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Sudan University of Science and Technology

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Fire safety management system in high-rise building

نظم إدارة السلامة من الحرائق في المباني العالية

A thesis Submitted in Partial fulfillment of the Requirement for the Degree of Master of Science in Civil Engineering (Construction Management)

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(قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا ۖ إِنَّكَ أَنتَ الْعَلِيمُ الْحَكِيمُ)

صدق الله العظيم

سورة البقرة – الاية **32**

Dedicated to

To my beloved parents, brothers and sisters, and friends.

To all the special people in my heart

Thank you from bottom of my heart for being my inspiration

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First of all, I thank Allah (SWT) for this help in giving me opportunity of extending my knowledge and learning, surely without his blessings, this work could not be completed.

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المستخلص

يعتبر قطاع صناعة التشيد من القطاعات المهمة التي تساهم في تطوير ونمو الاقتصاد ، في الاونة الاخيرة شهدت صناعة التشييد تطورا ملحوظا وذلك انعكس في ظهور المباني الحديثة ذات الارتفاعات العالية.و يجب مراعاة عدة جوانب أساسية في التصميم والتنفيذ لتفادي عدة مخاطر كمخاطر الحرائق في المباني العالية (موضوع الدراسة) ، حيث ناقشت الدراسة مخاطر الحرائق وطرق تفاديها.

ومع التطور العمراني والتكنولوجي اتيحت فرص لعمل تصاميم لمباني عالية ، ولكن يجب ان يتبع ذلك كل التصاميم الممكنة لتفادي حدوث خطر الحرائق ، وتهدف الدراسة الي التعرف علي اهم العناصر التي تقلل من مخاطر حدوث حرائق في المباني العالية وايجاد اهم الحلول ، ومن اهداف الدراسة تحديد اهم عناصر السلامة في المباني العالية ، وقد اشارت نتائج البحث الميداني الي أن اهم عنصر هو توفير علامات واضحه للمخارج ، ومعدات السلامة ولوحات ارشادية توضح للمستخدمين التصرف الامثل في حالة نشوب حريق .

الهدف الثاني للدراسة هو اهم جوانب السلامة من الحرائق حيث نتيائج البحث الميداني تشير الي توفير لوحات اشادية و العمل علي تدريب المستخدمين للتصرف المثل في حالة نشوب حرائق

الهدف الثالث بالدراسة هو كيفية تطوير طرق السلامة من الحرائق في المباني العالية ، وأن نتيجة البحث الميداني اشارت الي الاتي العمل علي تكثيف تدريب مستخدمي المباني العالية لزيادة معرفتهم وتوسع مداركهم للتجنب وتفادي مخاطر الحرائق والتركيز علي ان جميع اللمواد المشتعلة مخزنة بطريقة امنة وكل ذلك يتبعه الاستفادة من التكنولوجيا باستخدام افضل برامج السلامة من الحرائق .

وبتنفيذ ما اوصت به نتائج الدراسة يمكن تفادي الكثير من المخاطر والكوارث التي تسببها الحرائق .

Abstract

The sector of construction industry is one of the important industries that contribute in developing and growth of the economy. Recently the sector of construction industry have seen a remarkable development and this has reflected in the appearance of modern high buildings and many factors must be taken into account in designing and execution to avoid many risks like the risks of fires in tall buildings (study subject) whereby the study has discussed the risks of fires and means for avoiding them

With the physical and technological development and the research on opportunities of making designs of tall buildings and this must be associated with all the designs that enables avoiding occurrence of fires risk and the study aims to figure out the most important elements that reduce the risk of eruption of fires in the tall buildings and finding the most important solutions .One of the targets of the study is determining the most important elements of safety in the tall buildings and the outcomes of the field research have indicated the most important element is providing clear marks for exits , safety equipment and guiding signs that shows the users the best behavior in the events of eruption of fire.

The second objective of the study is the most important aspects of safety from fires whereby the results of the field research indicated providing guidance plates and working towards training the users on the perfect behavior in the event of fire eruption.

The third objective of the study is developing safety methods in the tall buildings and the result of the field research has indicated the following: working towards intensifying the training of the tall buildings users to increase their knowledge and awareness to avoid the risks of fires and ensure that all the inflammable materials are safely stores and all this is followed by benefiting from technology the best programs of safety from fires.

By implementing what was recommended by the findings of the study many risks and disasters can be avoided caused by fires

TABLE OF CONTENT

TITELE	PAGE NO
Ayah	I
DEDICATION	II
ACKNOWLEDGMEN	III
ABSTRACT	IV
TABLE OF CONTENT	VI
LIST OF FIGURE	X
LIST OF TABLE	XI
CHAPTER 1 INTRODUCTION	
1.1 Introduction	1
1.2 Background of the study	3
1.3 The aims of Study	4
1.4 Objectives of the Study	4
1.5 Research methodology	5
CHAPTER 2 LITERATURE REVIEW	
2.1 Introduction	6
2.2 History of High-Rise buildings	9
2.2.1 Three Generations of high-rise buildings	9
2.2.1.1 First Generation	10
2.2.1.2 Second Generation	11
2.2.1.3 Third Generation	11

2.3 What is Unique about Fire Safety for High-Rise Building 11

2.3.1 Egress Systems 12

2.3.2 Fire Department Access 12

2.3.3 The Forces of Nature 12

2.3.4 Increased Density of Occupant and Fuel Load 13

2.3.5 Complex Vertical Utility Services 13

2.3.6 Integrated Fire Problems 13

2.4 Risk of Fire in High-Rise Buildings 15

2.5 Basic Fire Safety strategies 19

2.6 Risk to Life from Fires in High-rise Apartment Buildings 19

2.7 Characters of Fire 21

2.7.1 The nature of fire 21

2.7.2 Sources of ignition 22

2.7.3 Combustion 22

2.8 Fire precautions 23

2.8.1 Means of escape 24

2.8.2 Firefighting equipment 24

2.8.3 Fire extinguishers 24

2.9 Hazards in High-Rise Buildings 25

2.9.1 Hazards of Materials 25

2.9.2 Sources of Oxidants 30

2.9.3 Sources of Heat Energy 30

CHAPTER 3 RESEARCH METHODOLOGY

3.1 Introduction 25

3.2 Objective Identification 27

3.3 Data collection 29

3.4 Questioner Design 29

3.4.1 The questionnaire 30

3.5 Ordinal Scale 1 to 5 in Ascending Order 30

3.6 Section1 38

3.6.1 General Information of Respondent 38

3.7 Section 2 39

3.7.1 Part 1 39

3.7.2 Part 2 39

3.7.3 Part 3 39

3.8 Data analysis 41

CHAPTER 4 RESULTS AND ANALYSIS

4.1 Introduction 47

4.2 Background Information of Respondents 43

4.3 The Age Group of the Respondents 44

4.4 The Gender of Respondents 45

4.5 The Highest Level of Education of the Respondents 46

4.6 The Current Level of Employment of the Respondents 47

4.7 The High-Rise Buildings Usage Frequency of the Respondents 48

4.8 The Most Frequent Usage Purpose of the Respondents 49

4.9 The Results of the Questionnaire Survey section 50

4.9.1 Part 1

4.9.2 Part 2

4.9.3 Part 3

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction 58

5.2 Conclusion 58

5.2 Recommendations 60

5.3 Recommendation for Further Studies 60

References 61

Appendices 62 – 72

List of Figures

Figure 4.1	the Age Group of the Respondents	44
Figure4.2	Gender of Respondents	45
Figure4.3	Level of Education of the Respondents	46
Figure 4.4	Level of Employment of the Respondents	47
Figure4.5	High-Rise Buildings Usage	48
Figure4.6	High-Rise Buildings Most Frequent Usage Purpose	49
Figure 4.7	Aspects that influence fire safety of High-Rise Building	51
Figure 4.8	Most Critical Aspects	54
Figure 4.9	Methods to Improve Fire Safety of High-Rise Building	56

List of Tables

Table 2.1	Summary of Fires for Apartments (NFPA)	14
Table 2.2	Summary of Fires by Occupancy Type in 1995	16
Table 4:1	the Age Group of the Respondents	44
Table 4:2	the Gender of Respondents	45
Table 4:3	the Highest Level of Education of the Respondents	46
Table: 4:4	the Current Level of Employment of the Respondents	47
Table 4:5	High-Rise Buildings Usage Frequency of the Respondents	48
Table 4:6	High-Rise Buildings Most Frequent Usage Purpose	49
Table 4.7	data obtained from the Questionnaire Survey	50
Table 4.8	data obtained from the Questionnaire Survey	53
Table 4.10	the results from the Questionnaire Survey	55

Chapter 1

1.1 Introduction

Construction industry is very wide, includes residential construction, commercial construction and facility building, and industrial construction that need specialist expertise, to contribute substantially to the economic growth of centuries the development in the construction industry has resulted in the increasing number of new construction building. However, most contractors are facing problems which affect the projects objectives.

High-rise buildings present several unique challenges not found in traditional low-rise buildings; longer egress times and distance, evacuation strategies, fire department accessibility, smoke movement and fire control. The multiple floors of a high-rise building create the cumulative effect of requiring great numbers of persons to travel great vertical distances on stairs in order to evacuate the building.

High-rise buildings have garnered significant attention in the fire safety world over the years. The public, code bodies, local, regional and federal governments, as well as the design, build, and ownership communities are all affected by high-rise building safety

Fire outbreaks occur as a result of “human factors”, such as carelessness, negligence or simply a lack of fire safety awareness. In response to this, fire safety management has become an integral aspect in the daily operations of high-rise buildings. This study presents the results of the investigation on fire safety management in high-rise buildings.

The objectives of the study are to identify the aspects of fire safety management that influences fire safety of high-rise building users to establish the most critical of these aspects; and to identify methods to improve fire safety of high-rise building users.

1.2 Background of the study:

Some of the most notable fires recorded in history dated back to as early as the year 1136. The towns of London, Bath and York suffered severe fire damage. The Great Fire of London in 1666 destroyed four-fifths of the city before finally being brought under control. In more recent times, the First Interstate Tower fire on the 4th of May, 1988 in Los Angeles resulted in the death of a building engineer and smoke inhalation by many of the 40 people inside the building at the time of the fire. In addition to this, the fire outbreak in The One Meridian Plaza on the 23rd of February, 1991 in Philadelphia resulted in the death of three fire fighters due to smoke inhalation and destroyed eight floors of this 38-storey high-rise building. Thus, it can be seen how important it is to have proper fire safety management to prevent history from repeating itself.

The threat of fire is always present in high-rise commercial office buildings and can be particularly dangerous to building occupants. As stated by The Merritt Company (1991), “The most critical exposures in high-rise structures include fire, explosion, and contamination of life-support systems such as the air and potable water supply. These threats can be actuated accidentally or intentionally and can quickly develop into catastrophic proportions because of the rapid propagation of fire, smoke and contaminants”. Despite the fact that fires are rare occurrences (Kruse, 1993), everyone working in a high-rise building must be ready to act quickly in the event of an occurrence. This is due to the fact that in a fire emergency, the first three to four minutes are crucial.

The timely handling of a fire emergency, according to sound procedures established well before the incident ever occurs, can prevent the emergency from becoming a catastrophe.

In conclusion, fire is a potentially life altering threat in any high-rise building and can create an even worse situation if there is no prior preparation for such an event. By conforming to the codes and requirements from the authorities, following sensible preventive actions and adequately training building occupants, security personnel and facility staff in proper response to fire emergencies, the overall threat of fire and fire related damages can be greatly reduced.

1.3 Aims of Study:

The aim of this study is to investigate the pertinent aspects of Fire Safety Management in high-rise buildings and to identify methods to improve fire safety of high-rise building users.

1.4 Objective of the Study:

- To identify the attributes of Fire Safety Management that influences fire safety

  Of high-rise building users;

- To identify The Most Critical Aspects of Fire Safety Management that Influences Fire safety of High-Rise Building Users
- To identify methods to improve fire safety of high-rise building users.

1.5 Research methodology

The research will be conducted in several stages to achieve all of the objectives of this study. The first stage would involve identifying the objectives. The second stage would be to conduct the literature review to find out more information about fire hazards and fire safety in general, thus achieving part of the first and third objective. This is also to ensure proper understanding of the subject matter and to enhance knowledge level. The third stage would involve conducting the field research from the case study chosen to fully achieve all three objectives. One of the methods that will be used in the field research would be to conduct professional interviews with the personnel involved in the implementation of fire safety management. Besides the professional interviews, a questionnaire survey would also be conducted in fulfillment of the objectives of the study. The questionnaire survey would be based on a Liker's Scale of 1 (Disagree) – 5 (Strongly Agree) and the respondents would be required to give their ratings based on the questions asked. The fourth stage of research would be to compile all the data obtained and conduct the analysis. The last stage would be the presentation of the analyzed data and writing of the report with conclusions and recommendations.

Chapter 2
Background and literature Review

2.1 Introduction

High-rise buildings present several unique challenges not found in traditional low-rise buildings; longer egress times and distance, evacuation strategies, fire department accessibility, smoke movement and fire control. The multiple floors of a high-rise building create the cumulative effect of requiring great numbers of persons to travel great vertical distances on stairs in order to evacuate the building.

High-rise buildings have garnered significant attention in the fire safety world over the years. The public, code bodies, local, regional and federal governments, as well as the design, build, and ownership communities are all affected by high-rise building safety. Organizations such as NFPA continue to provide resources to help ensure occupant and property protection during the time of a fire in a high-rise building.

The driving force behind the general take-up of High Rise building was the advances made during the industrial revolution and the subsequent population migration from rural to town and city living.

As the Towns and Cities became overpopulated the simplest expansion technique seemed to be to build higher and the ‘new technologies’ and monies coming out of the industrial revolution started to allow the building of very tall buildings.

America was the first country to start constructing tall buildings for general accommodation. In the mid 19th century Chicago (and soon after New York) embarked on ambitious High rise development, but as brick was the major construction material, the general limit to the buildings was 10 Stories. As advances were made the quest for the true Sky-scraper was started in earnest. By the turn of the 19th century High rise construction techniques had been all but perfected and with the adoption of the electrical Lift, High rise living was an established fact

Firstly, in the year 1853, an American by the name of Elisha Graves Otis, invented the world's first safety elevator. This new form of transportation enabled people to travel safely upward at a much greater speed and with considerable less effort than by walking. Secondly, in the 1870's, steel frames became readily available and led to the replacement of the weaker combination of cast iron and wood previously used In construction. Until then, the walls had to be very thick to carry the weight of each floor. It usually was agreed that a 12-inch wall was needed to support the first story, and an additional four inches was added to the thickness of the base to support each additional storey (IREM, 1985). This made it impossible to construct high-rise building economically. Whereas, steel frames were able to carry the weight of more floors, so walls became simply cladding for the purpose of insulating and adorning the building.

This development, which included applying hollow clay tiles to the steel supports, resulted in a fireproof steel skeleton and also permitted movable interior partitioning which allowed office suites to be reconstructed to meet the demands of new tenants.

Lastly, the invention of air conditioning by Carrier in 1902 addressed the issue of providing ventilation in high-rise buildings (IREM-1985).

At the turn of the century, tall buildings began to spring up in New York City. In1909, the 700-feet high (50 storey) Metropolitan Life Insurance Building was built and in 1913, the 792-feet high (57 storey) Woolworth Building was constructed. In 1930and 1931, two of the tallest buildings in the world were constructed in New York City, being the Chrysler Building (1046-feet high, 77 storey) and the Empire State Building(1250-feet high, 102 storey). Also, in 1931, the 55 storey Citibank Building was built.

After these buildings were erected, 40, 50, and 60 storey buildings were built all over the United States. In 1969, the John Hancock Center (1127-feet high, 100 storey) was built in Chicago.

From 1970 to 1990, there have been a combined total of 2273 new construction starts of buildings eight stories or more in the major metropolitan areas of New York, Chicago and Los Angeles (Dodge, 1991). Two of these buildings were the 110 storey New York World Trade Center which was completed in 1973. The South Tower was1362-feet high and the North Tower was 1368-feet high. Today, the world's tallest building is the 829.8 m tall **(Burj Khalifa**) in Dubai, United Arab Emirates. The tallest building in the world on the drawing board is Illinois Tower, a 5280-feet high (528 storey) office building. Frank Lloyd conceived this "mile-high" office building that was to have been constructed on Chicago's lakefront in 1956 (Fortune, 1992).

2.2 History of High-Rise buildings

2.2.1 Three Generations of high-rise buildings

Since the appearance of the first high-rise buildings around 1870, there has been transformation in their design and construction. This has culminated in glass, steel, and concrete structures in the International and post-modernistic styles of architecture prevalent today. Before proceeding further, it is appropriate to define what is considered a high-rise building. A building is an enclosed structure that has walls, floors, a roof and usually windows. According to The Merritt Company (1991), a high-rise structure is considered to be one that extends higher than the maximum reach of available fire-fighting equipment. In absolute numbers, this has been set variously between 75 and 100 feet, or about 7 to 10 stories. The height of a building is measured from the sidewalk level of the main entrance to the structural top of the building.

According to the late O'Hagan (1977), who was the former fire commissioner and chief of the New York City Fire Department, there have been three generations of high-rise buildings since the 1880's. This is briefly described below.

2.2.1.1 First Generation (1870 to 1920)

The exterior walls of these buildings consisted of stones or brick, although sometimes cast iron was added for decorative purposes. The columns were constructed of cast iron which were often unprotected, while steel and wrought iron were used for the beams, and the floors were made of wood. Often, elevator shafts were unenclosed.

The only means of escape from a floor was through a single stairway usually protected at each level by a metal-plated wooden door. There were no standards for the protection of steel used in the construction of these high-rise buildings.

2.2.1.2 Second Generation (1920 to 1940)

In this generation of buildings, the developments that occurred were mainly improvements to the weaknesses of first generation high-rise buildings. Firstly, non-combustible construction materials were used and this reduced the possibility of the collapse of structural members during a fire. Next, assemblies rated for a particular fire resistance were included in the construction. Assemblies are the barriers that separate areas and provide a degree of fire resistance determined by the specific fire resistance rating of the assembly itself (Craighead1995). Besides that, vertical shafts were also enclosed with protective openings which is the use of walls, floors and ceilings to create barriers against the spread of smoke and fire, was implemented.

2.2.1.3 Third Generation (1940 to Present)

Buildings constructed after World War II up until today make up the most recent generation of high-rise buildings. They are constructed of lightweight steel or reinforced concrete frames with exterior curtain walls. However, the majority of modern commercial high-rise buildings are steel framed. Interspersed among steel frame high-rise buildings are those of reinforced concrete construction, or a mixture of steel and concrete. In the centre of these buildings, or infrequently to the side, there is an inner core constructed of reinforced concrete. Most building services, being stairwells, elevator shafts, air-conditioning supply shafts, power, water and gas utilities, are enclosed in this central core. Extending out from this core are steel beams that connect to vertical columns located in the exterior walls. This type of construction means that there is no longer a requirement for interior vertical columns. Hence, these buildings have floor spaces free of such obstructions.

As mentioned by Brannigan (1993), modern high-rise buildings are lighter than the previous generations. Brannigan (1993) also goes on to mention that the development of fluorescent lights and air conditioning helped to remove limits to the floor area. Thus, building populations could be enormously increased and as a result, buildings have become substantially taller.

2.3 WHAT IS UNIQUE ABOUT FIRE SAFETY FOR HIGH-RISE BUILDINGS

The following represent some of the most significant of their unique features:

2.3.1-Egress Systems

The potential for crowding and slow movement in exit stairs in high buildings exists because of the increased number of storeys and because exit stairs do not normally increase in width as they descend, Stair shafts also represent one of the primary means by which smoke moves vertically. Additionally, the time it takes an occupant to descend a stairway increases with the height of the building, thus increasing the potential for smoke exposure. The basic issue is that the building egress system must provide sufficient evacuation time before smoke reaches lethal levels, and thus harms those occupants still remaining in the building.

2.3 .2 Fire Department Access

Even with modern aerial apparatus, the fire department can still reach only 6 or 7 floors in a building. Thus exterior rescue and firefighting is restricted to the lower floors. With a fire above the reach of ladders, firefighters must move vertically inside the building and launch an interior attack at the same time that occupants are descending the stairs. This can result in delays in reaching and attacking afire and to increased contamination of stair shafts if doors to exit stairs must be left open to run hoses.

2.3.3 The Forces of Nature

Stack effect and winds have a major impact on smoke movement in high buildings. Stack effect increases with increasing height of building.

Wind velocity and direction also affect the course of a fire. They are significantly less of a problem in lower buildings.

2.3.4 Increased Density of Occupant and Fuel Load

By adding floors to a building, the occupant and fuel densities increase within a given building footprint. Despite horizontal fire barriers, fire tends to move upward, thus potentially adding more fuel and affecting more occupants.

2.3.5 Complex Vertical Utility Services

A complex series of pipes, ducts, cables and conduit run vertically through high-rise buildings. As well, fire protection water supplies must also be provided from either the top or bottom of the building – both with associated problems. As a result of these vertical utilities, other fire problems can occur such as cables to fire systems are being damaged by fire on one level and affecting many other floors.

2.3.6 Integrated Fire Problems

High-rise apartment buildings are no longer standalone Structures. Typically, they are situated above shopping malls or other commercial occupancies, above atrium buildings containing, for example, offices, or above subway systems. Each occupancy has its own unique fire safety problems and coupled with those in a high-rise apartment building, the problems require special engineered solutions to ensure occupant safety.

Each of these unique features presents a special problem to be resolved before a designer can achieve a fire-safe high-rise design. While the Codes provide generalized solutions to many of the problems, architects must be aware of the problems and the need for unique solutions based on sound fire safety engineering.

2.4 Risk of Fire in High-Rise Buildings:

Direct data analysis of high-rise versus non high-rise is somewhat difficult to determine because the exact number of structures for some occupancies does not exist.

The best data exist for apartment buildings. Census data estimate the number of apartment housing units at anywhere between 15 million and 24 million (Hall, 1996).In 1993, the number of housing units in high-rise buildings was 2,294,000, which means 9.3-14.8% of all apartments were in high-rise buildings. During this period, approximately 8.8% of all apartment fire occurred in high-rises (Hall, 1997). Since the percentage of high-rise fires (8.8%) is lower than the percentage of high-rise apartments (9.3%), the risk for a fire in a high-rise apartment is somewhat lower in a high-rise building than an apartment that is not a high-rise.

Table 2.1: Summary of Fires for Apartments (NFPA)

Occupancy	**Percentage of Units That Could Be High-Rises**	**Reported High-Rise Fires**	**Percentage of Fires In High-Rises**
Apartments	9.3 – 14.8	7700	8.8

Since there are no data available that provide the exact number of high-rise offices, hotels/motels and facilities that care for the sick, the National Fire Protection association has calculated the number of existing structures using estimates based upon the total spare footage of the buildings. In 1992, there were 21,000 office occupancies, 5,000 health-care properties and an undetermined number of lodging properties with more than 100,000 square feet of space (Council on Tall Buildings and Urban Habitat, 1992). While it is unlikely that a high-rise building would have less than 100,000square feet of space, it is possible to have a building with more than 100,000 square feet that is not a high-rise. Therefore, the actual number of buildings over 100,000 square feet that are high-rises is only some fraction of the total number of occupancies.

Because the data necessary to determine the number of high-rise office structures, hotel/motel structures and facilities that care for the sick are not available, one cannot accurately determine the risk for a fire starting in these structures.

In 1995, it is estimated that approximately 19.7% of the hotel/motel fires occurred in high-rises (Hall, 1997). Approximately 9.4% of all office building fires occurred in high-rises and 31.0% of all fires in health care facilities occurred in high-rises (Hall, 1997)

Table 2:

Summary of Fires by Occupancy Type in 1995 (Offices, Hospitals and Hotels) (NFPA)

Occupancy	Reported High-Rise Fires	Percentage of Fires In High-Rises
Offices	500	9.4
Hospitals	800	31
Hotels/Motels	1000	19.7

The incidence of fires in the various classifications of high-rise structures has remained consistent over longer analysis periods. The National Fire Protection association estimates that from 1985-93, roughly one in every 12 reported apartment building fires was a high-rise building (Hall, 1996). One-sixth to one-fourth of reported hotel and motel fires have been in high-rises buildings (Council on Tall Buildings and Urban Habitat, 1992). Roughly one of every eight reported office building fires was in high-rise building and one-third of reported fires in facilities that care for the sick have been in high-rise buildings (Hall, 1996). These numbers are consistent with the percentages reported for 1995 data in Table 1 and Table 2

2.5 BASIC FIRE SAFETY STRATEGIES

Architects must understand basic fire safety strategies. One of the most frequently used means to define these strategies is found in NFPA 550 – Guide to the Fire Safety Concepts Tree. NFPA 550 presents its strategies in the form of a tree with a number of branches representing the individual strategies. The upper four levels of that tree are shown in Figure 1.

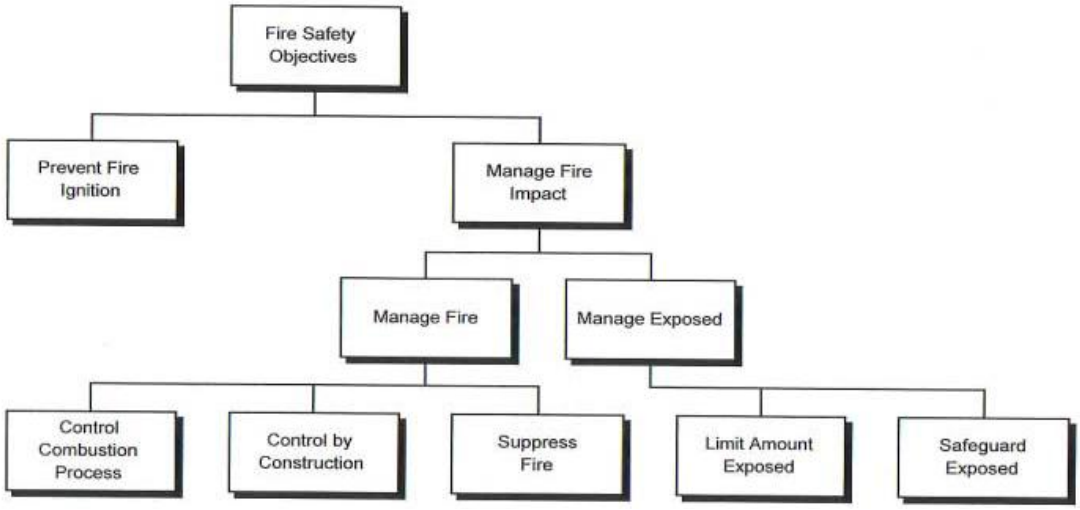

Figure 1: BASIC FIRE SAFETY STRATEGIES

Each box in the tree shows how the fire safety objectives of the box above can be met. For high-rise apartment buildings, the NBCC objectives are to minimize loss of life and injury to occupants as a result of a fire, especially to those occupants outside the apartment of fire origin. These, then, become the objectives which the architect must meet.

Prevent Fire Ignition Strategy – At the second level of the tree, it can be seen that two strategies can achieve that objective: Prevent Fire Ignition or Manage Fire Impact.

The tree assumes that, if the strategy is 100% reliable and effective in itself, the objective of the box above is met. While means to reduce fire ignitions are incorporated in the design and operation of a high-rise apartment building, statistics show that fire ignitions will still occur(e.g., cooking, smoking) and thus the strategy employed to achieve the objective is to manage the impact of the fire.

2.5.1 Manage Fire Impact

To manage the impact of the fire, an architect automatically thinks of compliance with the NBCC – and that is often one means of achieving that objective. However, it is preferable to follow the logic of the tree to ascertain which fire safety strategies to employ and how code requirements fit into these strategies. The third level of the tree shows how to achieve the objective of managing the impact of the fire (to minimize deaths and injuries): either the fire itself must be managed (Manage Fire) or those exposed must be managed (Manage Exposed). The “exposed” in this case refers to the occupants, but could also mean valuable property, the building or an essential activity. Since no strategy is 100% reliable and effective, architects (and the codes) will usually employ multiple strategies to manage both the fire and the exposed.

2.5.2 Manage Fire

The 4th level of the tree in Figure 1 shows that the fire can be managed by any one of three alternatives:

Control the Combustion Process – by controlling either the fuel (construction materials and contents) or the fire environment. Non-combustible construction and limitations on the quantity and flammability of combustible materials are employed. Interior wall and ceiling finishes, carpeting and insulations will burn, however, as will the furnishings which the occupants move into the building. Thus while this strategy has some impact, by itself it cannot achieve the objective; in particular, because there is no means to control the occupants’ furnishings.

2.5.2 Control by Construction

Limits the growth of fire and the movement of smoke using construction elements such as walls and floors. Fire-rated floor assemblies, apartment enclosures, corridors, shafts, etc are provided to meet this objective. Structural stability for certain duration under fire attack is part of the strategy. Case studies show that doors may not be closed or fire stops may be missing. Therefore, Control by Construction will not necessarily be 100% reliable and effective. It does, however, provide another basic building 8block for fire safety

2.5.4 Suppress Fire

Usually water is used to extinguish the fire, either automatically or manually. Standpipe systems provide the water supply for fire fighters, as well as for automatic sprinkler systems. Interior fire fighting in high-rise apartment buildings is difficult and is not always effective during the time needed for occupant evacuation. Studies (15) have shown that sprinkler systems are high reliable and effective, but not 100%. Thus, this strategy can serve as another building block but cannot be relied upon by itself to meet the manager for objective

2.5.5 Manage Exposed

Given that, in real life, the Manage Fire strategy may not be 100%reliable and effective; strategies are required to manage the occupant's exposed to the fire. The 4th level of the tree provides two means to achieve that objective:

2.5.6 Limit Amount Exposed

The number of occupants that are exposed to the fire is limited. Since architects have little control over the numbers of occupants in a building's lifetime, this strategy is one that is seldom employed at the design stage and will not be addressed further.

2.5.7 Safeguard Exposed

To protect them from the impact of the fire, the design must either defend the occupants in place or move them to a safe location. Smoke-filled exits may make it preferable for occupants in a high-rise apartment building to remain in their apartments (or especially on their balconies) to "wait out" the fire. This is a form of defend-in-place. A defend-in-place strategy must be under taken only with the full knowledge and participation of the responding fire department. This strategy is often employed to protect occupants with mobility limitations when they are expected to wait for assistance in a protected exit stair vestibule. Given the many difficulties with defend-in-place design and the currently-held belief that evacuation is essential, the alternative strategy of moving the exposed is usually employed. Moving the exposed occupants requires that the architect provide: a means to initiate movement (fire alarm/voice communication); a protected means to facilitate movement (smoke-free exit stairs of adequate size); and a safe destination, usually outside the building

Figure 1, the Fire Safety Concepts Tree, provides the architect with the strategies to achieve fire safety in high-rise buildings. In fact, by looking at these strategies, the architect can see the many fire safety elements currently incorporated into building codes. Architects will typically use an amalgam of these strategies in seeking to achieve the fire safety objective.

2.6 Risks to Life from Fires in High-rise Apartment Buildings

A precise risk to life from fire in high-rise apartments is not easily discernible due to the numerous deficiencies in data. However, by examining the factors which make up fire risk, the higher potential risk in high-rise apartments can be identified.

Risk is defined as the probability that an event will happen, multiplied by the consequences of that event when it does happen. The equation is shown as:

Risk = Probability x Consequences

The risk to life from fire is calculated on the basis of all probable fires occurring at all probable locations in a building while examining the consequences of all of these fire scenarios(2). For an in-depth review of this subject, architects are directed to the SFPE

Handbook of Fire Protection Engineering (3). It can quickly be seen then that the fire risk in a High-rise apartment building would be significantly higher than in a lower rise building given the potential for more fire locations, and greater consequences of the fire itself (e.g., stack effect) to a greater number of occupants. This means both the probability and the consequences would be much higher, and the resulting risk would be even higher. It is this higher risk, then, that results in demands for greater fire safety in high-rise apartment buildings

2.7 Characters of Fire:

2.7.1 The nature of fire

Generally, for a fire to occur, three elements are needed: fuel, oxygen and an ignition source. The aim of fire prevention is to avoid these three coming into contact - and fires can be extinguished by removing one of the three from the equation.

There are substances that will burn without oxygen - and certain chemicals and preparations can react to oxygen in the air or other chemicals to produce their own 'internal' source of ignition.

It is almost impossible, in most working environments to avoid oxygen and fuel coming together - to prevent fires, the quantities and locations of the fuels must be controlled and kept away from possible sources of ignition.

So, the first step in a fire risk assessment is to identify the possible sources of fuel and ignition.

(http://www.pcs.org.uk/en/resources/health_and_safety/hazardsatoz/fire-safety-1.cfm

2.7.2 Sources of ignition

There are common sources of ignition include:

- Heaters
- Boilers
- smoking materials
- heat from processes
- electrical apparatus - either in normal use and in cases of overload or failure
- ventilation outlets from heat-producing machinery
- Deliberate ignition - arson attacks etc

All possible ignition sources should be identified as part of the risk assessment. Wherever possible, these should be controlled and kept out of the workplace or well away from combustible materials.

Combustible materials

Everyday materials in workplaces, such as paper, furnishings etc., provide a ready source of fuel. Bulk supplies of such materials should be stored away from main work areas, in store cupboards, not left in a corner of the room on the floor.

Some materials - flammable liquids, gases, paint and varnish - ignite readily and burn with high heat or lots of smoke. Ideally such materials should be isolated from the workplace.

Where this is not possible, simple precautions such as fire-resistant store cupboards and keeping lids and covers on containers will help to minimise the risks.

Waste materials should never be allowed to accumulate in the workplace - good housekeeping is particularly important in minimising fire risks.

2.7.3 **Combustion**

Complete combustion occurs when the condition are favorable. The products of complete combustion are carbon dioxide in gaseous form, water in vapor form and heat energy. However, small quantities of carbon monoxide and partial flume gas components may form. The amount of energy released in the burning of a substance is called its heat of combustion or combustion enthalpy

Incomplete combustion occurs when the fuel element is not completely oxidized in the combustion process. Fire would occur in a less vigorous and smoldering state emitting thick smoke containing toxic gases and contaminants. Factors that give rise to incomplete combustion on a burning fuel material are as follows.

a) Insufficient air to the fuel material (*causing local fuel-rich and fuel-lean zones*);
b) Insufficient air supply to the flame (*providing less than the required quantity of oxygen*).
c) Insufficient reactant residence time in the flame (*preventing completion of combustion reactions*);
d) Flame impingement on a cold surface (*quenching combustion reactions*); and
e) Too low flame temperature (*slowing combustion reactions*).

When there is incomplete combustion to a burning fuel material, the formation and subsequent release of partially oxidized compounds such as carbon monoxide, aldehydes and ketones occurs. Should such adverse toxic smoke situation predominate in building fires, this would be the main contributing factor to the ill-favored consequence of high occupant-fatality rate not to mention the lifelong agony and suffering of the survivors.

2.8 Fire precautions

2.8.1 Means of escape

In the event of fire, people must be able to escape from the workplace in safety. Modern Building Regulations go a long way to ensuring adequate means of escape, but the following points should be borne in mind:

- With the possible exception of very small workplaces, people should be able to turn away from the point of the fire to escape. If they may have to pass a fire, in a corridor for example, the route may need additional protection by fire-resistant partitioning and/or self-closing fire doors.
- Fire travels up natural chimneys, such as stairways. These will need adequate protection.
- Doors should open in the direction of travel, whenever possible - and particularly if they lead from areas of high risk of fire, if they may be used by large numbers of people or if they are situated at the foot of stairways, creating a risk of crushing.
- All doors on escape routes must be capable of being easily and immediately opened from the direction of escape - including those to the outside. There are a variety of fixtures available to balance security with ease of escape. Advice can be obtained from the Fire Authority.
- Escape routes should be short and lead to the outside or to a 'place of safety' - that is, a place which is adequately protected from the risk of fire by partitions/doors. Generally, two to three minutes is considered a maximum safe time. People with mobility impairments will need to be considered here.
- Escape routes must not be obstructed and should be regularly checked to ensure that they are free from clutter.
- Adequate lighting is vital on escape routes - including alternative means of illumination should the electricity fail in the fire. Don't rely on natural light.
- If necessary, signs should be provided on doors and escape routes, clearly pointing the way out. These must comply with standard legislation on type, size and design.

2.8.2 Fire fighting equipment

Most premises are provided with some means of fighting a fire. Unless staff are properly trained, however, they can put themselves and others at risk in using this equipment.

It is vital that all staff are aware of who is trained and when it is safe to attempt to control or extinguish a fire themselves, rather than evacuate the area and rely on the skills of the fire brigade.

As a general rule, fire fighting equipment should only be used to limit the spread of fire to enable safe evacuation. Before tackling any fire, it is vital that the alarm is raised and the fire brigade are called.

2.8.3 Fire extinguishers

The most common form of fire fighting equipment are extinguishers.

Fires are broken into 4 classes, depending on the fuels involves:

- Class A Fires involving ordinary combustible materials
- Class B Fires involving flammable liquids.
- Class C Fires involving gases.
- Class D Fires involving burning metals.

Different extinguishers are appropriate for different classes of fires

2.9 Sources of Fire Hazards in High-Rise Buildings

Sources of fire hazards can be classified based on the triangle of fire, namely from materials, oxidants and heat energy. Each of these elements is described below (Tuhtar, 1989).

2.9.1 Hazards of Materials

Hazards of materials can be further classified into wood and wood-based products, plastics, textiles, liquids and gases. These are further described below.

2.9.1.1 Wood and Wood-Based Products

Wood and numerous wood-based products such as paper, cellulose-based fibrous materials and many others, are indeed ubiquitous. They are invariably involved in almost all kinds of fires. Therefore, understanding of their fire characteristics is important for fire protection.

The chemical content of dry wood and wood-based products is relatively simple. Carbon (50%), oxygen (40%) and hydrogen (6%) are the most abundant elements with nitrogen and mineral ash making up the remainder. However, these few elements are combined to form a large number of substances, of which cellulose (50%), lignin (26%) and extractable (1%) are the major components. Wood also contains water, either as moisture or absorbed water in wood cells. Whereas moisture is readily removed on heating wood and wood products above 380 K, absorbed water remains even after prolonged heating. Apparently, dry wood may still contain considerable amounts of water (5 – 6%).

Wood and wood-based products are combustible. They can burn in different modes such as smoldering, charring, ignition followed by flames, or burning with a lot of smoke.). Smoke produced from burning wood has characteristic recognizable odors. In comparison with other solids, the toxicity of smoke produced from wood burning is not pronounced. Except for carbon monoxide, other toxic gases are either absent or only present in traces (Tuhtar, 1989).

2.9.1.2 Plastics

Plastics are used practically everywhere, namely in building construction, homes, offices, shops, schools, hospitals, etc. A lot of equipment and applications, furniture, wall coverings, curtains, textiles and many other products either are made completely of plastic, or contain some plastic parts.

All plastics, regardless of chemical characteristics, being organic compounds are combustible. Various flame-retardants can considerably reduce flammability but cannot completely stop combustion. Ignition temperatures of plastics are somewhat higher in comparison with wood and wood-based products. However, the rates of flame spread are generally much higher than wood.

The burning of plastics rapidly produces smoke which is usually dense, contains a lot of soot and has a dark color. It has been found in many cases that the inhibition of flammability of plastics by flame-retardants increases smoke production. Thermoplastics soften on heating before reaching ignition temperature and harden on cooling. At higher temperatures, thermoplastics melt and flow. This characteristic of plastics is potentially hazardous since the flaming liquid may drip and thus spread the fire.

Another hazard is that during the burning process, some plastics release corrosive and toxic gases such as HCL, HF, HBr, HCN and NH3 . The conditions which enhance the emission of such gases during a fire are low ventilation and lengthy fire growth which increases fire temperatures to the point of an easy break of the polymer matrix and the release of simple gaseous constituents (Tuhtar, 1989).

2.9.1.3 Textiles

The widespread use of textiles in daily life, coupled with the fact that nearly all textiles are combustible, explain the leading role of textile fires in fire deaths. More than 50% of fatal incidents involve a fabric. As to the type of fabric first ignited, artificial fibers, cotton and rayon comprise the largest percentage (41%), whereas wool and wool mixtures are very rarely first ignited (1%). This marked difference is due to the differing ignition temperatures. While cotton and most artificial fibers ignite at relatively low temperatures (520 – 670 K), the ignition temperature for natural protein-based fabrics such as wool, silk and cashmere is between 840 and 880 K.

The fire characteristics of textiles depend on the nature and proportion of individual fibers, on their weight and the method of blending. Textiles based on cellulosic fibers such as cotton and jute behaves differently in fires compared to protein fibers. The latter ones do not burn readily; shrink at temperatures approaching their decomposition temperature and burn more slowly. Common artificial fibres such as nylon and rayon burn similarly to protein-based natural fibres. Thus, they are relatively safer compared to fabrics containing cellulose. However, when exposed to heat, artificial fibres often melt and stick to the skin. Therefore, they should not be employed for protective clothing.

Synthetic fabrics can be hazardous in some special atmospheres, such as oxygen-enriched atmospheres or atmospheres containing flammable gases and vapors because of the accumulation of static electricity . The discharge of this electricity to the ground or other objects may produce a spark of sufficient energy to ignite a flammable gas. In such situations, electrically conductive fabrics should be employed (Tuhtar, 1989).

2.9.1.4 Liquids

Flammable and combustible liquids are among the most fire hazardous materials. Fire statistics record that fires involving a liquid are the most frequent ones. Flammable and combustible liquids are the most hazardous in all instances when the liquid is exposed to air, such as in spillages . The fire and explosion characteristics of a liquid can be described using a number of parameters. Some of them are applicable to solid and gaseous materials as well. Thus, most of the hazards are similar to the ones already described earlier.

2.9.1.5 Gases

For fire protection purposes a gas may be defined as any substance which exists in a gaseous state at normal temperature and pressure. Since at these conditions many substances may exist as either liquids or gases, depending on the partial pressures of their vapours, it is generally accepted that all those liquids which exert a relatively high vapour pressure may be regarded as gases(Tuhtar, 1989).

In most situations, gases are used in large volumes. Since gases are much lighter than liquids and solids, the only practical means of having a reasonable quantity of gas on hand is either by gas compression in containers or by filling the containers with liquefied gas. Both these forms of gas-packing present hazards. Fire hazards of gases are very similar to those of liquids. This is not surprising since in fire hazards of liquids it is the vapor of a particular liquid which is hazardous, rather than the liquid phase itself. Thus, most of the hazards are also similar to the ones already described previously(Tuhtar, 1989).

In addition to the fire characteristics, many gases are hazardous on account of other properties. The hazard stems from properties such as toxicity, reactivity and chemical inertness (Tuhtar, 1989). However, the basic hazard of all gases and vapours, regardless of their chemical composition, is related to the change of gas pressure with changing temperature. From classical gas laws, the doubling of temperature leads to a doubling of gas pressure. Hence, gas containers would normally be ruptured in the event of a fire.

2.10 Sources of Oxidants

The second factor necessary for combustion to occur is the presence of an oxidant. This can be either in the form of free oxygen in the air or chemically bound oxygen present in reduction agents . These are further described below.

2.10.1 Oxygen in Air

It is obvious that a fire can occur only if an oxidant is present together with a combustible material, since only then, and in the presence of an ignition source, will the reductant be oxidized to the final combustion products . By far the most common oxidant is the oxygen in air itself. Oxygen in air comes in the form of molecular oxygen O2. It is a very reactive chemical species which is capable of oxidizing almost all other elements producing oxides as the final reaction products. Other forms of oxygen, such as atomic oxygen O or ozone O3 are even more reactive. However, they are normally present in air only in negligible concentrations, leaving the molecular oxygen as the predominant oxygen species. Compared to common oxidation reactions in which a material is slowly transformed to its oxidized form, fires can be regarded as oxidation reactions occurring very quickly

2.10.2 Chemically Bound Oxygen

Oxygen needed for the oxidation of the reductant may also come from some compounds in which it is chemically bound in the form of various groups, such as peroxide O22-, per chlorate ClO4, nitrate NO3, nitrite NO2, permanganate MnO4 , etc

Most compounds containing these groups are not combustible themselves, yet they are considered hazardous because they can liberate oxygen needed for combustion. In this way, the intensity of burning is increased since pockets of oxygen-enriched atmospheres are formed in the immediate vicinity of the decomposed compound. The release of oxygen from oxidants involved in a fire is accompanied by the evolution of heat. When water is employed for extinguishing such fires, steam explosions are possible, further augmenting the hazard of oxidants. Compounds containing bounded oxygen are widely used in many applications such as salt baths, bleaching powders and fertilizers.

2.9.3 Sources of Heat Energy:

The third factor necessary for the initiation of the reaction between a fuel and an oxidant is a source of heat energy. Only in some exceptionally rare circumstances will the sole contact between the fuel and oxygen lead to a spontaneous combustion. In the great majority of cases, an outside source of heat energy is necessary for the initiation of the combustion. The source of heat energy often behaves as a catalyst, especially in the piloted ignition. Its presence is necessary for the promotion of the combustion reaction, but only up to the point where the reaction becomes self-sustaining.

There are several distinct means of generating heat energy in the quantities and duration required for the initiation of fire. They may conveniently be divided into three broad categories, namely electrical, chemical and mechanical sources of heat energy . Each of these is further described below.

A. Electrical Heat Energy

Electricity is repeatedly quoted as a major cause of many fires. Fire statistics regularly show electricity to be responsible for between 20% and 40% of all fires of known origin . Although formally it is true that electrical heat energy does cause a significant number of fires, it is also undisputable that fires will seldom be initiated by the electricity if the electrical installations and equipments are made, used and maintained in accordance with the corresponding codes and standards.

Electrical heat energy is always generated when an electric conductor carries a current .From classical physics, it is known that the greater the current and resistance, and the longer the current flows through the conductor, the greater the heat energy liberated. For safe use of electrical conductors, electrical codes specify the maximum current which will not overheat them. The resistance of conductors is determined by the kind of material employed. Materials which are good conductors, such as copper, silver and aluminum are preferred and generally used. Finally, the time the current takes to pass through the conductor is determined by the intended use of electrical appliances, unless the appliance is left on unintentionally, causing an accidental fire.

B. Chemical Heat Energy

Heat energy necessary for the initiation of fires may be produced by several types of chemical reactions. Among them of primary concern to fire protection are combustion reactions. These reactions when brought to a completion release a considerable amount of heat known as the heat of combustion . Examples of common sources of heat energy formed by combustion reactions are open flames, a lighted cigarette, an acetylene torch used for cutting and welding, a hot fuel- fired boiler, a drier or a furnace surface. Other types of chemical reactions which release heat are spontaneous heating (self-heating) and spontaneous ignition (self- ignition).

C. Mechanical Heat Energy

It is well known that some forms of mechanical energy can be converted to heat energy (Parker and Long, 1972). The greater the mechanical work, the greater the amount of heat released. The mechanical heat energy, formed as result of mechanical failure or malfunction of equipment, is the source of ignition for a significant number of fires (5 – 10%) . Furthermore, when two moving solids are in contact, the resistance to relative motion is manifested in the form of heat due to friction. If heat due to friction is not dissipated as rapidly as it is formed, there will be overheating which may ignite the combustible material.

Chapter 3

Research methodology

3.1 Introduction

In this chapter, the methodology used in carrying out this study will be described in detail. The first step involved is the determination of the objectives and the scope of work involved. Subsequently, literature review was conducted to get a better understanding of the subject matter in line with the objectives of the study. This involved conducting personal interviews with the people involved in the day to day operations of the buildings, such as the projects Manager. This was necessary to obtain their professional opinions. From the information obtained through the literature review and personal interviews, the questionnaire is then developed and distributed to the targeted participants. the data obtained from the questionnaires are analyzed .This is followed by the discussions and suggestions and eventually, conclusions are drawn to conclude the study.

3.2 Objective Identification:

The purpose if this Study is to ensure the aim and objective are achievable much information has been studied on the fire safety management in high rise building to identify the best methodology to be adopted. Two major sections consisting of questionnaire and interview has been select as research methodology.

3.3 Data collection

The data collected by using questionnaire survey forms that were distributed to the targeted respondents. In total of 60 questionnaires that in 45 days, which distributed to a group of construction companies and construction sites in the state of Khartoum the questionnaire was designed in a user-friendly multiple choice

The questionnaire was subsequently revised based on the information and feedback provided by these people all the data required had been obtained, it was analyzed using statistical methods.

3.4 Questioner Design:

The questionnaire is designed based on information obtained from the literature review with the relevant high-rise building personnel. Interview questions centered on the aspects of Fire Safety Management that would influence fire safety of high-rise building users and also the methods that could be implemented to enhance fire safety of high-rise building users, in line with the objectives of the study.

3.4.1 The questionnaire :

The questionnaire is designed in two main sections.

Section 1 general information of the respondent.

Section 2 was divided into three parts.

Part 1 attempts to obtain the respondent's opinion regarding aspects of Fire Safety Management that influences fire safety of high-rise building users

Part 2 is intended to obtain the most critical of these aspects that influences fire safety of high-rise building users.

In **Part 3**, the respondent's opinions is sought to identify methods to improve fire safety of high-rise building users.

3.5 Ordinal Scale 1 to 5 in Ascending Order

From 1 to 5

Each scale represents the following rating:

1 = Disagree

2 = Uncertain

3 = Partially Agree

4 = Agree

5 = Strongly Agree

3.6 Section 1:

3.6.1 GENERAL INFORMATION OF RESPONDENT

1. What age group do you belong to?

	>20 years		41 – 50 years
	20 – 30 years		< 50 years
	31 – 40 years		

2. Gender.

	Male		Female

3. Education level:

	Diploma Level		Doctorate Level
	Degree Level		Others
	Masters Level		

4. At what level are you currently employed?

	Unemployed		Senior Management Level
	Executive Level		Others
	Management Level		

6. How often do you use high-rise buildings?

	Daily Basis		Monthly Basis
	Weekly Basis		Annual Basis
			Never

7. What do you most frequently use high-rise buildings as?

	Visitor		Owner
	Worker		Others

3.7 Section 2:

3.7.1 Part1:

The objective of this section is to identify the attributes of Fire Safety Management that would influence fire safety of high-rise building users

1- Training of high-rise building users in fire life safety
2- Conducting inspection of electrical installations
3- Provide clear signage indicating exit routes and location of fire safety equipment;
4- Implementing pest control program
5- Conducting inspection, operation and maintenance of fire safety equipment

3.7.2 Part2

The objective if this section is to identify the most critical attributes of Fire Safety Management that would influence fire safety of high-rise building users.

Please rank the following in order of how critical they are beginning from (1) to (6), where (1) indicates the most critical and (6) indicates the least critical.

1- Training of high-rise building users in fire life safety
2- Conducting inspection of electrical installations
3- Implementing pest control program
4- Provide clear signage indicating exit routes and location of fire safety equipment.
5- Conducting inspection, operation and maintenance of fire safety equipment
6- Ensure that flammable materials are stored in a safe area

3.7.3 Part3:

The objective of this section is to identify methods to improve fire safety of high-rise building users:

1- Conduct more training programs for high-rise building users to increase awareness and ability to react in case of emergency.
2- Implement Floor Warden System in high-rise buildings
3- Assign specific personnel as Building Emergency Response for emergency situations.
4- Conduct regular inspections of all electrical installations to minimize threat of fire.
5- Implement a regular pest control program to eliminate rodents and other pests from damaging electrical wires and causing short circuiting.
6- Ensure that flammable materials are stored in a safe area

3.8 Data analysis

The procedure used in analyzing the results of the questionnaire survey is aimed at establishing the relative importance between the various aspects of Fire Safety Management that influences fire safety of high-rise building users and to determine the most important aspect by ranking them according to the data given by the respondents. Apart from that, the questionnaire survey is also intended to seek the respondent's feedback with regards to the methods that may be undertaken to tackle the issue of fire safety in high-rise buildings.

Relative Important Index (RII) was used to determine the different factors causing fire safety management in high rise building by using the following expression:

$$RII = \frac{\sum_{i=1}^{5} aixi}{5 \times N}$$

Where:

ai is a constant expressing the weight of the *ith* response.

Xi is the frequency of the *ith* response of the total responses for each cause.

I is the response category index where ***i=*** 1,2,3,4 and 5 respectively.

N is the total number of respondents.

RII value is ranged between 0 to 1

CHAPTER 4

RESULTS AND ANALYSIS

4.1 Introduction

This chapter presents the analysis of the data Collected from the questionnaire survey and the data and the results produced are analyzed and discussed in fulfilment of the objectives of the study.

4.2 Background Information of Respondents:

Part 1 of the questionnaire is aimed at obtaining some background information about the respondents. From the field data collection, the following information has been obtained.

4.3 The Age Group of the Respondents:

It can be notice that from the data collected the majority of the respondent are between the ages of 20 – 30 years (53.7%) and the rest of others as fallow (31 – 40)years old (31.7%) and (41 – 50)years old (2.4%). Respondents below the age of 20 years 2.4% over the age of 50 years 12.2

The percentages shown in Table 4.1 and Figure 4.1 below:

Table 4:1 The Age Group of the Respondents:

Age	Frequency	Percent (%)	Cumulative (%)
< 20 Years	1	2.4	2.4
20 – 30 Years	21	51.2	53.7
31 – 40 Years	13	31.7	85.4
41 – 50 Years	1	2.4	87.8
>50 Years	5	12.2	100.0
Total	41	100.0	

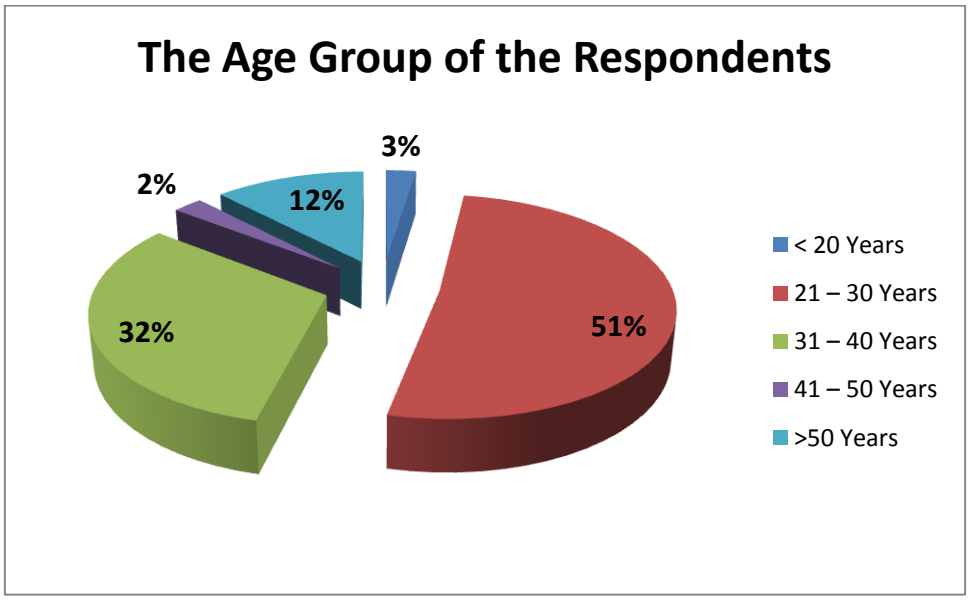

Figure 4.1: the Age Group of the Respondents

4.4 The Gender of Respondents:

From the data collected, it can be observed that the majority of the respondents are Male (80.5%). Females comprised the remaining 19.5% of the respondents. The percentages are shown in Table 4.2 and Figure 4.2 below:

Table 4:2: The Gender of Respondents:

Gender	Frequency	Percent (%)	Cumulative (%)
Male	33	80.5	86.8
Female	8	19.5	100.0
Total	41	100	

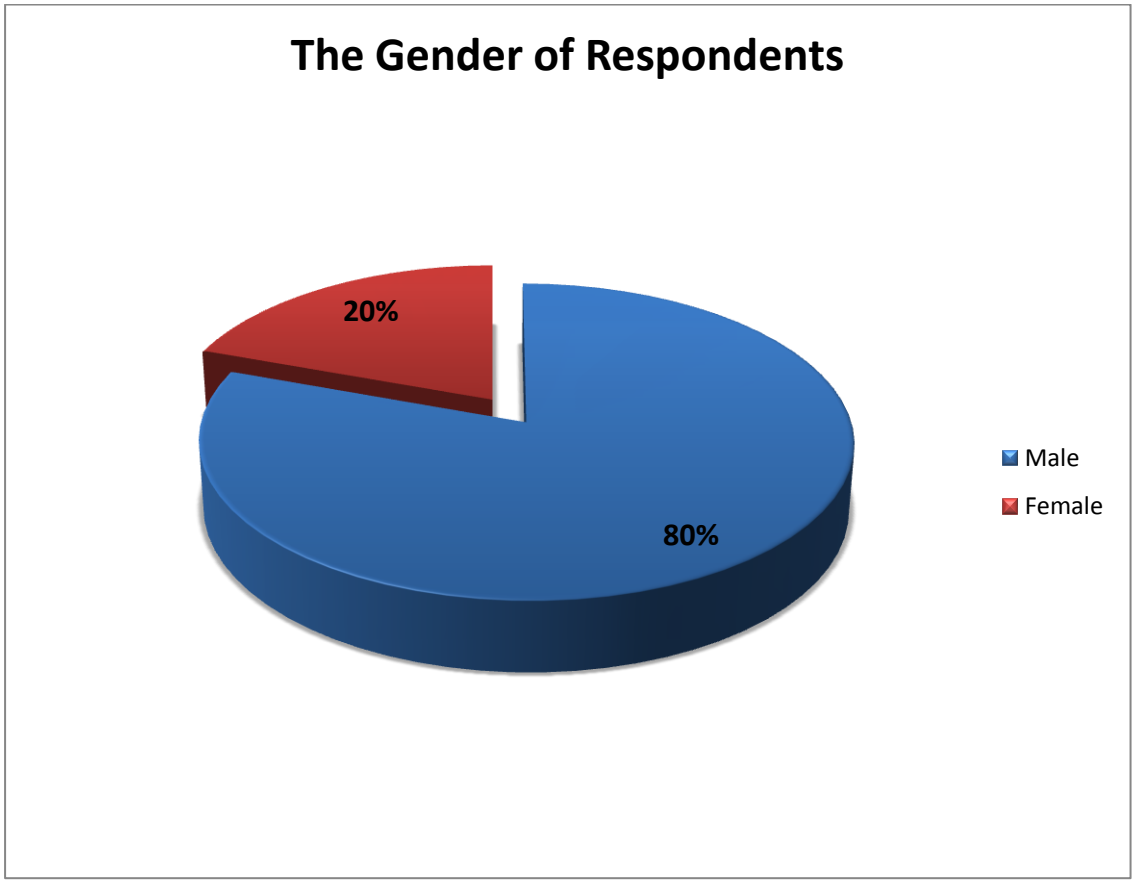

Figure4.2: Gender of Respondents

4.5 The Highest Level of Education of the Respondents:

From the data collected, it can be observed that the majority of the respondents are Degree level (56.1%) or master level (31.7%). This is followed by Doctorate level 4.9%. Respondents possessing masters qualifications comprised 4% of the total number of respondents. Lastly, respondents with only Diploma level comprised only 2.4%.

The percentages are shown in Table 4.3 and Figure 4.3 below:

Table 4:3 The Highest Level of Education of the Respondents:

Education Level	Frequency	Percent (%)	Cumulative (%)
Diploma level	1	2.4	2.4
Degree level	23	56.1	58.5
Master level	13	31.7	90.2
Doctorate level	2	4.9	95.1
Others	2	4.9	100.0
Total	41	100.0	

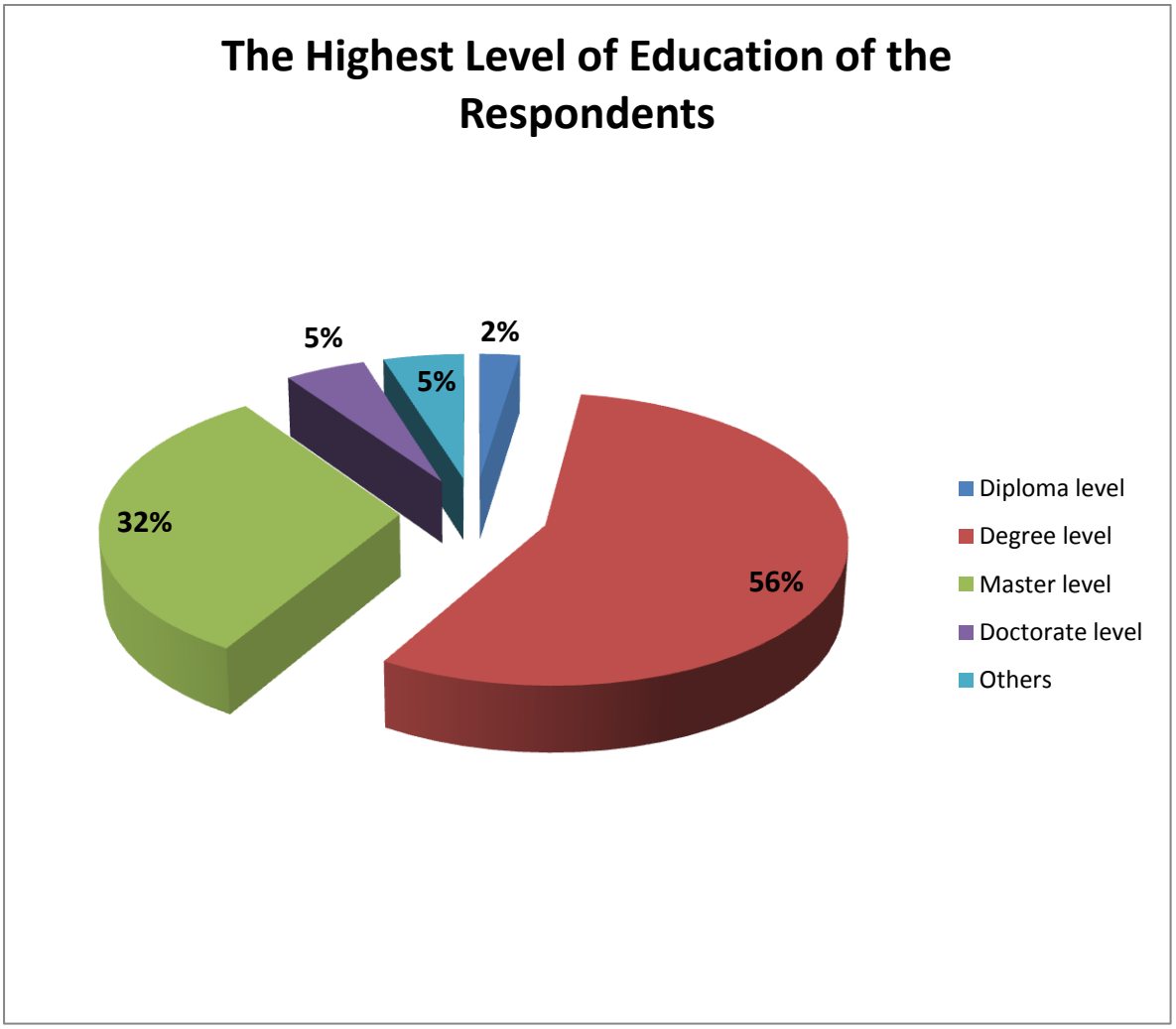

Figure4.3: Level of Education of the Respondents

4.6 The Current Level of Employment of the Respondents:

From the data collected, it can be observed that the majority of the respondents are currently employed at the Executive Level (39.0%). This is followed by respondents whom are currently employed at Management Level (24.4%) and Unemployed 12.2%). Only 7.3% of the respondents were from the Senior Management Level. Lastly, 17.1% of the respondents categorized themselves as others. The percentages are shown in Table 4.4 and Figure 4.4 below:

Table: 4:4: the Current Level of Employment of the Respondents:

Employment Level	Frequency	Percent (%)	Cumulative (%)
Unemployed	5	12.2	12.2
Executive level	16	39.0	51.2
Management level	10	24.4	75.6
Senior Management level	3	7.3	82.9
Others	7	17.1	100.0
Total	41	100	

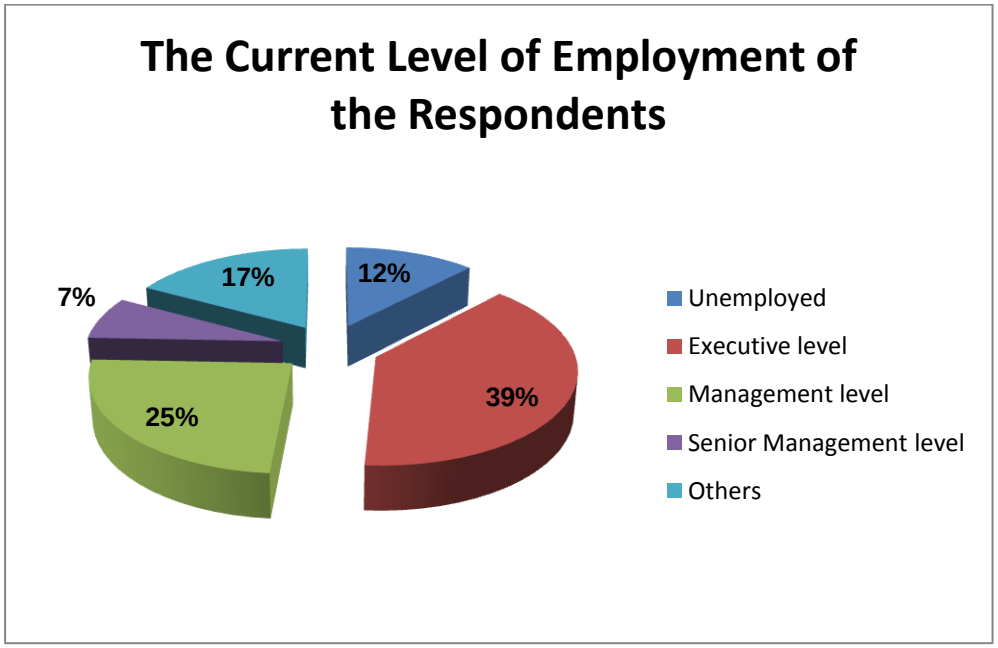

Figure 4.4: Level of Employment of the Respondents

4.7 The High-Rise Buildings Usage Frequency of the Respondents

From the data collected, it can be observed that the majority of the respondents use high-rise buildings on a daily basis (58.5%). This is followed closely by respondents who use high-rise buildings on a monthly basis (31.7%). Subsequently, the percentage reduces to 2.4% and 4.9% of respondents who use high-rise buildings on a annual Basis and weekly basis respectively. Lastly, only 2.4% of the respondents stated their never use high-rise buildings on a fortnightly basis. The percentages are shown in Table 4.5 and Figure 4.5 below:

Table 4:5 The High-Rise Buildings Usage Frequency of the Respondents:

Usage Frequency	Frequency	Percent (%)	Cumulative (%)
daily Basis	24	58.5	58.5
Weekly Basis	2	4.9	63.4
Monthly Basis	13	31.7	95.1
Annual Basis	1	2.4	97.6
Never	1	2.4	100.0
Total	41	100	

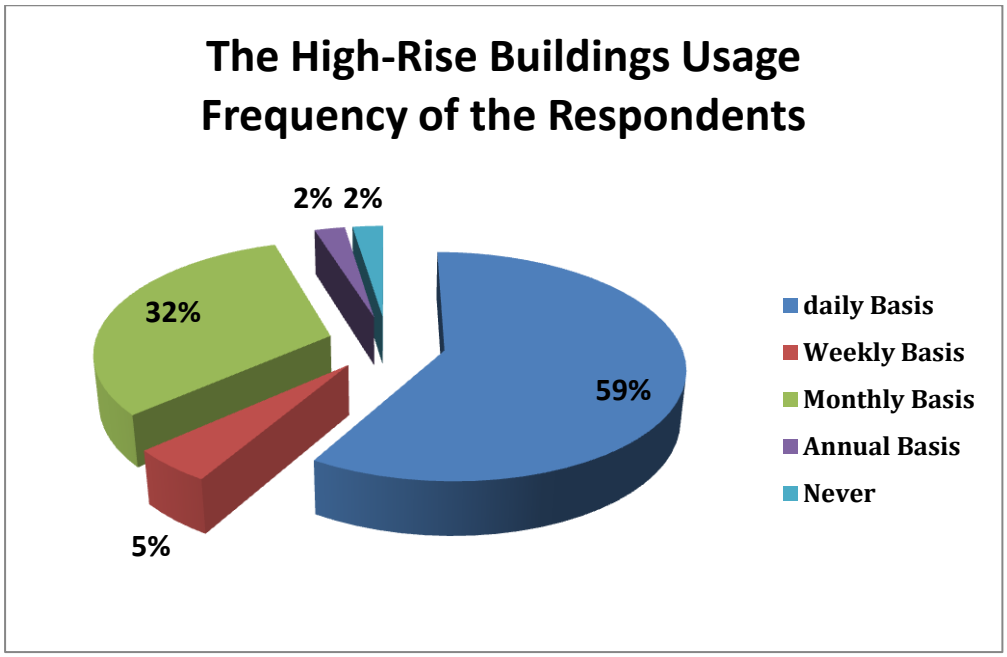

Figure4.5: High-Rise Buildings Usage Frequency of the Respondents

4.8 The High-Rise Buildings Most Frequent Usage Purpose of the Respondents:

From the data collected, it can be observed that the majority of the respondents most frequently use high-rise buildings as workers (70.7%). This is followed by respondents who are use high-rise buildings as visitor (22%). 7.3% were observed to be owner in high-rise buildings whereas 5% claimed to be owners of high-rise buildings. Lastly, the remaining 7.3% of the respondents stated owner of high-rise buildings. The percentages are shown in Table 4.6 and Figure 4.6 below:

Table 4:6 The High-Rise Buildings Most Frequent Usage Purpose of the Respondents:

Purpose	Frequency	Percent (%)	Cumulative (%)
Visitor	9	22.0	22.0
Worker	29	70.7	92.7
Owner	3	7.3	100.0
Total	41	100	

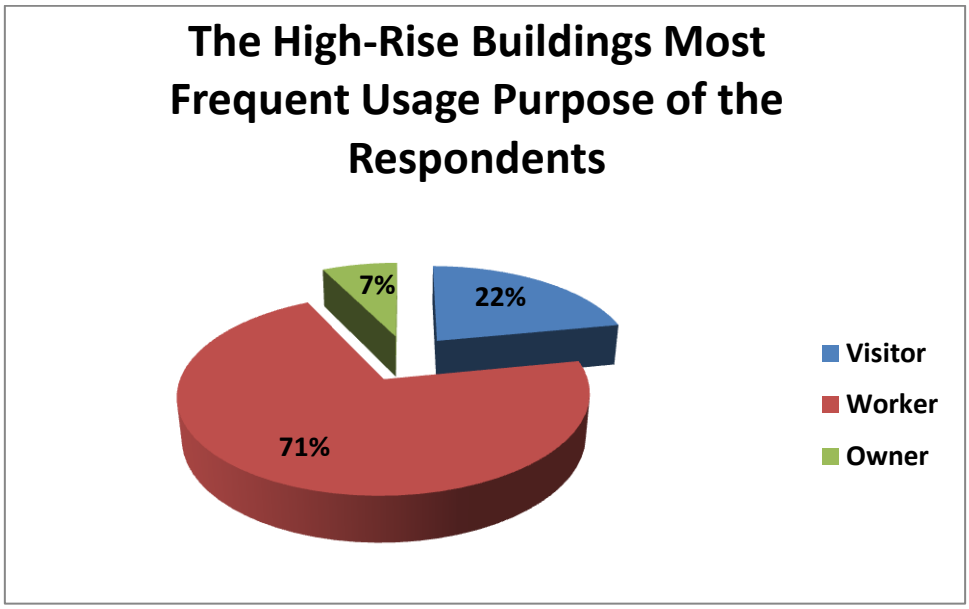

Figure4.6: The High-Rise Buildings Most Frequent Usage Purpose of the Respondents

4.9 The Results of the Questionnaire Survey section 2:

4.9.1 Part 1:

This section attempts to identify the aspects of Fire Safety Management that would influence the fire safety of high-rise building users. Analysis of the questionnaires showed that Provide clear signage indicating exit routes and location of fire safety equipment had ranked as the most aspects factor which influence fire safety of High-Rise Building users with RII (0.96), rank1 and the second aspect was conducting inspection and maintenance of fire safety equipment with RII (0.93), rank2. The least ranked was training of high-rise building users in fire life safety.

Table 4.7 shows the data obtained from the Questionnaire Survey

The Aspects of Fire Safety Management that Influences Fire Safety of High-Rise Building users:

Aspects that influence fire safety of High-Rise Building users		**Frequency Analysis**					**RII**	**RANK**
		1	**2**	**3**	**4**	**5**		
		No. of Resp						
A	Training of high-rise building users in fire life safety	5	0	0	8	28	0.86	4
B	Conducting inspection of electrical installations;	0	1	6	8	26	0.89	3
C	Provide clear signage indicating exit routes and location of fire safety equipment;	0	0	2	5	34	0.96	1
D	Implementing pest control program;	0	1	5	10	25	0.89	3
E	Conducting inspection and maintenance of fire safety equipment	0	1	1	10	29	0.93	2

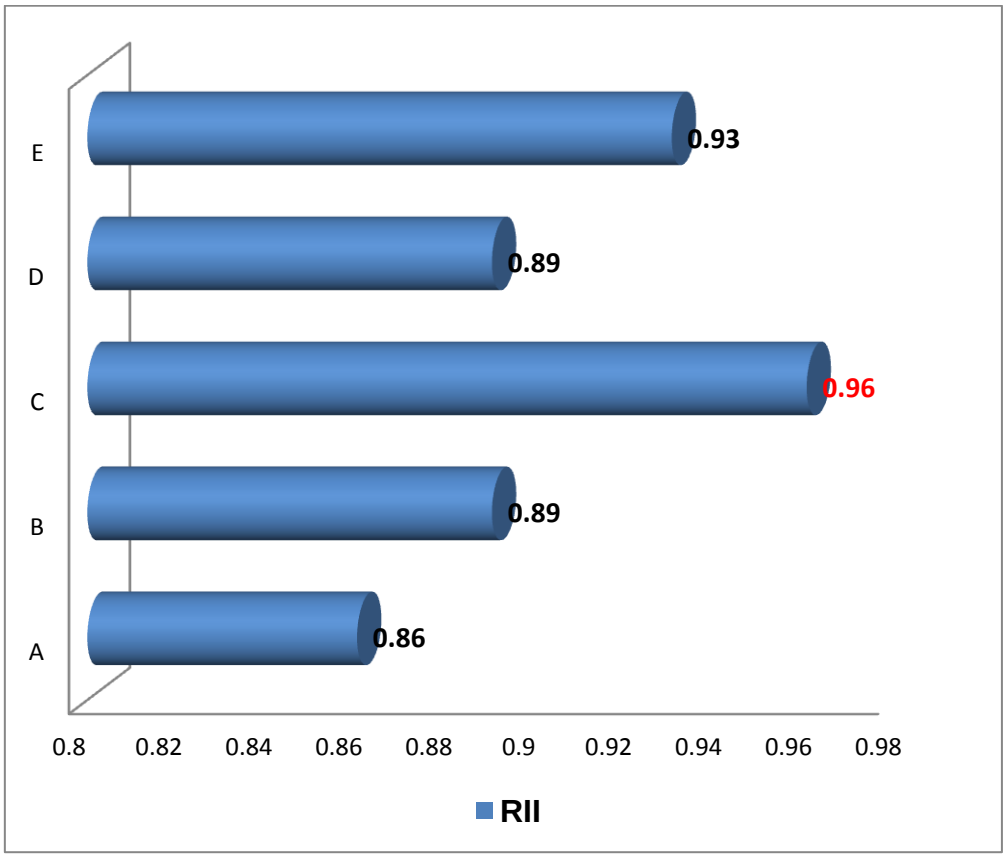

Figure 4.7: Aspects that influence fire safety of High-Rise Building users

4.9.2 Part 2:

The Most Critical Aspects of Fire Safety Management that Influences Fire safety of High-Rise Building Users:

This section attempts to identify the most critical aspects of Fire Safety management that would influence the fire safety of high-rise building users.
the ranking in Table 4.8, the most critical aspects of Fire Safety Management that influences fire safety of high-rise building users have been identified that Provide clear signage indicating exit routes and location of fire safety equipment is the most important and critical aspect of Fire Safety Management.

The second highest ranked critical aspect based on the field data collected is the training of high-rise building users in fire life safety because it helps the user to increase the awareness of the users towards fire safety, enhance their ability to react in the event of any emergency situation.

The third highest ranked *critical aspect based* on the field data collected is the ensure that flammable materials are stored in a safe area.

Table 4.8 shows the data obtained from the Questionnaire Survey

Most Critical Aspects that Influence fire Safety of High-Rise Building Users:

	Most Critical Aspects that Influence fire Safety of High-Rise Building Users	**Frequency**	**Percent**	**Cumulative Percent**
A	Training of high-rise building users in fire life safety	9	21.9	21.9
B	Conducting inspection of electrical installations	3	7.3	29.2
C	Implementing pest control program	6	14.6	43.8
D	Provide clear signage indicating exit routes and location of fire safety equipment.	11	26.8	70.6
E	Ensure that flammable materials are stored in a safe area	8	19.5	90.1
F	Conducting inspection and maintenance of fire safety equipment	4	9.8	100
	TOTAL	41	100	

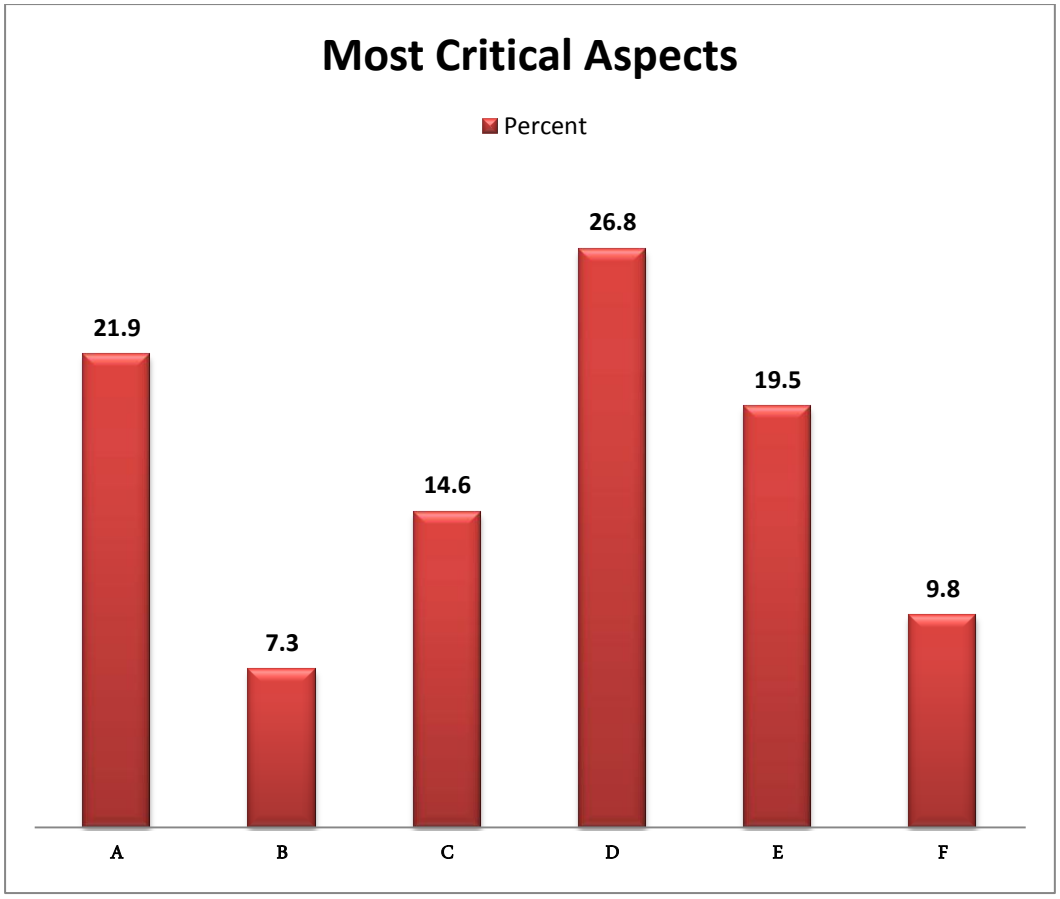

Figure 4.8: The Most Critical Aspects of Fire Safety Management that Influences Fire safety of High-Rise Building Users.

4.9.3 Part 3:

The Methods to Improve Fire Safety of High-Rise Building Users:

This section attempts to identify the methods to improve fire safety of high-rise building users.

Table 4.10 shows the results from the Questionnaire Survey

Methods to Improve Fire Safety of High-Rise Building Users:

Methods to Improve Fire Safety of High-Rise Building Users		**Frequency Analysis**					**RII**	**RANK**
		1	**2**	**3**	**4**	**5**		
		No. of Respondents						
A	Conduct more training programs for high-rise building users to increase awareness and ability to react in case of emergency	0	0	5	12	24	0.89	1
B	Assign specific personnel as Building Emergency Response for emergency situations.	0	0	4	12	24	0.88	2
C	Conduct regular inspections of all electrical installations to minimize threat of fire.	0	1	3	6	28	0.85	4
D	Implement a regular best control program to eliminate rodents and other pests from damaging electrical wires and causing short circuiting.	0	2	3	19	14	0.78	5
E	Ensure that flammable materials are stored in a safe area	1	1	1	3	32	0.87	3

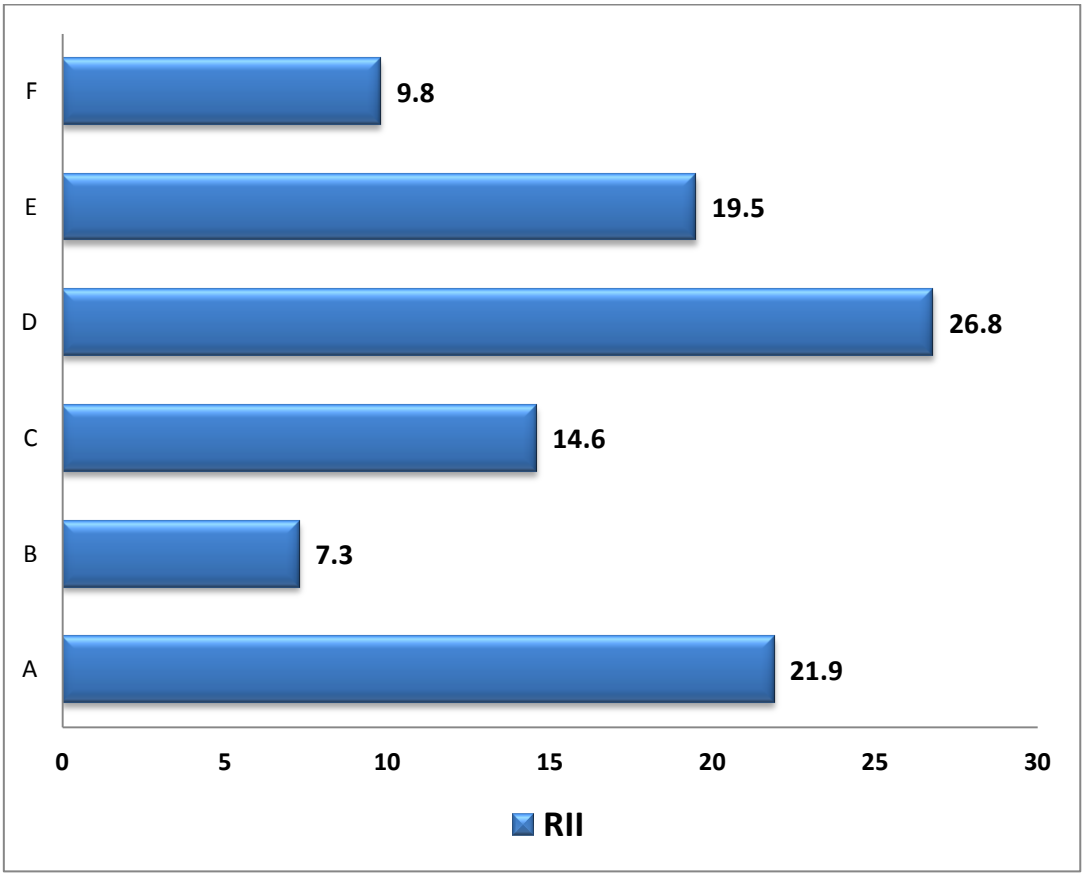

Figure 4.9: The Methods to Improve Fire Safety of High-Rise Building Users

This section attempts to identify the best methods to Improve Fire Safety of High-Rise Building Users from the data collected in table 4.10 , shown that conduct more training programs for high-rise building users is the best method to increase awareness and ability to react in case of emergency is the effective method to Improve Fire Safety of High-Rise Building Users .

The second highest ranked methods to Improve Fire Safety of High-Rise Building Users based on the field data collected is the Assign specific personnel as Building Emergency Response for emergency situations

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the conclusion of the study and also provides recommendations recommendation by summarizing the results of the analysis. Some recommendations for further studies are also included. Based on the literature review, data from the questionnaires distribution and analysis of the results, the three main objectives of this study have been achieved.

5.2 Conclusions:

As a conclusion, this study has successfully identified the three objectives that were previously stated:

Objective 1: To identify the attributes of Fire Safety Management that influences fire safety Of high-rise building users

According to the data collected from the questionnaire survey, The Aspects of Fire Safety Management that Influences Fire Safety of High-Rise Building users are ranked as follows

1- Provide clear signage indicating exit routes and location of fire safety equipment with RII (0.96)
2- Conducting inspection and maintenance of fire safety equipment with RII (0.93)
3- Conducting inspection of electrical installations and Implementing pest control program with RII (0.89)
4- Training of high-rise building users in fire life safety with RII (0.86)

Objective 2: To identify The Most Critical Aspects of Fire Safety Management that Influences Fire safety of High-Rise Building Users

According to the data collected from the questionnaire survey, the most critical aspects of Fire Safety Management that influences fire safety of high-rise building users are ranked as follows:

1- Provide clear signage indicating exit routes and location of fire safety equipment (26.8%)
2- Training of high-rise building users in fire life safety (21.9%)
3- Ensure that flammable materials are stored in a safe area (19.5%)
4- Implementing pest control program (14.6%)
5- Conducting inspection and maintenance of fire safety equipment (9.8 %)
6- Conducting inspection of electrical installations (7.3%)

Objective 3: To identify methods to improve fire safety of high-rise building users

According to the data collected from the questionnaire survey the Methods to Improve Fire Safety of High-Rise Building Users are ranked as follows:

1- Conduct more training programs for high-rise building users to increase awareness and ability to react in case of emergency with RII (0.89)
2- Assign specific personnel as Building Emergency Response for emergency situations with RII (0.88)
3- Ensure that flammable materials are stored in a safe area with RII (0.87).
4- Conduct regular inspections of all electrical installations to minimize threat of fire with RII (0.85).
5- Implement a regular best control program to eliminate rodents and other pests from damaging electrical wires and causing short circuiting with RII (0.78).

5.3 Recommendation

To improve the current study, some recommendations are given below:

a. The need to increase awareness of users in high-rise buildings by further training to act in case of fire.

b. The need for a contingency office (safety) in high-rise buildings to avoid fires.

c. The need for a specialist office to follow up safety procedures in high-rise buildings.

d. The importance of having safety tools for use in the case of emergency.

5.4 Recommendation for Further Studies:

There are some areas suggested for further study in the area of Fire safety Management as listed below:

a. The awareness level of high-rise building users towards implementation of fire Safety Management in high-rise buildings.

b. The attitude of high-rise building users towards fire safety with regards to the type of high-rise buildings.

c. The satisfaction level of high-rise building users towards Fire Safety Management in high-rise buildings.

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APPENDICES

QUESTIONNAIRE

FIRE SAFETY MANAGEMENT IN HIGH-RISE BUILDINGS

Dear Sir/Madam

I am pursuing a Master's of Science (Construction Management) from the Faculty of Civil Engineering, **Sudan University of Science and Technology**. As a requirement of fulfilling my course, I am conducting a survey to obtain data that are relevant to this research. I appreciate your kind participation by being one of my respondents in my research. You can be rest assured that ALL THE INFORMATION IN THIS SURVEY WILL BE STRICTLY KEPT PRIVATE AND CONFIDENTIAL.

Thank you.

Musab Amir

BACKGROUND INFORMATION OF RESPONDENT

1. What age group do you belong to?

	>20 years		41 – 50 years
	20 – 30 years		< 50 years
	31 – 40 years		

2. Gender.

	Male		Female

3. Education level:

	Diploma Level		Doctorate Level
	Degree Level		Others
	Masters Level		

4. At what level are you currently employed?

	Unemployed		Senior Management Level
	Executive Level		Others
	Management Level		

6. How often do you use high-rise buildings?

	Daily Basis		Monthly Basis
	Weekly Basis		Annual Basis
			Never

7. What do you most frequently use high-rise buildings as?

	Visitor		Owner
	Worker		Others

QUESTIONNAIRE SURVEY FORM

PART I

The objective of this section is to identify the attributes of Fire Safety Management that would influence fire safety of high-rise building users;
الهدف من هذا القسم تحديد عناصر ادارة السلامة التي توثر علي السلامة من الحرائق بين مستخدمين المباني العالية

1	2	3	4	5
Disagree لا اوافق	Uncertain غير متاكد	Partially agree اوافق جزئيا	Agree اوافق	Strongly Agree اوافق بشدة

A	Training of high-rise building users in fire life safety تدريب مستخدمي المباني العالية علي اجراءت السلامة في حالة نشوب حريق	1	2	3	4	5
B	Conducting inspection of electrical installations; اجراء المعاينات والفحص للتوصيلات الكهربائية	1	2	3	4	5
C	Provide clear signage indicating exit routes and location of fire safety equipment; توفير لوحات ارشادية توضح مخارج الطواري واماكن معدات السلامة	1	2	3	4	5
D	Implementing pest control program; تنفيذ افضل برامج التحكم والرقابة	1	2	3	4	5
E	Conducting inspection and maintenance of fire safety equipment عمل فحص وصيانة لمعدات السلامة	1	2	3	4	5

PART 2

The objective if this section is to identify the most critical attributes of Fire Safety that would influence fire safety of high-rise building users.

الهدف هذا القسم تحديداكثر العناصر اهمية للسلامة من الحرائق التي تؤثر علي السلامة من الحرائق لمستخدمين المباني العالية

Please rank the following in order of how critical they are beginning from (1) to (6), where

(1) indicates the most critical and (6) indicates the least critical.

A	Training of high-rise building users in fire life safety تدريب مستخدمي المباني العالية علي اجراءت السلامة في حالة نشوب حريق	
B	Conducting inspection of electrical installations اجراء المعاينات والفحص للتوصيلات الكهربائية	
C	Implementing pest control program تنفيذ افضل برامج التحكم والرقابة	
D	Provide clear signage indicating exit routes and location of fire safety equipment. توفير لوحات ارشادية توضح مخارج الطواري واماكن معدات السلامة	
E	Conducting inspection and maintenance of fire safety equipment عمل فحص وصيانة لمعدات السلامة	
F	Ensure that flammable materials are stored in a safe area التاكد من ان جميع المواد القابلة للاشتعال مخزنة في مناطق امنة	

PART 3

The objective of this section is to identify methods to improve fire safety of high-rise building users.الهدف من هذا القسم تحديد وسائل تحسين اجراءت السلامة من الحرائق لمستخدمي المباني العالية

1	2	3	4	5
Disagree لا اوافق	Uncertain غير متاكد	Partially agree اوافق جزئيا	Agree اوافق	Strongly Agree اوافق بشدة

A	Conduct more training programs for high-rise building users to increase awareness and ability to react in case of emergency اجراء المزيد من الدورات التدريبية لمستخدمي المباني العالية لزيادة الوعي والقدرة التصرف الامثل في حالات الطواري	1	2	3	4	5
B	Assign specific personnel as Building Emergency Response for emergency situations.تكليف موظفين مدربين في المبني للاستجابة لحالات الطواري	1	2	3	4	5
C	Conduct regular inspections of all electrical installations to minimize threat of fire. اجراء تفتيش دوري للتوصيلات الكهربائية للتقليل من مخاطر الحريق	1	2	3	4	5
D	Implement a regular best control program to eliminate rodents and other pests from damaging electrical wires and causing short circuiting. تنفيذ برنامج دوري لمكافحة الافات لمنع الفئران والافات الاخري من اتلاف الاسلاك الكهربائية والتسبب في حدوث حريق	1	2	3	4	5
E	Ensure that flammable materials are stored in a safe area التاكد من ان جميع المواد القابلة للاشتعال مخزنة في مناطق امنة	1	2	3	4	5

Other Suggestions:

Thank you for your co-operation