IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 3, June 2024

Assessing and Improving Fire Safety Measures of Healthcare Facilities with Special Reference to Pedestrian Flow Evacuation Simulation and Evacuation Dynamics

Pravin Tathod[1] and Hardik Dixit[2]
Professor, Department of Industrial Safety Engineering[1]
PG Scholar, Department of Industrial Safety Engineering[2]
Shiv Kumar Singh Institute of Technology & Science, Indore, India

Abstract: *Fire protection and safety measures in hospitals are of utmost importance to ensure the safety of patients, staff, and visitors. In case of a fire, it is crucial to evacuate people safely and quickly. However, evacuation in hospitals is a complex process due to the presence of patients with varying degrees of mobility, staff, and visitors, and the hospital's unique layout. This project aims to assess and improve fire protection and safety measures in hospitals, focusing on pedestrian flow evacuation. The project team conducted a comprehensive literature review of various research papers to gain a better understanding of fire basics, the leading causes of death in case of fire, and the challenges that arise during evacuation. The literature review revealed that fires in hospitals are rare, but when they occur, the consequences can be catastrophic. The leading cause of death in case of fire is smoke inhalation, and the most significant challenge during evacuation is the movement of patients with mobility issues. The literature review also highlighted the importance of smoke detection systems, sprinkler systems, and fire-resistant materials in hospitals. These systems and materials can significantly reduce the risk of fire and minimize the damage caused by a fire. Additionally, the literature review revealed that the use of ire drills is critical to prepare staff and patients for an emergency. To gain a better understanding of the challenges that arise during evacuation, the project team conducted interviews with hospital staff and patients. The interviews revealed that the most significant challenge during evacuation is the movement of patients with mobility issues. These patients require specialized equipment and assistance to move, which can slow down the evacuation process. The interviews also revealed that staff training is critical to ensure an efficient evacuation process. Staff members need to be trained on the proper evacuation procedures, the location of emergency exits, and how to use specialized equipment during evacuation. The project team created a simulation of a hospital floor with pedestrians to investigate the dynamics of evacuation. The simulation revealed that the movement of patients with mobility issues significantly slowed down the evacuation process. The simulation also highlighted the importance of clear signage and staff guidance during evacuation. Based on the literature review, interviews, and simulation, the project team identified several ways to improve fire protection and safety measures in hospitals. These include conducting regular fire drills to prepare staff and patients for an emergency, installing smoke detection systems, sprinkler systems, and fire-resistant materials in hospitals, and providing staff training on proper evacuation procedures and the use of specialized equipment during evacuation. By implementing these measures, hospitals can improve their fire protection and safety measures and ensure the safety of patients, staff, and visitors during an emergency. The project takes hospital occupancy as the research object, sets the fire scenario, manipulates Pathfinder simulation software to establish the evacuation model, studies the evacuation rules in fire, ascertains the key problems in evacuation, and gets the maximum number of people evacuated during the safe evacuation time*

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 3, June 2024

Keywords: Health care facility, Hospital, Fire, Safety, Evacuation, Pedestrian, Smoke ventilation, Mobility, Safety measures etc.

I. INTRODUCTION

Hospitals are usually considered a safe heaven and support system for the people involved in an emergency situation. Hospitals have variety of materials that can contribute towards a happening of fire. Hospital fires are disruptive in terms of threat to life, damage to property and interruption of services. Our study showed that electrical short circuit is the most common cause of fire. Our aim is to identify potential Fire hazards and improve Fire and safety in healthcare Facilities. The very first requirement in a hospital is that it should do the sick no harm. In order to fulfill this, administration in hospitals needs to conceptualize and regularize certain set of criterions to function and should not, in any situation, deviate from safety standards depicted by governing bodies. Effective safety management system requires implementation of meticulously planned logistics and readiness in case of an emergency. The past accidents happened in hospitals reflect poorly on the implementation of proper safety protocols and inadequacy of emergency response. Safety must be made as a value for the organization. The protection of any facility requires the identification and assessment of organizational Vulnerabilities. Although healthcare facilities have the same protection needs, the degree of Vulnerability varies from one facility to another. In general, the public perceives hospitals as a highly secure facility because its job entitles providing a safe environment for its patients; however, the number of medical fire disasters around the globe shows otherwise. This disaster events shine light on the danger and potential fire threats that hospital patients will have to face while pursuing for their health. Fire safety in hospitals is a very important aspect of hospital architecture and maintenance. However, the work done so far to measure these fire safety norms is meager and needs urgent attention. Hospital authorities do not pay much importance to this aspect of internal threat in a health care facility imparting directly to cause dent on patient safety. Fires can be devastating, especially in a hospital where a large number of people who need to be evacuated may be vulnerable- immune compromised, on life support, and incapable of moving on their own. The persons inside a hospital are of various physical and mental characteristics that have dissimilar reactions toward fire. Evacuation during fire accidents becomes difficult for these patients. There are special requirements that must be met while evacuating such people in case of Fire emergencies. A hospital attracts large people who visit the different sections of a hospital on daily basis. Even though they may arrive into the hospital in vehicles, their movements within the hospital units are mainly pedestrianized. The provisions for their movements in the hospital as well as the efficacy of their movements, the special needs to be understood, for effective design of facilities and for easy and safe evacuation in times of emergency. The purpose is to deliver long-term as well as short term solutions to prevent fires first and to fight fire hazards in healthcare facilities if they occur. The objective is to propose simulation modeling as a tool to understand, analyze, and improve hospital evacuation plans.

1.1 Background and Motivation

Fire safety in healthcare facilities is incredibly important, considering the care required for vulnerable people within such facilities. These premises require a lot of precaution in every aspect, as health and safety are at the forefront of concern. With the possibility of many patients dealing with mobility issues, in the event of a fire, the evacuation process may prove more difficult in healthcare Facilities than in other usual facilities. Taking the time to understand what the common hazards could be within a hospital environment takes priority. Hospitals create plenty of notable fire safety risks due to housing so many vulnerable people. Not only will a fire put endangered people at risk, but it could also harm staff members and cause the hospital to stop functioning properly. Increasing patient numbers and demands for more hospital beds all makes the original hospital architecture inadequate and demands for hospital expansion. While additions or alterations must be added to the building in order to meet both human demands and medical needs, constructions within hospitals may have adverse effects on its patients. A 2020 study in the International Journal of Community Medicine and Public Health analyzed 33 major fire mishaps in Indian hospitals between 2010 and 2019, of which 25 occurred in government hospitals. Only 19 of the 33 hospitals had a functional firefighting system. People losing their lives at a place which is supposed to be a beacon of health is a tragic phenomenon. Therefore, It is the responsibility of every healthcare establishment to ensure that fire safety standards and regulations are followed to prevent fire accidents and the consequent human suffering.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 3, June 2024

1.2 Case studies of hospital fires

1.2.1 AMRI Hospital, Kolkata

On December 2011, a major Fire Accident at AMRI hospital in Kolkata killed around 95 people. The main cause of this mishap was an Electrical Short Circuit and stocking of Combustible Substances in the basement. This was a case of negligence by the management of the hospital. During the Incident, the hospital had around 160 patients and also many staff members. At least 50 patients were there in the intensive ward.

Fig 1.1 AMRI Hospital Fire

1.2.2 IMS & SUM Hospital in Bhubaneshwar

October 17, 2016, we saw one of the worst Fire accidents in IMS & SUM Hospital, Bhubaneswar. 22 were killed and 120 were injured. In this case, the hospital staff tried to douse the Fire with Fire extinguishers and inthis process, they lost almost 20 crucial minutes before they called the Fire Department. This shows the lack of preparedness of the hospital staff during emergencies.

Fig 1.2 IMS & SUM Hospital Fire

1.2.3 Rohini Super specialty hospital in Hanamkonda

On October 17, 2017, an electrical short-circuit triggered a Fire in Rohini super specialty hospital in Hanamkonda, Telangana. 199 patients were admitted to this hospital at the time of the accident. Two patients died and four were injured. The hospital's Fire Safety system did not work during this crucial time. Everyone including the doctors and hospital staff was in a state of panic and did not know how to respond.

Fig 1.3 Rohini Super Specialty Hospital Fire

1.2.4 MY Hospital Indore

The lives of 47 newborn babies were in danger when a Fire broke on November 4, 2017, at MY Hospital, Indore. Fortunately, there was no loss of life. But it is alleged that the hospital has been flouting Fire Safety laws. In all the cases, the Fire Safety laws have been violated.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 3, June 2024

Fig 1.4 MY Hospital Fire

1.3 Objectives of research

1) To assess and improve the Fire and Safety provisions in healthcare Facilities.
2) To identify the potential fire hazards in healthcare facilities
3) To understand the challenges/difficulties faced during Evacuation of occupants in healthcare facilities.
4) To provide a systematic evacuation plan using simulation.

1.4 Scope of the research

1) The project covers the minimum design criteria and details of the various fire protection facilities to be provided in healthcare facilities according to NBC-2016.
2) The project covers the general requirements of a standard healthcare building to carry out quick and safe evacuation.

II. AREA OF STUDY

2.1 Health Care Occupancy:

An occupancy used to provide medical or other treatment or care simultaneously to four or more patients on an inpatient basis, where such patients are mostly incapable of self-preservation due to age, physical or mental disability, or because of security measures not under the occupants' control.

Health care occupancies are like ambulatory health care occupancies in that they contain four or more patients who are incapable of self-preservation; however, health care patients are inpatients, rather than outpatients, and are provided with housing and sleeping accommodations to facilitate extended care. Examples are hospitals, nursing homes, and limited-care facilities, which could include something like psychiatric hospitals. These facilities are provided with the highest level of life safety features due to the number of patients expected to be unable to evacuate themselves on an around-the-clock basis. For health care occupancies, the Code utilizes a defend-in-place strategy, in which patients are moved from the area of fire origin to an adjacent, protected smoke compartment, without requiring vertical travel in the building. While all three of these occupancies provide varying degrees of health care services, the protection requirements for life safety from fire vary significantly, all dependent on the occupant risk.

Health care occupancy classification, applicable building codes, should be considered early in project design. Health care facilities are unique in that there may be multiple, differing authorities having jurisdiction (AHJs) overseeing the design, construction, and operation of the facility. These different AHJs may use different standards or different versions of the same standards. Health care occupancy classification is important to determine for fire protection (smoke zones, smoke control) and for future adaptability of the HVAC system for a more restrictive occupancy. Health care facilities are increasingly diversifying in response to a trend toward outpatient services. The term clinic may refer to any building from a residential doctor’s office to a specialized cancer treatment center. Integrated regional health care organizations are becoming the model for medical care delivery as outpatient facilities take on more advanced care and increasingly serve as the entryway to the acute care hospital. These organizations, as well as long established hospitals, are sometimes constructing buildings that look less like hospitals and more like luxury hotels and office buildings. However, when specific health care treatments in these facilities are medically consistent with hospital-based treatment activity, then the environmental design guidance applicable to the hospital-based treatment should also apply to the clinic’s treatment environment.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 3, June 2024

The general hospital provides a variety of services; its environmental conditions and design criteria apply to comparable areas in other health care facilities. The general acute care hospital has a core of patient care spaces, including rooms for operations, emergency treatment, delivery, patients, and a nursery. Usually, the functions of radiology, laboratory, central sterile, and pharmacy are located close to the critical care space. Inpatient nursing, including intensive care nursing, is also within the complex. The facility also incorporates a kitchen, dining and food service, morgue, and central housekeeping support.

2.2 Fire protection in Hospitals:

The aim of a fire protection system is to protect a building's occupants and minimize the damage associated with fire. Overall, the goal is to provide the widest possible window for a safe evacuation, whilst also reducing potential repair costs.

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. In structures, be they land-based, offshore or even ships, the owners and operators are responsible to maintain their facilities in accordance with a design-basis that is rooted in laws, including the local building code and fire code, which are enforced by the authority having jurisdiction

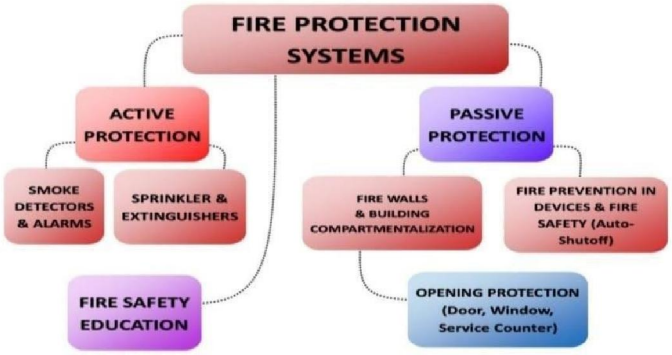


Fig 3.9 Fire Protection System

2.3 Emergency in a Hospitals:

Hospitals are expected to maintain services for patients during disasters. Facilities shall develop and be prepared to implement an emergency preparedness plan that will assess, prepare for, respond to, mitigate and recover from disasters. It is important that facilities have an emergency preparedness plan those addresses required topics and is useful to employees in emergency situations

Fig 3.13 Emergency

2.4 Goals of Emergency Preparedness:

• Prevention of loss of life.

• Prevention or mitigation of trauma to patients and other occupants.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 3, June 2024

• Maintenance of hospital services to the greatest extent possible, given the severity of the disaster.
• Prevention or minimization of property loss.

2.5 Five phases of emergency management:

- Prevention
- Mitigation
- Preparedness
- Response
- Recovery

2.6 Manual carry evacuation techniques:

Manual evacuation is the process of transporting casualties by manual carries. It is accomplished without the aidof a litter or other forms of transport. It is intended to end at the point where a more sophisticated means of evacuation becomes available. For example, manual evacuation ends when a litter, vehicle, or other form of conveyance is available.

Fig 3.14 Blanket Drag

Fig 3.15 Pack-Strap Carry

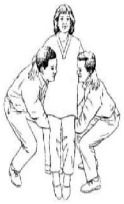


Fig 3.16 Swing Carry

2.7 Evacuation dynamics:

This brings about serious safety issues for the participants and the organizers who have to be prepared for any case of emergency or critical situation. Usually in such cases the participants have to be guided away from the dangerous area as fast as possible. Therefore the understanding of the dynamics of large groups of people is very important. In general, evacuation is the egress from an area, a building or vessel due to a potential or actual threat. In the cases described above the dynamics of the evacuation processes is quite complex due to the large number of people and their interaction, external factors like fire etc., complex building geometries, Evacuation dynamics has to be described and understood on different levels: physical, physiological, psychological, and social. Accordingly, the scientific investigation of evacuation dynamics involves many research areas and disciplines. The system "evacuation process" (i.e. the population and the environment) can be modelled on many different levels of detail, ranging from hydro-dynamic models to artificial intelligence and multi-agent systems. There are at least three aspects of evacuation dynamics that motivate its scientific investigation:

1) As in most many-particle systems several interesting collective phenomena can be observed that need to be explained;
2) Models need to be developed that are able to reproduce pedestrian dynamics in a realistic way, and
3) The application of pedestrian dynamics to facility design and emergency preparation and management.

The investigation of evacuation dynamics is a difficult problem that re quires close collaboration between different fields. The origin of the apparent complexity lies in the fact that one is concerned with a many- 'particle' system with complex interactions that are not fully understood. Typically the systems are far from equilibrium and so are e.g. rather sensitive to boundary conditions. Motion and behavior are influenced by several external factors and often crowds can be rather inhomogeneous

III. PROBLEM IDENTIFICATION

There are several concerns in fire safety of a hospital building. Provision of fire prevention and protection plans must be prepared and communicated to prevent losses due to fire. According to the studied data, few hospitals

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 3, June 2024

with high-tech protection systems were not competent enough in fire safety management. Faults and difficulties identified are as follows:

- Absence of fire protection and firefighting systems.
- Non- compliance of law enforcement.
- Non-functional Fire protection systems.
- No maintenance and inspection of firefighting appliances.
- Incompetency of hospital staff regarding safety issues.
- Combustible materials used and stored in the building.
- Poor accident management methodology.
- No proper smoke management systems.
- Lack of adequate fire risk assessments.
- No provision of Assembly areas.
- No proper and easy access to Fire extinguishers.
- No proper early detection system and alarm system.
- No escape routes plans.
- Improper illumination and ventilation.
- Improper construction with no passive fire protection facilities.
- Lack of fire safety awareness among people.
- Untrained staff
- No proper emergency response plan.
- Poor Housekeeping
- Lack of communication systems.
- Overloading of high voltages and current leading to short circuit
- No proper maintenance of Electrical systems.
- Overcrowding.
- No path route sign boards.
- Obstruction between Evacuation routes.
- Fire mock drills are not conducted.
- Improper handling of chemicals.

IV. PROBLEM FORMULATION

4.1 Legal parameters

Buildings on the basis of occupancies have been divided into different groups in NBC 2016. Hospitals have been classified as sub-division C-1 under Group C for Institutional Buildings with some specific requirements applicable for this category in addition to the general requirements common for all occupancies.

As per the fire load calculated it is considered as Moderate hazard occupancy as per NBC 2016. Group C Institutional Buildings

These shall include any building or part thereof, which is used for purposes, such as medical or other treatment or care of persons suffering from physical or mental illness, disease or infirmity; care of infants, convalescents or aged persons and for penal or correctional detention in which the liberty of the inmates is restricted. Institutional buildings ordinarily provide sleeping accommodation for the occupants.

4.2. Sub-division C-1 Hospitals and sanatoria

This sub-division shall include any building or a group of buildings under single management, which is used for housing persons suffering from physical limitations because of health or age, for example, hospitals, infirmaries, sanatoria and nursing homes.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 3, June 2024

		Type of Installation									Water Supply (In liters)		Pump Capacity (in L/min)	
S.No.	Type of Building/ Occupancy	Fire Extinguisher	Hose Reel	Dry Riser	Wet Riser	Downcomer	Yard Hydrant	Automatic Sprinkler System	Manually operated Electric Fire Alarm System	Automatic Detection & Fire Alarm System	Underground static water storage tank	Terrace tank	Pump near underground static water storage tank with min pressure 3.5Kg/cm2 at terrace level	At the terrace tank level with min pressure 2 Kg/cm2
	INSTITUTION BUILDINGS													
a	Hospitals, Sanitoria & Nursing Homes (C-1)													
1	Less than 15 m in height with plot area up to 1000m2													
i	Up to ground plus one storey, with no beds	R	R	NR	NR	NR	NR	R (NOTE 1)	R	NR	NR	2500 (2500) SEE NOTE 2	NR	NR
ii	Up to ground plus one storey with beds	R	R	NR	NR	R	NR	R (NOTE 1)	R	NR	NR	5000 (5000) SEE NOTE 2	NR	450(450) SEE NOTE 2
iii	Ground plus 2 or more storeys, without beds	R	R	NR	NR	R	NR	R (NOTE 1)	R	R	NR	5000 (5000) SEE NOTE 2	NR	450 (450) SEE NOTE 2
iv	Ground plus 2 or more storeys, with beds	R	R	NR	R	NR	NR	R (NOTE 1)	R	R	50000	5000 (5000) SEE NOTE 2	NOTE 3	NR
2	Less than 15 m in height with plot area more than 1000m2	R	R	NR	R	NR	R	R (NOTE 1)	R	R	10000	10000	NOTE 3	NR
3	Above 15m height but not exceeding 24m in height	R	R	NR	R	NR	R	R (NOTE 6)	R	R	100000	20000	NOTE 4	NR
4	Above 15m height but not exceeding 30m in height	R	R	NR	R	NR	R	R (NOTE 6)	R	R	150000	20000	NOTE 5	NR
		R = Required			NR = Not required									
	Note 1	Required to be installed in basement if area of basement exceeds 200m2												
	Note 2	Additional value given in parenthesis shall be added if basement area exceeds 200m2												
	Note 3	One electric & one diesel pump of capacity 1620 lpm and one electric pump of capacity 180 lpm												
	Note 4	One electric & one diesel pump of capacity 2280 lpm and one electric pump of capacity 180 lpm												
	Note 5	One electric & one diesel pump of capacity 2280 lpm and one electric pump of capacity 180 lpm												
	Note 6	To be installed at all floors at appropriate places and in consultation with local fire authorities												

Table: 4.1 Minimum Requirements for Fire Fighting Installations in Hospitals

In buildings or sections occupied by bed-ridden patients where the floor area is over 280 m2, facilities shall be provided to move patients beds to the other side of a smoke barrier from any part of such building or section not directly served by approved horizontal exits or exits from the first floor (floor 2) of a building to the outside.

Not less than two exits of one or more of the following types shall be provided for every floor, including basement, of every building or section:

- Doors leading directly outside the building;
- Stairways;
- Ramps;
- Horizontal exits;
- Fire tower.

All required exits that serve as egress from hospital or infirmary sections shall be not less than 2 m in clear width including patient bedroom doors to permit transportation of patients on beds, litters, or mattresses. The minimum width of corridors serving patients bedrooms in buildings shall be 2400 mm. For detailed information on recommendations for buildings and facilities for the physically handicapped, reference may be made to good practice.

•Elevators constitute a desirable supplementary facility, but are not counted as required exits. Patient lifts shall also be provided with enough room for transporting a stretcher trolley.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 3, June 2024

Any area exceeding 500 m2 shall be divided into compartments by fire resistant walls. Doors in fire resistant walls shall be so installed that these may normally be kept in open position, but will close automatically. Corridor door openings in smoke barriers shall be not less than 2000 mm in width.

Provision shall also be made for double swing single/double leaf type door.

Wherever any inmates are confined in any locked rooms or spaces, adequate guards or other personnel shall be continuously on duty or immediately available to provide for release of inmates or for such other action as may be indicated in case of fire or other emergency.

No building constructed in whole or in part of combustible materials shall be used to confine inmates in cells or sleeping quarters, unless automatic sprinkler protection is provided.

All buildings or sections of buildings in penal and mental institutions used for manufacturing, storage or office purposes shall have exits in accordance with the provisions of the Code for those occupancies.

4.3 NABH (National Accreditation Board for Hospitals and Healthcare Providers) Role:

NABH is committed to ensuring quality & safety of hospitals and healthcare organizations. The Facility Management & Safety Standard covers Fire & other hazards. The standards applicable for fire hazards are:

NABH Standard	NABH objective element	Guidelines for objective elements	Relevance of objective element
FMS. 1: The organization is aware of and complies with the relevant rules and regulations, laws and byelaws and requisite facility inspection requirements	FMS 1a	The management is conversant with the laws and regulations and knows their applicability to the organization.	Legal Compliance
FMS.2: The organization's environment and facilities operate to ensure safety of patients, their families, staff and visitors.	FMS 2b	Drawing related to Fire escape Routes (NBC guidelines)	Infrastructure point of view
FMS.2: The organization's environment and facilities operate to ensure safety of patients, their families, staff and visitors.	FMS 2c	Fire exit signage's (NBC guidelines)	Infrastructure point of view
FMS.5: The organization has plans for fire and non-fire emergencies within the facilities.	FMS 5a	Fire exit plan for each floor displayed & in each patient Room (NBC guidelines)	Infrastructure Design point of view
FMS.5: The organization has plans for fire and non-fire emergencies within the facilities.	FMS 5a	Exit Door should remain open on all the time (NBC guidelines)	Infrastructure Design point of view
FMS.5: The organization has plans for fire and non-fire emergencies within the facilities.	FMS 5a	Emergency illumination system in case of Fire (NBC guidelines)	Infrastructure Design point of view
FMS.5: The organization has plans for fire and non-fire emergencies within the facilities.	FMS 5a	Adequate Fire detection system across Hospital i.e. smoke & Fire sensors (NBC guidelines)	Infrastructure Design point of view
FMS.5: The organization has plans for fire and non-fire emergencies within the facilities.	FMS 5a	Adequate Fire Fighting system across Hospital i.e. sprinklars,extinguishers, hydrants (NBC guidelines)	Infrastructure Design point of view
FMS.5: The organization has plans for fire and non-fire emergencies within the facilities.	FMS 5a	Central Fire alarm system monitored 24 X 7	Infrastructure Design point of view
FMS.5: The organization has plans for fire and non-fire emergencies within the facilities.	FMS 5a	Designated place for assembly of patients/staff in the event of fire	Operational point of view
FMS.2: The organization's environment and facilities operate to ensure safety of patients, their families, staff and visitors.	FMS 2a	Operational & Maintenance plan of Fire equipment including refilling of extinguisher	Hospital Operational point of view
FMS.2: The organization's environment and facilities operate to ensure safety of patients, their families, staff and visitors.	FMS 2a	Up-to-date fire drawing to be available	Hospital Operational point of view
FMS.5: The organization has plans for fire and non-fire emergencies within the facilities.	FMS 5a	Deployment of Fire Officer	Hospital Operational point of view
FMS.5: The organization has plans for fire and non-fire emergencies within the facilities.	FMS 5a	Adequate training plans for Hospital staff on how to protect patients from fire, how to evacuate patients from fire besides knowing how to report fire, nearest fire escape route, nearest fire extinguisher etc	Hospital Operational point of view
FMS.5: The organization has plans for fire and non-fire emergencies within the facilities.	FMS 5a	Schedule to conduct mock fire drills (at least twice in a year)	Hospital Operational point of view
FMS.5: The organization has plans for fire and non-fire emergencies within the facilities.	FMS 5a	Maintenance of mock fire drills records	Hospital Operational point of view

Table:4.2 NABH Standard Applicable for Fire Hazards

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 3, June 2024

V. MATERIAL AND METHODOLOGY

5.1 Minimum Essential Fire Safety Measures Checklist According to National Accreditation Board for Hospitals & Healthcare Providers:

National Accreditation Board for Hospitals & Healthcare Providers (NABH)

Minimum Essential Fire Safety Measures Checklist

Applicable to Healthcare Units under all schemes of Certification and Accreditation

These guidelines are meant to ensure patient safety and in no way absolves the organization of fulfilling its statutory obligations with regard to fire safety.

Valid fire NOC

Present

Verify that minimum essential fire safety measures are in place and/or functioning

Absent

Approval/Registration from local health authority e.g. nursing home act/DHO.

If fire NOC is not applicable, organization to provides justification for the same.

If fire NOC is applicable, confirm that the organization has applied for fire NOC and there is regular correspondence (at least once in three months) with fire department which is acknowledged. Any correspondence received from the fire department has to be submitted

Third party inspection certificate should be available. The third party audit should provide evidence to suggest that statutory norms are adhered to. The third party inspection certificate is valid for a maximum period of one year.

Any observation by the third party should have been addressed.

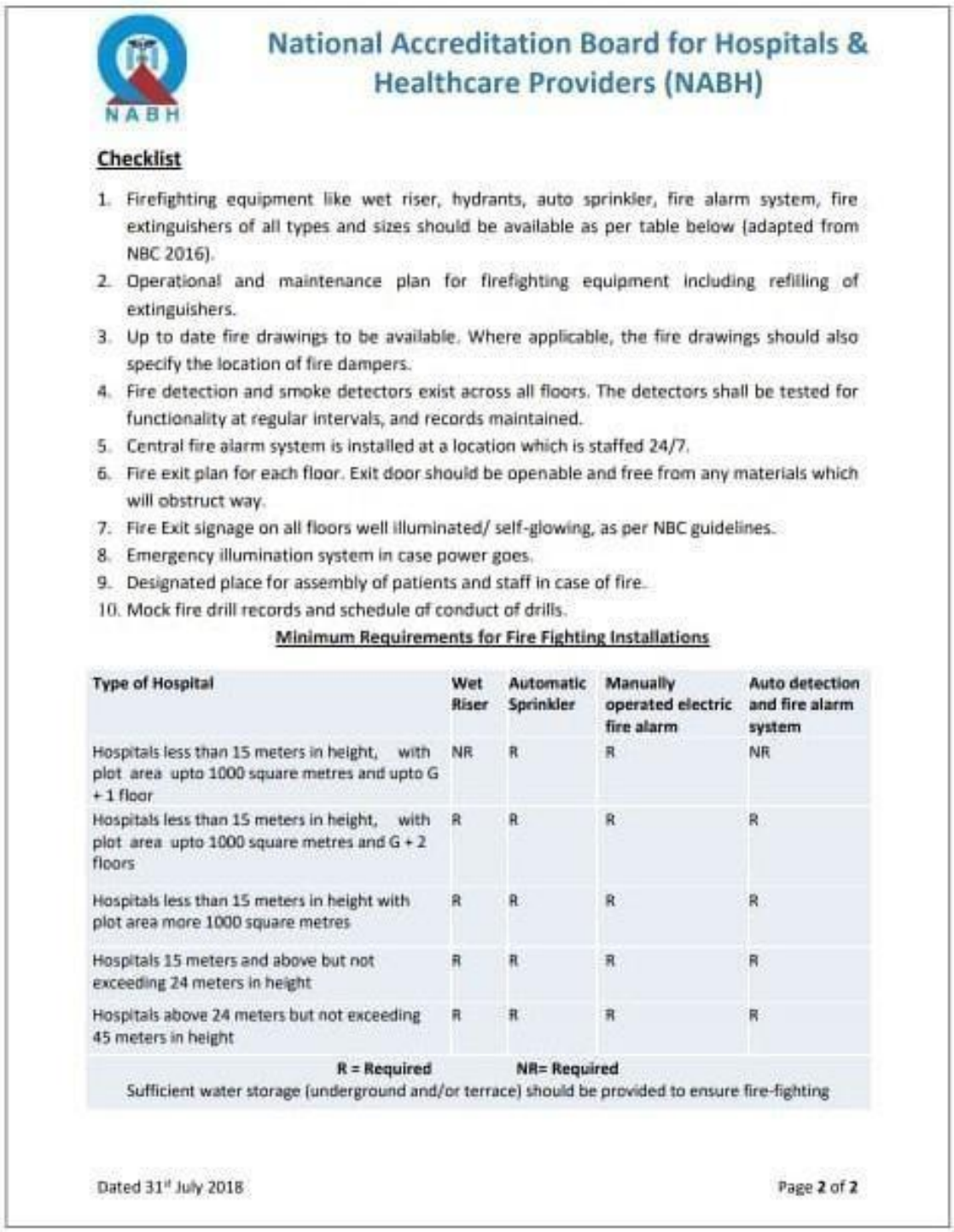
Head of the organization/Promoter to give an undertaking on the organization's letter-head stating that fire safety measures are in place and adhered to at all times.

During assessment, verify that the points in the checklist are in place and are functioning.

Dated 31st July 2018

Page 1 of 2

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 3, June 2024



National Accreditation Board for Hospitals & Healthcare Providers (NABH)

Checklist

1. Firefighting equipment like wet riser, hydrants, auto sprinkler, fire alarm system, fire extinguishers of all types and sizes should be available as per table below (adapted from NBC 2016).
2. Operational and maintenance plan for firefighting equipment including refilling of extinguishers.
3. Up to date fire drawings to be available. Where applicable, the fire drawings should also specify the location of fire dampers.
4. Fire detection and smoke detectors exist across all floors. The detectors shall be tested for functionality at regular intervals, and records maintained.
5. Central fire alarm system is installed at a location which is staffed 24/7.
6. Fire exit plan for each floor. Exit door should be openable and free from any materials which will obstruct way.
7. Fire Exit signage on all floors well illuminated/ self-glowing, as per NBC guidelines.
8. Emergency illumination system in case power goes.
9. Designated place for assembly of patients and staff in case of fire.
10. Mock fire drill records and schedule of conduct of drills.

Minimum Requirements for Fire Fighting Installations

Type of Hospital	Wet Riser	Automatic Sprinkler	Manually operated electric fire alarm	Auto detection and fire alarm system
Hospitals less than 15 meters in height, with plot area upto 1000 square metres and upto G + 1 floor	NR	R	R	NR
Hospitals less than 15 meters in height, with plot area upto 1000 square metres and G + 2 floors	R	R	R	R
Hospitals less than 15 meters in height with plot area more 1000 square metres	R	R	R	R
Hospitals 15 meters and above but not exceeding 24 meters in height	R	R	R	R
Hospitals above 24 meters but not exceeding 45 meters in height	R	R	R	R

R = Required **NR= Required**

Sufficient water storage (underground and/or terrace) should be provided to ensure fire-fighting

Dated 31st July 2018 Page 2 of 2

Table: 5.1 Movement Constraint of Occupants

5.2 Pathfinder by thunderhead engineering:

Pathfinder is a simulation software that is used to model the movement of people in various types of buildings, such as airports, hospitals, stadiums, and more. It is commonly used to optimize building designs and ensure the safety of

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 3, June 2024

occupants in emergency situations. Pathfinder uses advanced algorithms to simulate the behavior of pedestrians, taking into account factors such as their walking speed, direction, and density. This allows architects and engineers to test different design scenarios and identify potential issues before construction even begins. For example, they can test how people will move through a building during a fire or other emergency, and make design changes to ensure that everyone can evacuate safely. Thunderhead Engineering is the company that developed Pathfinder. They are a software development company that specializes in creating simulation tools for the architecture, engineering, and construction industries. Their software is used by some of the largest and most well-known companies in the world to improve building design and safety. Thunderhead Solutions has a team of experts who are constantly working to improve the software and add new features to meet the evolving needs of the industry.

5.3 Simulation Model Details:

We had made a model of an hospital floor to be evacuated, the floor has the total area floor of 2595 m2 Which is divided into different wards and sections which consist of a General ward of area 606 m2, 2 Super deluxe rooms of 112 m2 area each, 11 Deluxe rooms with area of 55 m2 each, 4 cabins of doctors of area 50 m2 each and the open areas and corridors with area of 950 m2.The geometry of chair, stretcher and evacuation assistant are shown below. The evacuation chair requires only one assistant during movement, while the stretcher requires two assistants. The size of the chair are the default size provided by the pathfinder. During movement in Pathfinder, a geometric envelope of the vehicle and assistants is used to detect collisions.

Wheelchair

Stretcher

Fig.5.1 Collision Geometry of Wheelchairs and Beds with Assistance

The above figure shows the layout of the floor with the positions of the patients and the staff.

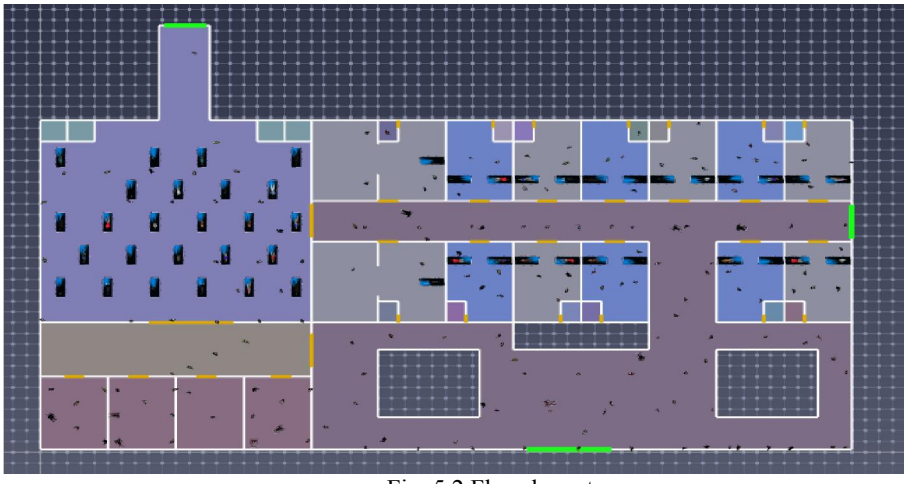


Fig. 5.2 Floor layout

Occupants	Bed	Staff	Visitors	Wheelchairs
Speed	0.5m/s (Constant)	1.19m/s (Constant)	0.5-1.2 m/s(Variable)	0.5m/s (Constant)
Assistance required	2 Assistants	No Assistant	No Assistant	1 Assistant

Table 5.2 Movement Constraint of Occupants

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 3, June 2024

VI. RESULT OF SIMULATION

Profile	Count	Minimum time	Maximum time	Average time
Bed	49	6.3	45.1	25.2
Staff	85	18.8	115.4	65.6
Visitors	80	0.2	80.9	27.2
Wheelchair	10	5.3	49.3	29.5
All Profiles	224	0.2	115.4	41.4

Table 5.3 Details of Occupants during Evacuation

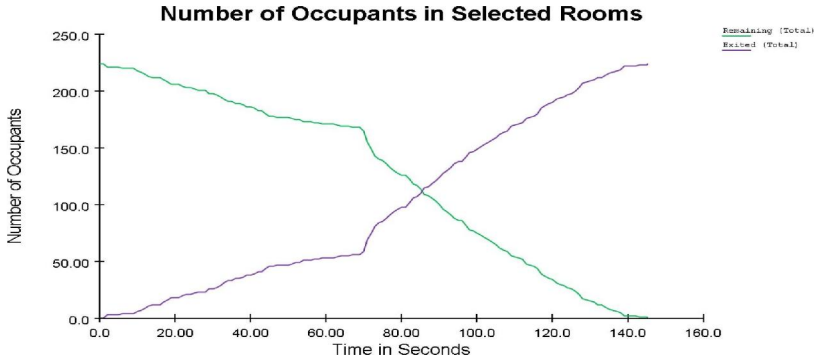


Fig. 5.3 Graph of Number of Occupants with Respect to Time

VII. OBSERVATIONS AND FINIDING SUMMARY

7.1 Observations

Hospital visits were conducted to observe potential fire hazards in healthcare facility which may affect the safety of the occupants. The problems faced during the evacuation process were also observed.

The observations made are discussed below:

Fires in healthcare facilities can be caused by a variety of factors, including:

1. Electrical Issues: Electrical problems are a common cause of fires in healthcare facilities. Overloaded circuits, faulty wiring, and malfunctioning electrical equipment can all contribute to electrical fires.
2. Smoking: Smoking is a common cause of fires in healthcare facilities, especially in areas where patients are allowed to smoke.
3. Cooking: Cooking is another common cause of fires in healthcare facilities. Kitchens and food preparation areas must be equipped with proper ventilation and fire suppression systems to prevent fires.
4. Heating: Faulty heating systems, such as space heaters, can also cause fires in healthcare facilities.
5. Chemicals: Healthcare facilities use a wide range of chemicals for cleaning and disinfecting. These chemicals can be flammable and must be handled and stored properly to prevent fires.

Evacuating healthcare facilities during a fire scenario can be a challenging task due to the unique characteristics of these facilities. Observations were made regarding problems that may be encountered during the evacuation process which are as follows:

1. Limited mobility of patients: Patients in healthcare facilities may have limited mobility, making it difficult for them to evacuate quickly in the event of a fire. This can be particularly challenging for patients who are bedridden or require assistance with walking.
2. Crowding and congestion: Healthcare facilities can be crowded, especially during peak hours, which can make evacuation more challenging. The presence of medical equipment, such as IV poles and oxygen tanks, can also create congestion and make it difficult for people to move around.
3. Staff training and preparation: Healthcare facility staff may not be adequately trained or prepared for emergency situations such as fires. This can result in confusion and delay during evacuation, which can put patients and staff at risk.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 3, June 2024

4. Communication issues: Communication can be a challenge during an emergency situation, particularly in healthcare facilities where there may be language barriers or communication difficulties due to hearing or speech impairments.
5. Evacuation routes and accessibility: Healthcare facilities often have multiple floors and complex layouts, making it difficult to identify evacuation routes and exits. In addition, some exits may be inaccessible due to the presence of smoke or fire, which can further complicate the evacuation process.
6. Patient identification and tracking: In a large healthcare facility, it can be challenging to quickly identify and track patients during an evacuation. This can create confusion and delay in getting everyone to safety.
7. Medical needs during evacuation: Patients in healthcare facilities may have specific medical needs that require attention during the evacuation process. This can include the need for oxygen, medication, or medical equipment, which can make the evacuation more complex.

During an evacuation, smoke can hinder people's ability to see, causing confusion, disorientation, and panic, which can lead to injuries and delays in the evacuation process. Additionally, smoke can make it difficult to breathe, causing respiratory distress, and potentially increasing the risk of death for those who are unable to evacuate quickly.

7.2 Important Findings

Pathfinder software can be particularly useful during the evacuation process in hospitals, which can be complex and challenging due to the presence of patients who may require specialized care and equipment. Here are a few ways in which Pathfinder software can help in this context:

1. Patient tracking: Pathfinder software can be used to track the movement of patients during an evacuation, ensuring that they are safely transported to the appropriate areas of the hospital or to external medical facilities. This can be particularly important for patients who require specialized care or equipment.
2. Route optimization: Pathfinder software can help to identify the most efficient routes for transporting patients and staff during an evacuation, taking into account factors such as the location of exits, the capacity of corridors and elevators, and the location of critical equipment.
3. Staff training: Pathfinder software can be used to simulate evacuation scenarios, allowing staff to practice their roles and responsibilities in a safe and controlled environment. This can help to improve their response times and reduce the risk of injury during a real emergency.
4. Capacity analysis: By modelling the behaviour of staff and patients during evacuations, Pathfinder software can provide an estimate of the time it will take to evacuate the hospital. This can be useful in determining the necessary resources, such as personnel and transportation, to facilitate an efficient evacuation.
5. Communication: Pathfinder software can be used to develop clear and effective communication strategies for staff and patients during an evacuation, helping to ensure that everyone is informed and knows what to do.

Overall, the use of Pathfinder software can help hospitals to plan and prepare for the safe and efficient evacuation of patients and staff in the event of an emergency.

VIII. RECOMMENDATIONS AND FUTURE SCOPE

8.1 Recommendations

The issues which have listed in problem statement are all potential fire safety hazards that can pose a significant risk to occupants of a hospital or any other building. To ensure the safety of patients, staff, and visitors, it is essential to address these issues and implement appropriate measures to prevent fires or respond effectively if they occur.

Some of the measures that can be taken to address these issues include:

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 3, June 2024

1. Installing fire protection and firefighting systems, including sprinklers, fire alarms, smoke detectors, and fire extinguishers.
2. Ensuring compliance with local fire codes and regulations.
3. Conducting regular inspections and maintenance of fire protection systems and equipment to ensure they are functional and effective.
4. Providing training and education to hospital staff on fire safety issues, including proper use of fire protection equipment and evacuation procedures.
5. Minimizing the use and storage of combustible materials in the building and ensuring they are properly stored and handled.
6. Developing and implementing a comprehensive accident management methodology that includes emergency response procedures, communication protocols, and evacuation plans.
7. Installing proper smoke management systems to prevent the spread of smoke and toxic fumes during a fire.
8. Conducting regular fire risk assessments to identify potential hazards and develop appropriate mitigation measures.
9. Providing designated assembly areas outside the building for occupants to gather during an evacuation.

It is highly recommended that all the healthcare facilities should customize their own evacuation simulation model according to the occupancy building layout using pathfinder software and then display it on the screen. Displaying evacuation simulations on screen provides a realistic visualization which can help the occupants to understand better and visualize emergency procedures. It can also help staff to retain information and improve their response during an actual emergency. Displaying evacuation simulations on screen is often a cost- effective alternative to physical evacuation drills, which can be expensive and disruptive to regular operations. Healthcare facilities can record and analyze the data to monitor the performance of the evacuation plans and also identify areas for improvement.

8.2 Future Scope

The future scope of the project is quite promising, and there are several potential avenues for future development and research.

Firstly, the project can be expanded to include a more extensive analysis of the factors that impact the safety of healthcare facilities in the event of a fire, such as the location and accessibility of fire exits, the availability of fire suppression systems, and the effectiveness of fire safety training for staff and patients. This could involve collecting and analyzing data from a range of different healthcare facilities to identify common challenges and opportunities for improvement.

Secondly, the project could be extended to include the use of more advanced simulation techniques, such as computer-aided design (CAD) and virtual reality (VR), to more accurately model and simulate evacuation scenarios in healthcare facilities. These advanced techniques could provide more detailed and realistic representations of the physical layout and pedestrian flow patterns within healthcare facilities, allowing for more accurate assessments of fire safety measures and more effective improvements.

T**hirdly**, the project could be expanded to include a broader focus on emergency preparedness and response in healthcare facilities, including not only fire safety but also other types of emergencies such as natural disasters, mass casualty events, and infectious disease outbreaks. This could involve developing comprehensive emergency response plans, training staff and patients on emergency procedures, and conducting regular drills and exercises to ensure readiness.

Overall, the future scope of this project is vast, and there are many opportunities for further research and development to enhance fire safety measures and emergency preparedness in healthcare facilities, ultimately leading to improved outcomes for patients, staff, and the wider community.

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 3, June 2024

REFERANCES

[1]. Madhav Madhusudan Singh, Critical Analysis Of Fire Safety In Public & PVT Hospital In Delhi NCR.
[2]. Huang De-Ching, Chien Shen-Wen, Lin Chien-Hung, Huang Po-Ta, Song Yi-Ting, Sie Huei-Ru, A Study for the Evacuation of Hospital on Fire during Construction.
[3]. Y zou, Journal of Healthcare Engineering Vol 1: Healthcare Facility Evacuations.
[4]. S A Tabish, Fire Safety in Health Care Facility.
[5]. Oregon State Fire Marshal, Fire & Life Safety Practices in Hospitals.
[6]. NBC 2016 Part IV Fire and Life Safety.
[7]. NFPA 101, Life Safety Code.
[8]. Hunt, Aoife, Edwin R. Galea and Peter J. Lawrence, Hospital evacuation using Pathfinder.
[9]. The eight leading causes of hospital fires. http://www.fiercehealthcare.com/story/eight-leading-causes-hospital-fires/2009-10-20. Accessed 8 February 2014.
[10]. Cleveland Clinic, St. Anthony's Hospital, and Mercy Hospital fires: case studies. www.nfpa.org. Accessed 8 February 2014.
[11]. Hospital Barros Luco fire. PAHO report dated 27 May 2003.
[12]. Calderon Guardia Hospital fire. http://www.nbcnews.com/id/8551431/ns/world_news-americas/t/die-costa-rica-hospital-fire/#.UwKPntiYaM8. Accessed 8 February 2014.
[13]. St Jude Hospital. PAHO situation report dated 9 June 2010.
[14]. St. Joseph Mercy Hospital fire. http://www.stabroeknews.com/2010/archives/05/10/breaking-news-fire-destroys-st-joseph-mercy-hospital/. Accessed 8 February 2014.
[15]. Kolkata Hospital fire. http://www.bbc.co.uk/news/world-asia-india-16104610. Accessed 8 February 2014.
[16]. Psychiatric Hospital No. 14 fire. http://www.bbc.co.uk/news/world-europe-22304728. Accessed 8 February 2014.
[17]. Fire resistance properties of materials. http://publicecodes.cyberregs.com/icod/ibc/2009f2cc/icod_ibc_2009f2cc_7_par004.htm. Accessed 8 February 2014.
[18]. Sprinkler systems in healthcare premises. http://nahfo.com/files/Knowledge/SprinklerGuide1.pdf. Accessed 8 February 2014.
[19]. Smoke extractors. http://www.hevacomphelp.com/mech/1pdf/BEL/0009.PDF. Accessed 8 February 2014.