

(3) Response to alarms.

(4) Isolation of fire.

(5) Evacuation of immediate area.

Q. Elevator control , Power and Control Wiring

NFPA (7.2.13.7*), IBC (3412.6.14) Elevator machine rooms that contain solid-state equipment for elevator operation shall be provided with an independent ventilation or air-conditioning system to protect against the overheating of the electrical equipment. The system shall be capable of maintaining temperatures within the range established for the elevator equipment. Elevator equipment, elevator communications, elevator machine room cooling, and elevator controller cooling shall be supplied by both normal and standby power. Wiring for power and control shall be located and properly protected to ensure at least 1 hour of operation in the event of a fire.

R. Corridor/Room Separation

(7.1.3.1) Exit Access Corridors, 14.3.6 Corridors:

Corridors shall be separated from other parts of the story by walls having a 1-hour fire resistance rating in accordance with Section 8.3, unless otherwise permitted by the following:(1) Corridor protection shall not be required where all spaces normally subject to student occupancy have not less than one door opening directly to the outside or to an exterior exit access balcony or corridor. (2) In buildings protected throughout by an approved, supervised automatic sprinkler system.

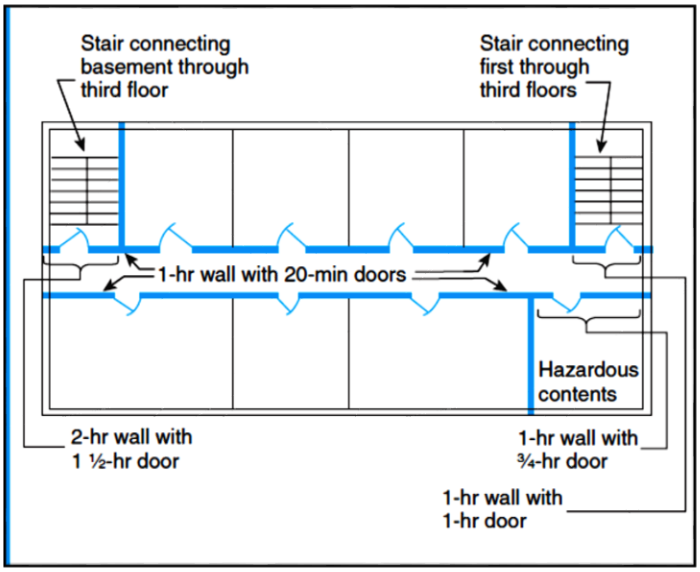

Fig (3.12): Protection of corridors, NFPA.

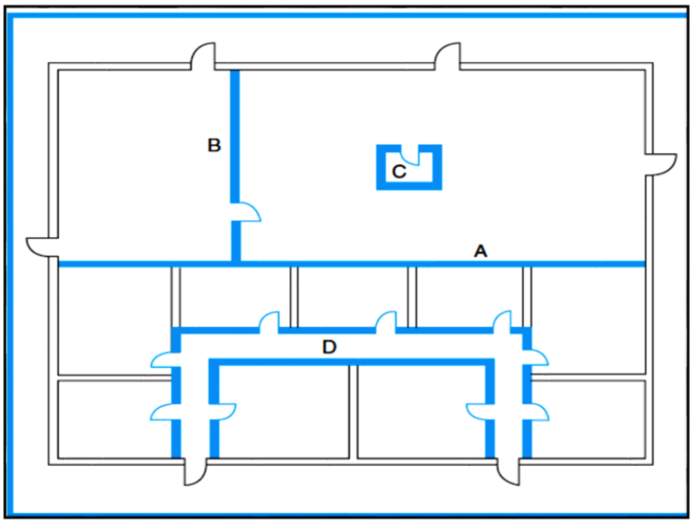

Fig (3.13): typical fire barriers, NFPA.

S. Tenant and dwelling unit separations.

Evaluate the fire-resistance rating of floors and walls separating tenants, including dwelling units.

Table (3.21): Tenant and dwelling unit separations, IBC.

Classifying occupancy		**Individuals grouping(A-2)**
Industrial (I)	i-1	****
	i-2	2
	i-3	1*
Commercial (C)	C	2
Occupantail management	O	1
Dwelling	D1	1
	D2	1
Organization	R1	2
	R2	2
Individuals grouping	A1	1
	A3	1
	A4	1

*In Parking Building separation will be 1.5hour at least

*** Not allowed to be in the same building

Chapter 4

Results and Discussion

This Chapter includes analysis and discussion of the results that have been collected from Islamic University (IUG) buildings survey. Three buildings have chosen and the proposed framework has been applied to measure the degree of compatibility of buildings in the Islamic University with fire safety codes.

4.1 Scientific Laboratory Building

Scientific Laboratory Building was selected as an example of modern buildings that contain the technology in its equipment and it contains laboratories and stores of chemicals.

4.1.1 General Description

- Scientific laboratory building is located in the south-eastern side of the Islamic University and consists of a basement, ground floor and six upper floors, with 4 meters height to each one and with total height up to 29.55 m.
- The total area of the building is 2023 m^2 which include the horizontal open spaces like vertical openings (stairs, elevators) and skylight service opening bedsides the area of external walls.
- Structural system consists of two main components (columns and beams in the slabs) which the material of their construction is reinforced concrete.
- The Scientific laboratory building includes underground floor which has the Centre of Environment which has laboratories, stores of chemicals and glassware besides administrative and services rooms, also the ground floor and six floors include repeated Student Affairs, admissions, financial, administrative and services rooms, also sections of "physics, environment, earth sciences, medical analysis, biology, medical optics and mathematics''

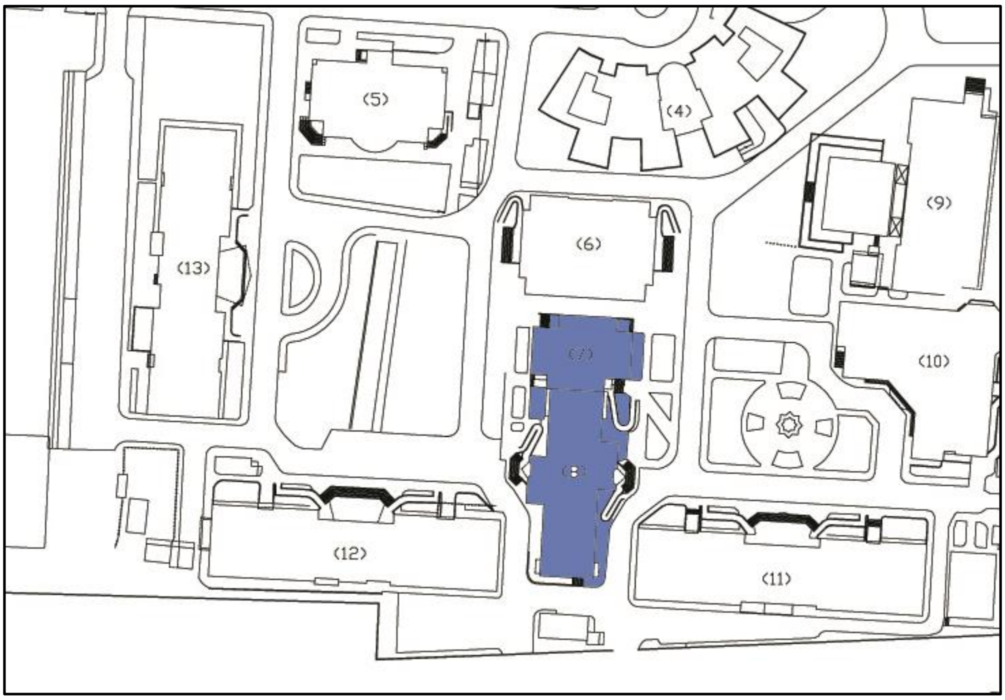

Fig (4.1): Scientific Laboratory Building.

4.1.2 Evaluation The Degree of Compliance with fire safety factors System Code Requirements:

A) Construction.

- **Current state:**

Building elements (columns, beams and slabs) consist of reinforced concrete material that provides 4 hours of fire resistance.

- **Degree of Compliance:** Code requires 1 hour at least and have 4 hours so it's ok.

B) Mixed Occupancy.

- **Current state:**

- The Scientific laboratory building includes underground floor which has the Centre of Environment which has laboratories, stores of chemicals and glassware besides administrative and services rooms, also the ground floor and six floors include repeated Student Affairs, admissions, financial, administrative and services rooms, also sections of "physics, environment, earth sciences, medical analysis, biology, medical optics and mathematics'' .

- building rooms subdivided by concrete hollow blocks which resist with 2hour at least
    - **Degree of Compliance:** It’s ok.

C) Compartmentation

- **Current state:**
  There isn’t any fire wall divides each floor in the building to fire zones, because the area of each floor equal to 2023 m^2 and each fire zone must be 400 m^2 so each floor must divide to 5 zones .
- **Degree of Compliance:** It’s not ok.

D) Smoke Control

- **Current state:**
- The active smoke control was installed, which include addressable smoke detectors in each zone that connected to master fire alarm control panel.
- The passive smoke control is applicable, building rooms subdivided by concrete hollow blocks which resist with 2 hour at least.
- **Degree of Compliance:** It’s ok.

E) Segregation of Hazards.

- **Current state:** the underground floor includes the Centre for Environment which has laboratories, stores of chemicals and glassware (that classified as a hazard area), besides administrative and services rooms**,** building rooms subdivided by concrete hollow blocks which resist with 2 hour at least.
- **Degree of Compliance:** It’s ok.

F) Vertical openings.

- **Current state:**
  The building include 4 external exist stairways in the Ground Floor for escape and 4 internal stairways connect the floors, also it has 2 atriums, both of them hasn’t any fire protection such (fire wall or partition, fire door and fire window) which must protected by 2 hours fire separation, however it includes 4 elevators surrounded by reinforce concrete walls that protect against fire for 4 hours.
- **Degree of Compliance:** It’s ok.

G) NFPA90B HVAC systems.

- **Current state:**

  The building provided with grills that connected with ducts include motorized volume damper which directs the air flow in a particular direction and prevents the passage of large items and pull out the vitiated air from bathrooms, kitchens, labs, and other floor rooms beside air handling unit, centrifugal fan and air compressors.

- **Degree of Compliance:** It's ok.

H) Interior Finish

- **Current state:**

  The interior finishing that consist of walls, roofs and grounds finishing presented as below:

- Walls finishing presented by using (white Acrylic paint with 25flame spread ,matte oil painting with 35-50 flame spread , Italy ceramic with 0 flame spread, porcelain with flame spread $\leq$ 25).
- Roofs finishing presented by using (white Acrylic paint and gypsum rented ceiling with 15-20 flame spread)
- Grounds finishing presented by using (porcelain, Mosaic Tiles with flame spread $\leq$ 25, Italy ceramic).

- **Degree of Compliance:** All interior finish have class A, so it's ok.

I) Fire Detection

J) Fire Alarm.

- **Current state for factor (I and J):**

  The building provided by fire alarm system represented by addressable smoke detectors, heat detectors , horns and Manual fire alarm activation devices such as break glass distributed through floors of the building and all of them connected to alarm control panel with four addressable loops.

- **Degree of Compliance:** It's ok.

K) Automatic Sprinklers.

- **Current state:** The building provided with Manual control extinguisher system that include the manual gas and powder extinguishers and Standpipe system which represented by fire rolls (Lahafot) type beside Galvanized iron pipes which used on fire Extinguishing to provide stand pipe system with water, however there isn't automatic sprinkling system in the building

- **Degree of Compliance:** Ok for manual fire extinguishing system but not ok for automatic sprinkler system.

L) Travel Distance to Exits.

- **Current state:**
  The travel distance from the most remote point in the floor does not exceed 60 or 90 m.
- **Degree of Compliance:** It's ok.

M) Exit Access (Dead End).

- **Current state:**
  The dead end distance from the most remote point in the floor equal approximately 15m.
- **Degree of Compliance:** It's ok.

N) Egress Route.

- **Current state:**

- The building include 2 main egress exists each one with 3.8m width from the north and south side of the building, also it includes 8 exists with 1.75m width for each one around the building , then the total width for egress exists equal 21.6 m .
- Each floor has occupant load approximately equal 400 person per floor and each floor has 4 exists represented by stairways with 1.5m width, then the total width of stairways exists equal 6m with Egress capacity equal (6000mm/7.6mm=790 person) for all stairs that connected two floors .

- **Degree of Compliance:** It's ok.

i. Stairway Marking.

- **Current state:**

There is a stairway and exist marking which indicate to egress exist access in the building.

- **Degree of Compliance:** It's ok.

ii. Illumination of Means of Egress.

- **Current state:**

All building provided by illumination with 18, 32 and 36 watt fluorescent distributed in all rooms, corridors, stairways, exists and every place needs light.

- **Degree of Compliance:** It's ok.

O) Emergency Illumination of Means of Egress.

- **Current state:**

The building is provided with emergency lighting which located in corridors, waiting halls, stairways, lounges and Halls with wide spaces among all floors.

- **Degree of Compliance:** It's ok.

P) Occupant Emergency Program.

- **Current state:**

There isn't any applicable fire safety plan and training courses for workers in the building hasn't done, also all fire alarm systems are inactive.

- **Degree of Compliance:** It's not ok.

Q) Elevator control ,Power and Control Wiring

- **Current state:** There isn't any room for elevator services control in the building.
- **Degree of Compliance:** It's not ok.

R) Corridor/Room Separation

- **Current state:**

According to code provision there isn't a need for corridor walls to be rated for fire.

- **Degree of Compliance:** It's ok.

S) Tenant and dwelling unit separations.

- **Current state:**

There isn't a dwelling units in the building.

- **Degree of Compliance:** It's ok.

4.1.3 CODE COMPLIANCE REVIEW CHECK LIST

Existing occupancy: scientific laboratories building in Islamic university

Number of stories: 7

Year building was constructed: 2013-2014

Area per floor: 2023 m^2

Type of construction: I and II structure

Table (4.1): the proposed model for measuring the compatibility of lab. Building

Safety Parameters		**Code reference for safety factors**	**Compatibility state**		**Parameter weight**
			Ok	**Not ok**	
1.	Construction • Building Height • Building Area	IBC 503	✓		18.85%
2.	Vertical Openings(atriums) • Automatic sprinkler protection • Fire alarm system. • Interior Finish	IBC 404 NFPA 8.6.7	✓		17.92%
3.	Compartmentation • Smoke Barrier Penetration	IBC 3412.6.3		✓	3.68%
4.	Unit Separations	IBC 709.3	✓		1.47%
5.	Corridor Partitions/Walls • Corridor width • Dead Ends	IBC 1017 NFPA 7.1.3.1 NFPA18.3.6.2.2 IBC 1017.3	✓		6.11%
6.	Segregation of Hazards/incidental use	NFPA 13.3.2	✓		3.7%
7.	HVAC Systems	IBC 716 IBC 3412.6.7	✓		3.68%
8.	Fire Detection	IBC 909 NFPA 9.6 33.3.3.4.8	✓		3.91%
9.	Maximum Exit Access travel distance	IBC 3103.4	✓		7.36%
10.	Smoke Control	IBC 716.2	✓		2.44%
11.	Exit System(Means of Egress) • Exit signs • Illumination level. • Areas of refuge • INTERIOR STAIRS	IBC 1001 NFPA 3.3.1 NFPA 3.3.18	✓		4.85%
12.	Dead End /Exit access	IBC 3412.6.12 NFPA 12.2.5 NFPA 13.2.5	✓		2.87%
13.	Emergency Lighting	IBC 3412.6 NFPA 33.3.2.9	✓		0.74%
14.	Elevator Controls	IBC 708.14		✓	1.47%

Safety Parameters		Code reference for safety factors	Compatibility state		Parameter weight
			Ok	Not ok	
15.	Fire Alarm	IBC 907NFPA 38.3.4.1	✓		5.33%
16.	Mixed Occupancies • Non separated occupancies • Separated occupancies	IBC 508.3.2 NFPA 6.1.14.3 NFPA 6.1.14.4 IBC 508.3.3	✓		1.84%
17.	Automatic Sprinklers	IBC 903 NFPA 12.3.5.2, NFPA 12.3.5.3		✓	9.52%
18.	Interior Finishes • Wall and ceiling Rooms • Wall and ceiling/exit access • floors	IBC 801 NFPA 10.2.1 NFPA33.3.3.3.2	✓		2.13%
19.	Occupant Emergency program	NFPA 38.4.2		✓	2.13%
	Total compatibility percent			83%	%

4.2 Educational staff and administration building

Educational staff and administration building was selected as an example of administrative buildings in the university which includes many of administrative offices.

4.2.1 General Description

- Educational staff and administration building is located in the eastern side of the Islamic University and consists of a basement, ground floor and four upper floors, with 3.84 meters height to each one and with total height up to 19.2 m.
- The total area of the building is 1603 m^2 approximately which include the horizontal open spaces like vertical openings (stairs, elevators) and skylight service opening bedsides the area of external walls.
- Structural system consists of two main components (columns, shear walls and beams in the slabs) which the material of their construction is reinforced concrete.
- Educational staff and administration building includes many of administrative offices for the presidency of the university, the Vice-Presidents, college chancellors, Office of Academic Affairs, e-learning, Engineering College , Arts ,

Education ,Sharia law colleges and graduate studies in addition to a conference room.

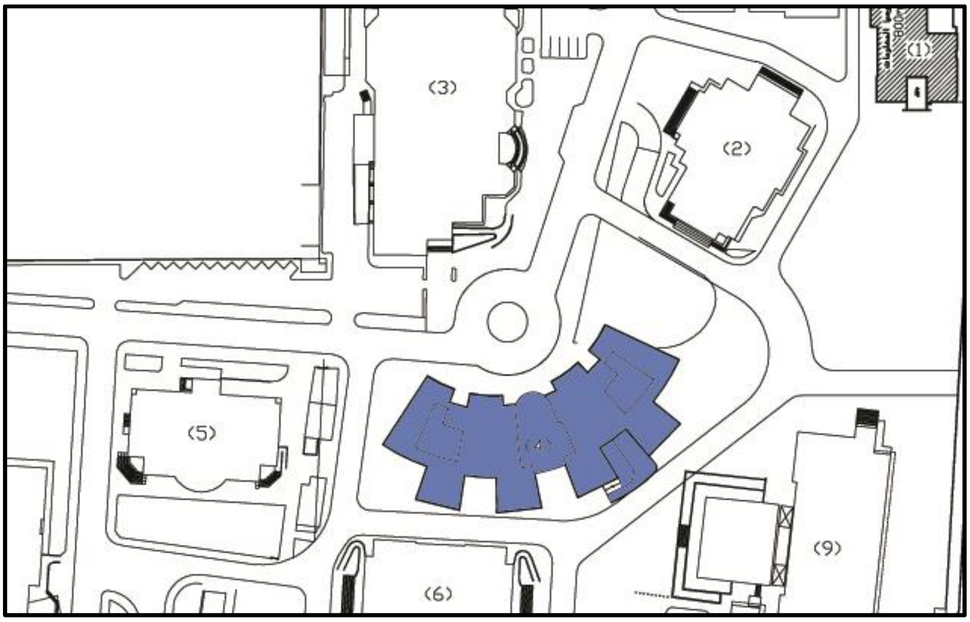

Fig (4.2): Educational staff and administration building.

4.2.2 Evaluation The Degree of Compliance with fire safety factors System Code Requirements:

A. Construction.

- **Current state:**

Building elements (columns, beams, shear walls and slabs) consist of reinforced concrete material that provides 4 hours of fire resistance.

- **Degree of Compliance:** It's ok.

B. Mixed Occupancy.

- **Current state:**

The building does not contain a different occupancy, it includes many of administrative offices for the presidency of the university, the Vice-Presidents, college chancellors, Office of Academic Affairs, e-learning, Engineering College , Arts , Education ,Sharia law colleges and graduate studies in addition to a conference room.

- **Degree of Compliance:** It's ok.

C. Compartmentation

- **Current state:**

There isn't any fire wall divides each floor in the building to fire zones, because the area of each floor equal to 1603 m^2 and each fire zone must be 400 m^2 so each floor must divide to 4 zones .

- **Degree of Compliance:** It's not Ok.

D. Smoke Control

- **Current state:**

- The active smoke control was installed, which include addressable smoke detectors in each zone that connected to master fire alarm control panel.
- The passive smoke control is applicable, building rooms subdivided by concrete hollow blocks which resist with 2 hour at least.

- **Degree of Compliance:** It's ok.

E. Segregation of Hazards.

- **Current state:**

There is a Mechanical Room beside an electrical room which surrounded by concrete hollow blocks wall which provide 2 hours fire resistance at least.

- **Degree of Compliance:** It's ok.

F. Vertical openings

- **Current state:**

The building include 4 external exist stairways and 3 internal stairway connect the floors surrounded by shear wall which resist 4hours against fire, also it includes 4 elevators surrounded by shear walls that protect against fire for 4 hours.

- **Degree of Compliance:** It's ok.

G. NFPA90B HVAC systems.

- **Current state:**

The building provided with Central air conditioning units with heat pump machine which contains internal and external unit , the internal unit include galvanized and isolated distribution boxes to measure the temperature of the room ,also air-conditioning machine include all flexible pipes for air transport, beside air exits(grills),isolated tin connectors and volume damper .

- **Degree of Compliance:** It's ok.

H. Interior Finish

- **Current state:**

The interior finishing that consist of walls, roofs and grounds finishing presented as below:

- Walls finishing presented by using (white Acrylic paint with 25flame spread ,matte oil painting with 35-50 flame spread , Italy ceramic with 0 flame spread, porcelain with flame spread ≤ 25).
- Roofs finishing presented by using (white Acrylic paint and gypsum rented ceiling with 15-20 flame spread)
- Grounds finishing presented by using (porcelain, Mosaic Tiles with flame spread ≤ 25, Italy ceramic).
  - **Degree of Compliance:** All interior finish have class A, so it's ok.

I. Fire Detection.

J. Fire Alarm.

- **Current state for factor (I and J):**

The building provided by fire alarm system represented by addressable smoke detectors, heat detectors , horns and Manual fire alarm activation devices such as break glass distributed through floors of the building and all of them connected to alarm control panel with four addressable loops.

- **Degree of Compliance:** It's ok.

K. Automatic Sprinklers.

- **Current state:**

The building provided with Manual control extinguisher system that include the manual gas and powder extinguishers and Standpipe system which represented by fire rolls (Lahafot) type beside Galvanized iron pipes which used on fire Extinguishing to provide stand pipe system with water, however There isn't automatic sprinkling system in the building .

- **Degree of Compliance:** Ok for manual fire extinguishing system but not ok for automatic sprinkler system.

L. Travel Distance to Exits.

- **Current state:**

The travel distance from the most remote point in the floor does not exceed 60 m.

- **Degree of Compliance:** It's ok.

M. Exit Access (Dead End)

- **Current state:**

The dead end distance from the most remote point in the floor equal approximately 15m.

- **Degree of Compliance:** It's ok.

N. Egress Route.

- **Current state:**

- The building include one main egress exist with 8.75m width, also it includes 3 exists two with 4.08m width and last one with 2m, then the total width for egress exists equal 18.91 m .
- Each floor has occupant load approximately equal 180 person per floor and each floor has 3 exists represented by stairways with 1.64m width for each, then the total width of stairways exists equal 6.56m with Egress capacity equal (1640/7.6mm=215 person) to stairs for two connected floors .

- **Degree of Compliance:** It's ok.

i. Stairway Marking.

- **Current state:**

There is a stairway and exist marking which indicate to egress exist access in the building.

- **Degree of Compliance:** It's ok.

ii. Illumination of Means of Egress.

- **Current state:**

All building provided by illumination with 18, 36 and 40 watt fluorescent distributed in all rooms, corridors, stairways, exists and every place needs light.

- **Degree of Compliance:** It's ok.

O. Emergency Illumination of Means of Egress

- **Current state:**

There isn't an emergency illumination system in the building.

- **Degree of Compliance:** It's not ok.

P. Occupant Emergency Program.

- **Current state:**

There isn't any applicable fire safety plan and training courses for workers in the building hasn't done, also all fire alarm systems are inactive.

- **Degree of Compliance:** It's not ok.

Q. Elevator control ,Power and Control Wiring

- **Current state:**

There is a Mechanical Room in the basement floor.

- **Degree of Compliance:** It's ok.

R. Corridor/Room Separation

- **Current state:**

  According to code provision there isn't a need for corridor walls to be rated for fire.

- **Degree of Compliance:** It's ok.

S. Tenant and dwelling unit separations.

- **Current state:**

There isn't a dwelling units in the building.

- **Degree of Compliance:** It's ok.

4.2.3 Code Compliance Review Check List

Existing occupancy: Educational staff and administration building in Islamic university

Number of stories: 5

Year building was constructed: 2002

Area per floor: 1063 m^2

Type of construction: I and II structure

The proposed model for measuring the compatibility of buildings:

Table (4.2): the proposed model for measuring the compatibility of Administration building.

Safety Parameters		**Code reference for safety factors**	**Compatibility state**		**Parameter weight**
			ok	**Not ok**	
1.	Construction • Building Height • Building Area	IBC 503	✓		18.85%

Safety Parameters		Code reference for safety factors	Compatibility state		Parameter weight
			ok	Not ok	
2.	Vertical Openings(atriums) • Automatic sprinkler protection • Fire alarm system. • Interior Finish	IBC 404 NFPA 8.6.7	✓		17.92%
3.	Compartmentation • Smoke Barrier Penetration	IBC 3412.6.3		✓	3.68%
4.	Unit Separations	IBC 709.3	✓		1.47%
5.	Corridor Partitions/Walls • Corridor width • Dead Ends	IBC 1017 NFPA 7.1.3.1 NFPA18.3.6.2.2 IBC 1017.3	✓		6.11%
6.	Segregation of Hazards/incidental use	NFPA 13.3.2	✓		3.7%
7.	HVAC Systems	IBC 716 IBC 3412.6.7	✓		3.68%
8.	Fire Detection	IBC 909 NFPA 9.6 33.3.3.4.8	✓		3.91%
9.	Maximum Exit Access travel distance	IBC 3103.4	✓		7.36%
10.	Smoke Control	IBC 716.2	✓		2.44%
11.	Exit System(Means of Egress) • Exit signs • Illumination level. • Areas of refuge • INTERIOR STAIRS	IBC 1001 NFPA 3.3.1 NFPA 3.3.18	✓		4.85%
12.	Dead End /Exit access	IBC 3412.6.12 NFPA 12.2.5 NFPA 13.2.5	✓		2.87%
13.	Emergency Lighting	IBC 3412.6 NFPA 33.3.2.9		✓	0.74%
14.	Elevator Controls	IBC 708.14		✓	1.47%

Safety Parameters		Code reference for safety factors	Compatibility state		Parameter weight
			ok	Not ok	
15.	Fire Alarm	IBC 907 NFPA 38.3.4.1	✓		5.33%
16.	Mixed Occupancies • Non separated occupancies • Separated occupancies	IBC 508.3.2 NFPA 6.1.14.3 NFPA 6.1.14.4 IBC 508.3.3	✓		1.84%
17.	Automatic Sprinklers	IBC 903 NFPA 12.3.5.2, NFPA 12.3.5.3		✓	9.52%
18.	Interior Finishes • Wall and ceiling Rooms • Wall and ceiling/exit access • Floors	IBC 801 NFPA 10.2.1 NFPA33.3.3.3.2	✓		2.13%
19.	Occupant Emergency program	NFPA 38.4.2		✓	2.13%
	Total compatibility percent		82.46%		%

4.3 Information Technological building

Information technology building has been chosen as a model-based representative for the teaching building at the university which includes several laboratories and teachers' rooms.

4.3.1 General Description

- Technological information building is located in the north east side of the Islamic University and consists of ground floor and five upper floors, with 4 meters height to each one and with total height up to 20 m.
- The total area of the building is 800 m² approximately which include the horizontal open spaces like vertical openings (stairs, elevators) and skylight service opening bedsides the area of external walls.
- Structural system consists of two main components (columns, shear walls and beams in the slabs) which the material of their construction is reinforced concrete.

- Technological information building includes several laboratories and teachers' rooms and rooms for(department heads , chancellor ,vice chancellor), as well as workshops and smart room , incubator rooms ,clerks room ,maintenance workshops , a conference room and rooms for the students training.

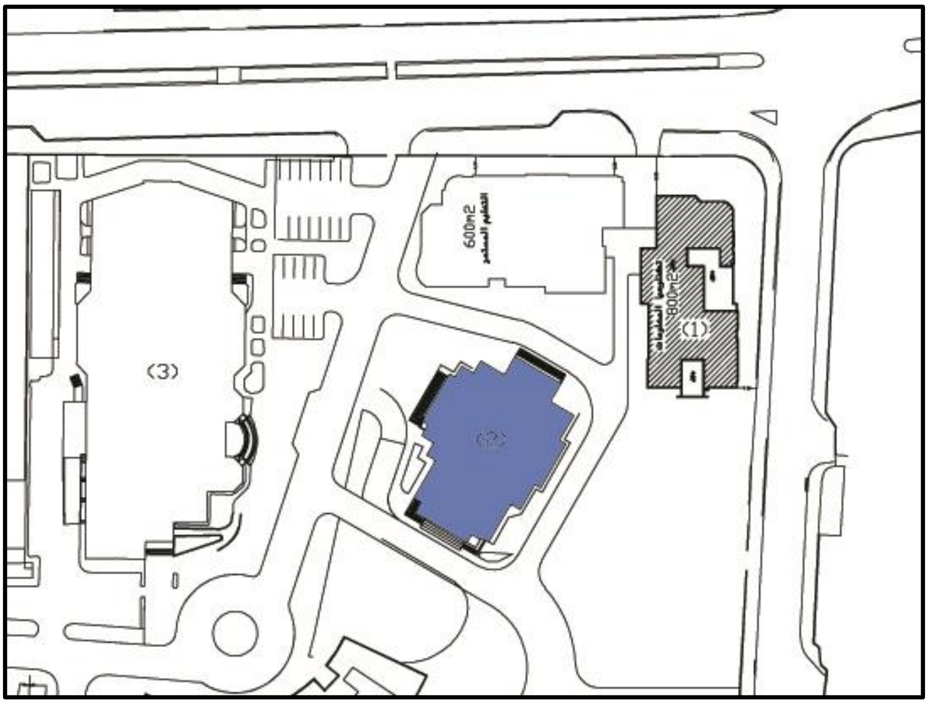

Fig (4.3): Technological information building.

4.3.2 Evaluation The Degree of Compliance with fire safety factors System

Code Requirements:

A. Construction.

- **Current state:**

Building elements (columns, beams, shear walls and slabs) consist of reinforced concrete material that provides 4 hours of fire resistance,

- **Degree of Compliance:** It’s ok.

B. Mixed Occupancy.

- **Current state:**

- The building does not contain a different occupancy, The building includes several laboratories and teachers' rooms and rooms for(department heads , chancellor ,vice chancellor)as well as workshops and smart room , incubator rooms ,clerks room ,maintenance workshops ,a conference room and rooms for the students training .

- **Degree of Compliance:** It's ok.

C. Compartmentation

- **Current state:**

There are doors from glass and aluminium divide each floor in the building to 3 fire zones, because the area of each floor equal to 800m² and each fire zone must be 400m² so each floor must divide to 2 zones ,the aluminium glazing door resist 1hour at least.

- **Degree of Compliance:** It's Ok.

D. Smoke Control

- **Current state:**

- The active smoke control was installed, which include addressable smoke detectors in each zone that connected to master fire alarm control panel.
- The passive smoke control is applicable, building rooms subdivided by concrete hollow blocks which resist with 2hour at least.

- **Degree of Compliance:** It's ok.

E. Segregation of Hazards.

- **Current state:**

  There is an electrical room which surrounded by concrete hollow blocks wall which provide 2hours fire resistance at least.

- **Degree of Compliance:** It's ok.

F. Vertical openings

- **Current state:**

The building include 2 internal exist stairways connect the floors surrounded by reinforced concrete wall which resist 4hours against fire and an entrance stairway lead to outdoors, also it includes 2 elevators surrounded by shear walls that protect against fire for 4 hours.

- **Degree of Compliance:** It's ok.

G. NFPA90B HVAC systems.

- **Current state:**

The building provided Central air suction machine with grills in order to pull the bad air from bathrooms, kitchens and halls but there isn't a Central air conditioning units.

- **Degree of Compliance:** It’s not ok.

H. Interior Finish

- **Current state:**

The interior finishing that consist of walls, roofs and grounds finishing presented as below:

- Walls finishing presented by using (white Acrylic paint with 25flame spread ,matte oil painting with 35-50 flame spread , Italy ceramic with 0 flame spread, porcelain with flame spread $\leq$ 25).
- Roofs finishing presented by using (white Acrylic paint and gypsum rented ceiling with 15-20 flame spread)
- Grounds finishing presented by using (porcelain, Mosaic Tiles with flame spread $\leq$ 25, Italy ceramic).

- **Degree of Compliance:** All interior finish have class A, so it’s ok.

I. Fire Detection.

J. Fire Alarm.

- **Current state for factor (I and J):**

The building provided by fire alarm system represented by addressable smoke detectors, heat detectors , horns and Manual fire alarm activation devices such as break glass distributed through floors of the building and all of them connected to alarm control panel with four addressable loops.

- **Degree of Compliance:** It’s ok.

K. Automatic Sprinklers.

- **Current state:**

The building provided with Manual control extinguisher system that include the manual gas and powder extinguishers and Standpipe system which represented by fire rolls (Lahafot) type beside Galvanized iron pipes which used on fire Extinguishing to provide stand pipe system with water, however There isn’t automatic sprinkling system in the building .

- **Degree of Compliance:** Ok for manual fire extinguishing system but not ok for automatic sprinkler system.

L. Travel Distance to Exits.

- **Current state:**

The travel distance from the most remote point in the floor less than 60 m.

- **Degree of Compliance:** It's ok.

M. Exit Access (Dead End)

- **Current state:**

The dead end distance from the most remote point in the floor less than 15m.

- **Degree of Compliance:** It's ok.

N. Egress Route.

- **Current state:**

- The building include one main egress exist with 11.8m width, also it includes one exist with 4.52m width, then the total width for egress exists equal 16.32 m.
- Each floor has occupant load approximately between(230,115,200) person per floor and each floor has 2 exists represented by stairways with 1.66m width for each, then the total width of stairways exists equal 6.64m with Egress capacity equal (1660/7.6mm=218 person) to stairs for two connected floors .

- **Degree of Compliance:** It's ok.

i. Stairway Marking.

- **Current state:**

There is a stairway and exist marking which indicate to egress exist access in the building.

- **Degree of Compliance:** It's ok.

ii. Illumination of Means of Egress.

- **Current state:**

All building provided by illumination with 36 and 40 watt fluorescent distributed in all rooms, corridors, stairways, exists and every place needs light.

- **Degree of Compliance:** It's ok.

O. Emergency Illumination of Means of Egress.

- **Current state:**

There isn't an emergency illumination system in the building.

- **Degree of Compliance:** It's not ok.

P. Occupant Emergency Program.

- **Current state:**

There isn't any applicable fire safety plan and training courses for workers in the building hasn't done, also all fire alarm systems are inactive.

- **Degree of Compliance:** It's not ok.

Q. Elevator control ,Power and Control Wiring

- **Current state:**

There isn't an elevator machine Room in the basement floor.

- **Degree of Compliance:** It's not ok.

R. Corridor/Room Separation

- **Current state:**

According to code provision there isn't a need for corridor walls to be rated for fire.

- **Degree of Compliance:** It's ok.

S. Tenant and dwelling unit separations.

- **Current state:**

There isn't a dwelling units in the building.

- **Degree of Compliance:** It's ok.

4.3.3 Code Compliance Review Check List

Existing occupancy: Technological information building in Islamic university

Number of stories: 6

Year building was constructed: 2004

Area per floor: 800 m²

Type of construction: I and II structure

The proposed model for measuring the compatibility of buildings:

Table (4.3): the proposed model for measuring the compatibility of IT building.

Safety Parameters		Code reference for safety factors	Compatibility state		Parameter weight
			Ok	**Not ok**	
1.	Construction • Building Height • Building Area	IBC 503	✓		18.85%

Safety Parameters		Code reference for safety factors	Compatibility state		Parameter weight
			Ok	Not ok	
2.	Vertical Openings(atriums) • Automatic sprinkler protection • Fire alarm system. • Interior Finish	IBC 404 NFPA 8.6.7	✓		17.92%
3.	Compartmentation • Smoke Barrier Penetration	IBC 3412.6.3	✓		3.68%
4.	Unit Separations	IBC 709.3	✓		1.47%
5.	Corridor Partitions/Walls • Corridor width • Dead Ends	IBC 1017 NFPA 7.1.3.1 NFPA18.3.6.2 .2 IBC 1017.3	✓		6.11%
6.	Segregation of Hazards/incidental use	NFPA 13.3.2	✓		3.7%
7.	HVAC Systems	IBC 716 IBC 3412.6.7		✓	3.68%
8.	Fire Detection	IBC 909 NFPA 9.6 33.3.3.4.8	✓		3.91%
9.	Maximum Exit Access travel distance	IBC 3103.4	✓		7.36%
10.	Smoke Control	IBC 716.2	✓		2.44%
11.	Exit System(Means of Egress) • Exit signs • Illumination level. • Areas of refuge • INTERIOR STAIRS	IBC 1001 NFPA 3.3.1 NFPA 3.3.18	✓		4.85%
12.	Dead End /Exit access	IBC 3412.6.12 NFPA 12.2.5 NFPA 13.2.5	✓		2.87%
13.	Emergency Lighting	IBC 3412.6 NFPA 33.3.2.9		✓	0.74%
14.	Elevator Controls	IBC 708.14		✓	1.47%
15.	Fire Alarm	IBC 907 NFPA 38.3.4.1	✓		5.33%

Safety Parameters		Code reference for safety factors	Compatibility state		Parameter weight
			Ok	Not ok	
16.	Mixed Occupancies • Non separated occupancies • Separated occupancies	IBC 508.3.2 NFPA 6.1.14.3 NFPA 6.1.14.4 IBC 508.3.3	✓		1.84%
17.	Automatic Sprinklers	IBC 903 NFPA 12.3.5.2, NFPA 12.3.5.3		✓	9.52%
18.	Interior Finishes • Wall and ceiling Rooms • Wall and ceiling/exit access • Floors	IBC 801 NFPA 10.2.1 NFPA33.3.3.3.2	✓		2.13%
19.	Occupant Emergency program	NFPA 38.4.2		✓	2.13%
	Total compatibility percent			82.46%	%

4.4 Comparison between results of current study and previous studies:

Comparison has been done between the study results of Alfagr albadeaa building in Saudi Arabia and Cairo University buildings study results in Egypt, with the results of the Islamic university buildings.

- **Alfagr Albadeaa building in Saudi Arabia:** is a Residential hotel building consisting of basement +Ground floor+ balance + Services +9 frequently floors + dormitories floor with area of 842m², From (Evaluation of the safety and security means in high-rise residential buildings) thesis prepared by Hasan Omer Hamoda, July 2012.
- **Architecture Building in Cairo university**: is an Educational building consists of a ground floor and seven upper floors with 35m and 2110 m², constructed 1991 from (compatibility of the Existing buildings to fire safety code) prepared by Hesham Ismail Ahmed, 2012.
- **Technological information building is** located in the north east side of the Islamic University and consists of ground floor and four upper floors, with 4 meters height to each one and with total height up to 20 m with 800m².

Table (4.4): Comparison between results of current study and previous studies.

Safety Parameters		Saudi Arabia comp.		EGYPT comp.		GAZA comp.		Parameter weight
		ok	not	ok	not	Ok	not	
1.	Construction • Building Height • Building Area	✓			✓			18.85%
2.	Vertical Openings(atriums) • Automatic sprinkler protection • Fire alarm system. • Interior Finish	✓			✓	✓		17.92%
3.	Compartmentation • Smoke Barrier Penetration		✓	✓		✓		3.68%
4.	Unit Separations	✓		✓		✓		1.47%
5.	Corridor Partitions/Walls • Corridor width • Dead Ends	✓		✓		✓		6.11%
6.	Segregation of Hazards/incidental use	✓		✓		✓		3.7%
7.	HVAC Systems	✓		✓		✓		3.68%
8.	Fire Detection	✓		✓		✓		3.91%
9.	Maximum Exit Access travel distance	✓		✓		✓		7.36%
10.	Smoke Control	✓		✓		✓		2.44%
11.	Exit System(Means of Egress) • Exit signs • Illumination level. • Areas of refuge • INTERIOR STAIRS	✓			✓	✓		4.85%
12.	Dead End /Exit access	✓			✓	✓		2.87%
13.	Emergency Lighting	✓			✓		✓	0.74%
14.	Elevator Controls		✓		✓		✓	1.47%
15.	Fire Alarm	✓			✓	✓		5.33%
16.	Mixed Occupancies • Non separated occupancies • Separated occupancies		✓		✓	✓		1.84%
17.	Automatic Sprinklers	✓			✓		✓	9.52%

Safety Parameters		Saudi Arabia comp.		EGYPT comp.		GAZA comp.		Parameter weight
		ok	not	ok	not	Ok	not	
18.	Interior Finishes • Wall and ceiling Rooms • Wall and ceiling/exit access • Floors	✓		✓		✓		2.13%
19.	Occupant Emergency program		✓		✓		✓	2.13%
	Total	92.7%		34.48%		82.46 %		100%

4.5 The Main Results:

1. There are 19 fire safety factors result from the integration between the selected international fire codes (NFPA, IBC, Chicago).
2. The factors are divided to 3 parts, High-impact factors represent 16% with 46% impact, Medium effect factors represent 42% with 39% impact, and Weak influence factors represent 42% with 15% impact.
3. Construction factor and vertical opening factor represent 37% from the total impact of fire safety factors.
4. The most non Compatibility factors in the buildings represent by **(**Compartmentation, HVAC Systems, Emergency Lighting, Elevator Controls, Automatic Sprinklers, Occupant Emergency program)
5. Although the fire alarm system is installed in most buildings, it is inactive.
6. There isn't a gas alarm system in the laboratories building where there is a chemical storages and a lot of labs.
7. Lack of maintenance, poor design and misuse are the main causes of fire accidents.
8. Through the comparison between current study and previous study, it appeared that hotel in Saudi Arabia has best range of compatibility.

Chapter 5

Conclusions and Recommendations

This chapter summarizes the whole work that was carried out through conclusion and recommendations for fire safety factors at Islamic university buildings. This chapter clarifies where research objectives are met over the final findings of this study, and some actions that may improve fire safety management are recommended. Moreover, some future researches as results of findings are suggested.

5.1 Conclusion of the research aim and objectives

In attaining the aim of research, and objectives that achieved through the findings of the analyzed checklist data. The findings are found as the following:

- To identify the international fire safety codes which used in risk indexes and Select codes to study and compare between them.
- To Study the alternative methods which make the existing building agree with international codes.
- To Analysis and Identify the factors that leading to reduce the compatibility of building with fire protection standers.
- To Applicate an evaluation framework to some educational buildings in the Islamic University- Gaza and determine the extent of the compatibility of the proposed check list through the application on the buildings.

5.1.1 Key findings related to objective one

- The objectives were: "To identify the international fire safety codes which used in risk indexes and Select codes to study and compare between them".
- These objectives are achieved through studying many fire codes "NFPA,IBC,CHICAGO" with deep focusing on the fire safety factors that affect the ability of university building to resist fire risk.

5.1.2 Key findings related to objective two

The objective was: "To Study the alternative methods to make the existing building agree with international codes".

- This objective is achieved through understanding the division of the fire risk assessment methods which are separated into (checklists, Narrative method, Risk Indexes, probabilities).

5.1.3 Key findings related to objective three

The objective was: “To Analysis and Identify the factors that leading to reduce the compatibility of building with fire protection standers”.

- This objective is achieved through selecting three codes of fire safety then making a comparison between them and merging them to choose the best fire safety factors.

5.1.4 Key findings related to objective four

The objectives were: “To Applicate an evaluation framework to some educational buildings in the Islamic University- Gaza and determine the extent of the compatibility of the proposed check list through the application on the buildings”.

- This objective is achieved through selecting three buildings and the proposed framework has been applied to measure the degree of compatibility of buildings at the Islamic University with fire safety codes. Scientific Laboratory Building was selected as an example of modern buildings that contain the technology in its equipment, and it contains laboratories and stores of chemicals. Educational staff and administration building was selected as an example of administrative buildings in the university which includes many of administrative offices. Information technology building was chosen as a model-based representative for the teaching building at the university which includes several laboratories and teachers' rooms.
- And the degree of computability of the building. 83% for Scientific Laboratory Building, 82.46% for Educational staff and administration building and 82.46% for Information technology building, the most non Compatibility factors in the buildings represent by (Compartmentation, HVAC Systems, Emergency Lighting, Elevator Controls, Automatic Sprinklers, and Occupant Emergency program).

5.2 Recommendation

- **Through the results of the study, recommend the following:**

1. Making sure that the structure of the building resist fire effects.
2. Concentrating on making evaluation to construction, vertical opening, automatic sprinkled, travel distance, corridor separation, and fire alarm because they represent 65% of the total effects.
   a. Making control and containment of the fire and limiting its spread through:
   b. Separating the building floors into compartment or zones in order to prevent fire spread.
   c. Installation of automatic fire alarm system.
   d. Providing corridors and exist scape with emergency lighting in the case of electricity power cut.
   e. Illumination marking for corridors, stairway, and escape exits must be provided.
   f. Installation of fire-resistant doors to prevent fire fumes or smoke from spreading to the exits Escape.
3. While designing, making sure of having free ways to escape and that the open direction of doors in the design and implementation in line with the escape path.
4. Installing a direct line between the main control panel of the fire alarm system and the control room with Civil Defense Department to notify firefighters automatically once the early fire alarm system is operated.
5. Making a permanent maintenance to the firefighting equipment's.
6. Ensuring the availability of minimum protection requirements for fire protection.
7. Spreading awareness and guidance programs for the citizens about dangers of fire and its causes, proper handling to combat them through creating general culture aims to encourage citizens to actively participate in the development of those buildings.
8. Gaza Municipality Specialists must adhere to the civil defense law and its regulations on high-rise buildings.
9. Making an experience and training courses for the application of evacuation plans in high-rise buildings in cooperation with the concerned authorities to ensure the

safety act if fire takes place. This is also to ensure the effectiveness of devices and equipment for that purpose.

10. Developing the technical and professional skills for e workers, technicians and specialists in this field training and benefiting from the experiences of other countries.
11. Circulating the regulations and conditions of prevention of fire to all engineering offices.
12. Activating the role of fire safety management, such as training the occupants to evacuate and train employees how to carry out extinguishing process.

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