Application of Smart and Early Fire Detection Systems in Hospitals: Insights from Iraq

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Abstract

Fires pose a significant threat to safety in healthcare facilities, and early detection of fires is crucial to ensure the safety of patients, staff and infrastructure. Smart systems utilize advanced technologies such as sensing, data analysis and effective monitoring to swiftly detect fires and take appropriate measures. This research examines the application of smart systems in the early detection of fire accidents in hospitals.

In smart systems, the sensors collect data and send it to a central control unit that uses data analysis algorithms to analyze the information and detect any indications of a fire. In the event of abnormal changes or ignition, alarm devices are activated and relevant teams are immediately notified to take necessary actions, including patient evacuation if required.

The system enhances the safety of patients and staff by providing timely alerts and evacuation guidance. Additionally, the use of data analysis enables predictive capabilities, allowing for the identification of fire-prone areas or equipment malfunctions and implementation of preventive measures.

Thus, it plays a crucial role in ensuring the safety of patients, staff, and infrastructure. Through the use of sensor networks, data analysis, and real-time monitoring, these systems enable swift detection of fires and effective responses with evacuation measures. The integration of such systems enhances fire safety preparedness, reduces risks, and maintains the continuity of healthcare services in hospitals.

The research employs a theoretical framework that includes several aspects. It begins by defining the search terms and then study the determinants related to security and fire safety in hospitals. It then identifies the latest fire alarm and extinguishing systems.

It makes recommendations that will improve the performance of hospitals and prepare them to confront fire risks.

Keywords: Smart technologies, Environmental safety, Hospitals, Fires, Early detection.

Introduction

Security and safety factors in buildings are represented by a group of factors, determinants and standards that aim primarily to limit any human or material losses in the event of any emergency, within the narrowest possible scope to prevent its occurrence or spread. These factors are also almost completely in the hands of the designer, as he can influence it and

increase its efficiency, which leads to raising the functional efficiency of the building in general. There is no doubt that the issue of fire operations and combating it is one of the most basic aspects related to security and safety in buildings. Needless to say, this must occupy an important space in the awareness of a designer, especially since it is related to the security and safety of lives. It is possible that all services in a hospital will stop because of it. In fact, it is extremely difficult to evacuate those in a hospital. It is a fact that must be transferred from mere general perception to binding and obligatory design specifications, so that adherence to these specifications becomes a matter in the consciousness of an architect (Heba & Abda, 2016).

Fires pose a terrible danger to buildings and facilities. They spread so quickly that one may not be able to catch it. Firefighting efforts become extremely difficult, when they penetrate into the vacuum components of the buildings. The destructive and damaging effect of the elements result from the properties of materials, construction, their expansion, and corrosion. Buildings lose their fire resistance due to tension, shear, bending, and compression efforts. Fires change the center of the mass of a building and thus changes its structural behavior.

Fire has many effects on materials. They may lead to melting, cracking, twisting, or shrinking. Protecting people's lives when a fire breaks out depends on the resistance of the building, its construction and finishing materials. Thus, occupants of a building can escape in the event of a fire, if the time specified by the requirements and the fire codes have been adhered to, with the least help from others.

Therefore, fire safety has become a major concern. Fire risks are fatal and harmful to the security of the health industry as much as the others and raise concerns for human life. The best way to minimize these losses is to respond to the emergency as quickly as possible. Thus, a need has arisen for stand-alone heater detection systems among others. These systems provide rapid detection, alarm notification and generally initiation of termination next to the heater. Systems equipped with smoke and temperature sensors can detect unfavorable accidental situations as soon as they occur, and with the help of the processing unit, they can immediately alert to take cautious action. In these deadly cases, early detection and rapid alert can result in less loss of property and life (Shah & Satam,2019).

Hospitals are considered some of the most important facilities gathering for people, some of whom are unable to move, and some of whom live with the help of medical equipment. Thus, they are completely different from any other facility occupied by healthy people who can escape if they hear the alarm bells or receive news of a fire accident or the occurrence of any infection.

Hospitals in Iraq face many risks and crises among which the following issues have been identified.

- A lack of knowledge of the foundations for employing smart architecture in hospital emergencies, which can achieve better performance and efficiency.
- A loss of connection between the design aspects of hospitals and smart architecture as a scientific method for organizing spaces in a way that ensures safety procedures in them.

In this context, this research examines the application of smart and early fire detection systems in hospitals in Iraq. It has the following goals and objectives.

1. To provide work strategies that deal with safety procedures in hospitals through the application of smart systems and capabilities.
2. To articulate the strategic steps of the technology-based design elements that must be followed when carrying out the design work of health buildings by employing modern technologies and technological systems for smart health buildings, which works to increase awareness among local architects of the latest systems used globally in this field.
3. To promote technological progress by using smart and modern emergency systems when designing hospitals in order to reduc deaths, diseases, and risks resulting from fires and disasters.

The importance of this research stems from the following.

1. It being a study that deals with the evaluation of the means of prevention and safety and the application of smart systems in hospitals and their impact on the performance of workers.
2. Providing new information to researchers in the field of prevention and safety management.
3. It could facilitate the Ministry of Health which would work to develop means of prevention and safety and improve the performance of the workers.

Review of Literature

Many previous studies have addressed the issue of fires but have not focused specifically on hospitals. For example, recently, Ahn & Choi (2023) have confirmed the possibility of using fire detectors along with a computer vision-based CCTV indoors. This fire detector can achieve early fire detection, which suggests that casualties or property damage can be minimized. In addition, if a building uses CCTV, it can be used without installing additional devices, which can help minimize additional costs. In addition, it can be utilized without the time required for an individual to directly check the situation of a fire.

Al-Wahib and Abdul-Hakim (2007), determine the extent to which safety measures are available that aim to reduce fire accidents in government hospitals in the city of Riyadh. They establish the extent of applying preventive measures aimed at reducing fire incidents. They identify the obstacles that prevent the provision and application of safety means and preventive measures to the fullest extent in the government hospitals.

Al-Nimra and Jawad (2009) have studied the determinants related to how security and safety factors are applied in buildings (fire and firefighting works) and the impact of those applications on architectural design. They show that the architect is obliged to take these into account during the design stages. Alqourabah & Muneer(2020) have looked at building an advanced fire alarm system using heat and smoke alarms. The system reads the flame, heat, and smoke data using IoT, analyzes these data, and then quickly triggers the automatic water sprinkler. Thus the importance of this study is to provide a low-cost fire alarm system considering affordability, effectiveness and responsiveness.

Fengju Bu & Gharajeh (2019) provide an insight into the key features of different environments including different buildings and mines that should be taken into account when designing fire detection systems. They then discuss some smart fire detection systems. These systems are classified into two groups: smart forest fire detection systems and smart fire detection systems for all buildings. They use different smart technologies to detect fire incidents with high accuracy in different environments. Performance of the fire detection systems is compared with each other in terms of detection rate, accuracy, true positive rate, false positive rate, etc. under different evaluation scenarios.

Shah and Satam (2019) develop a fire and smoke detection system, which can sense smoke and the rise in temperature and alert users by activating a buzzer. It can also send commands on virtual terminals of android phones through wifi modules. Fire hazards are not uncommon. In fact, in order to avoid injury from fire accidents, smoke detectors are put in at high-security places. The hardware used is Ardunio Uno, Temperature Sensor, Smoke sensor, Wifi Module and Buzzer. Software use Arduino IDE and V-Terminal as a mobile application. These smoke discoverors detect smoke and the fire breaks invoke an early alarm. This way, before a fire spreads to different components of a building, people can be evacuated and counter-measures can be taken immediately.

Chowdhury illustrates a Fuzzy Rule based Intelligent Security to detect fires. He analyzes the mechanism of a firecatching process, and implement it by using a microprocessor based hardware and intelligent fire recognition software. He has also implemented a fuzzy rule based intelligent early fire detection warning system. The early warning before the fault with none ambiguity will avoid the disaster against the fault taking some preventive measures.

Theoretical Framework: Terminology of the Study

Following are some of the often-used terminologies in the field of fire.

Smart Technologies: refers to the integration of computing and telecommunication technology into other technologies that did not previously have such capabilities. What makes a technology 'smart' is its ability to communicate and work with other networked technologies, and through this ability to allow automated or adaptive functionality as well as remote accessibility or operation from anywhere.

The idea is that as smart technologies become networked. They can then share information with each other or work together. In this way, smart technologies may be more energy efficient, more-timely in the functions they perform, or more powerful when coordinated or shared. The totality of smart technologies and the potential they offer is often referred to as the Internet of Things (IoT) (Office for Information Technology, Williams)

Environmental Safety: Safety means maintaining human safety and health by providing safe work environments free of hazards, diseases and injuries. It consists of a set of preventive measures, rules and systems that protect lives and property from surrounding risks. Safety can also be described as "the set of engineering, organizational, and educational methods aimed at protecting humans and property." (Musa & Muhammad, 2008).

Hospitals: A hospital can be described as a comprehensive system consisting of a group of integrated and coordinated subsystems, including the basic medical services system, the additional medical services system, the hospitality services system, and the administrative services system. These systems interact together to achieve comprehensive patient and casualty care and support educational, training and research activities for learners and medical personnel (Jalda, Salim Boutros,2007).

The Concept of Fires

Fire is a chemical phenomenon that occurs when fuel combines with oxygen in the air under the influence of a certain temperature for each substance. The ignition temperature varies between different materials. A fire requires three basic elements: fuel, heat, and oxygen. This concept is known as the "ignition triangle."

Expected Risks in Hospitals

Hospitals are exposed to a wide range of risks that threaten environmental safety, and these risks must be identified and their causes identified in order to benefit from them in the future in appropriate treatment methods (Al-Aqayla, 2004). These risks are:

1. Mechanical risks: Such as the presence of unsafe materials, service supplies and work tools, in addition to the risk of falling and theft.
2. Electrical risks: These risks include electric shocks and fires, and these fires occur as a result of the temperature of electrical conductors rising to the point that it leads to the ignition of materials close to the heat source.
3. Structural risks: These result from civil works, maintenance, and construction materials, as well as the cracking or collapse of part of the buildings.
4. The dangers of not knowing: The dangers of lack of knowledge and ignorance of the operation and use of work tools and means, lack of training and failure to adhere to the rules, principles and instructions of prevention (Al-Aqayla, 2004).
5. Biological risks: These result from medical and therapeutic materials and vital and preventive activities such as infection transmission and water pollution (Mikhail, 2010).
6. Physical risks: These are the dangers resulting from working environmental conditions such as noise, radiation, dust, heat, and vibrations.

Design Standards for Protection from Fire Hazards

A designer must take the necessary measures to avoid fires and focus primarily on factors that help stop the activity of chemical reactions expected to occur. There are three aspects.

1. Fire prevention: These are the technical measures necessary to reduce the risk of fires.
2. Fire protection: These are the technical measures necessary to reduce the risk of fires if they occur).
3. Fire control: These are the procedures that are taken to deal with fires and extinguish them effectively).

Therefore, the role of the designer is focused on prevention and control processes. From fire to the determinants that ensure the success of applying the security and safety standards necessary to enhance the building's performance in the event of a fire. This includes the performance of the building itself, the performance of its occupants, and the performance of the firefighting teams. The architectural design in each of them aims to achieve the maximum levels of safety and effectiveness. Therefore, an architectural design includes all the design standards that ensures preventing the spread of fires and containing them, accelerating the process of safely evacuating the building in the event of an emergency, and providing the necessary means to facilitate the process of fighting the fire by the fire brigades (Al-Nimra, Nader Jawad, 2009).

Determinants of Increasing Building Performance

The design process for any building includes a set of determinants that contribute to preventing the spread of fire, working to contain it, and reducing the damage resulting from it. These determinants are classified as follows:

A- Resistance of the construction element to fire: The resistance of the structural element depends on two features: structural stability (how long the element can withstand the fire before it collapses), and separation (preventing the fire from spreading from one side of the structural element to the other side), and the determinants of the structural element are as follows: -

1- Consider using non-flammable materials that do not cause harmful gases when exposed to heat

2- Choose the appropriate finishing materials for the space, and the structural structure must be fire-resistant for a period of not less than 4 hours. (Pan American Health Organization,2014)

3- Providing good ventilation and safe and easy-to-access corridors for dangerous spaces that may cause fire, by providing emergency exits and stairs with insulated doors that open to the outside.

4- Place instructional signs for all safety devices used, and prohibit smoking inside the rooms (National Committee for the Saudi Building Code,2007)

B- Work to Restrict the Spread of Fire: The design limitations of fire prevention are to restrict the spread of fire in a specific area and limit it to a small area for a longer period, so the following measures must be taken:

1- Designing smart fire-resistant partitions that operate automatically when a fire occurs, as the hospital is divided into zones, so that the area of one department does not exceed (400) meters.

2- An independent secondary fire sector must be created for each location exceeding 50 people, in addition to considering each department in the hospital a separate fire sector, and also identifying industrial hazard areas such as mechanical and electrical rooms as separate fire sectors (Heba & Abda, 2016)

3- Installing fire-resistant doors in escape exits and places with high privacy

4- The size of any fire sector should not exceed 40 metres, and the locations of stairs and escape routes should be divided into separate fire sectors, and vertical spaces

such as skylights, elevators and any other openings should be isolated using insulating walls and doors at the same level (Heba &Abda, 2016)

C- **The Fire Alarm System**: The fire alarm system is used as an early warning method to alert building users of an emergency danger to enable them to leave the building as quickly as possible. This system is generally divided into automatic (automatic) fire alarm system and manual fire alarm system (Heba & Abda, 2016).

1- Distribution of smoke detectors, audio and visual alarms, and glass breaker switches
2- Distribution of manual alarm means on each floor through at least one alarm system, and additional means in the corridors, stairs, and at the doors of the exit routes, so that the access distance for one unit does not exceed 31 meters.
3- Cables and wires in alarm devices are either insulated copper conductors or optical fibers and are insulated with several layers of (PVC), rubber, or polyethylene (National Committee for the Saudi Building Code, 2007).
4- Insulating materials must be used and cables should be laid in special paths that have a fire resistance rating of no less than 2 hours.

D- **Design of Fire Extinguishing Systems:** When designing smart fire systems in hospitals, following should be taken into account:

1- Height of the hospital building, area per floor and the total building area.
2- Architectural design of escape systems and the material used in extinguishing
3- The pressures and water flow rates required for extinguishing, as the pressure necessary to put out the fire must be determined efficiently and in a timely manner.

Determinants of Building Occupant Performance (Design of Escape Routes and Exits)

The design of escape exits is considered one of the most important design determinants for preventing fire and protecting building occupants. To design these routes and exits, the four different stages of escape must be known in the event of an emergency (Sayed & Ali, 1997) Which is represented in the Figure (1.1).

1- The first stage (A) is the distance that the patient travels from the point he is in the room to the door when the fire occurs.
2- The second stage (B) is the movement from the door of the room to the corridor open to the room on the floor to the door of the escape stairway leading outside the building.
3- The second stage (C) is the movement of people inside the escape stairs
4- The second stage (D) is the movement from the end of the stairs on the ground floor until the person reaches the safety point

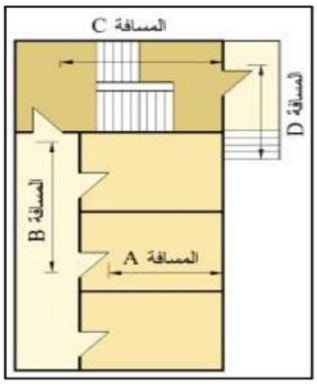

Fig. 1: The four different stages of escape in the event of a fire
Source: Sayed & Ali, 1997

Design specifications for escape areas are as follows:

1. The ends of the corridors should be free and their width should not be less than (1.80 m) in hospitals.
2. Placing indicative signs to clarify the movement of the direction of decline and rise
3. The width of the exit unit, which is estimated by the distance between the person's shoulders (0.56 m), and that the exit unit must not be less than two units, i.e. (1.0 m).
4. The distance to reach the escape exit must not exceed (45) m, and this distance depends on the type of use of the building and the materials used in construction work.
5. The flow rate from the escape exit. This rate is estimated at forty people per minute
6. Determine the number of exits
7. The time specified for the evacuation of people is estimated at two to three minutes, and this depends on the type of occupancy of the building and construction materials.

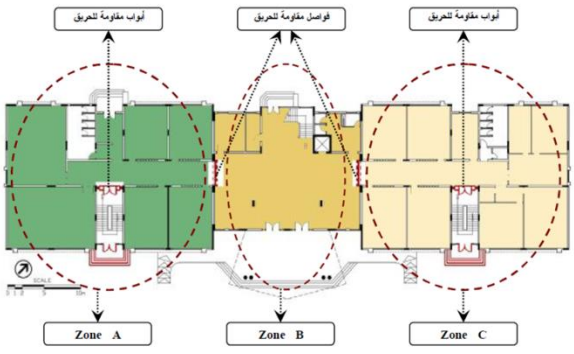

Fig. 2: limiting the spread of fire
Source: Al-Nimrah &Jawad, 2009

Design Specifications to Facilitate the Firefighters' Mission

1. Firefighters are considered the most important and first line of defense for fighting fires and limiting their spread, and the success of their mission depends on the architect's consideration of the following design parameters:
2. Installing a line between the control panel of the fire alarm system and the control room located at the Civil Defense Department, to automatically inform firefighters when the fire alarm system is activated.

3. Flexibility in the design of external window openings, to facilitate firefighters' access to all floors through them. Providing outdoor yards and tanks with emergency water resources to facilitate the process of firefighters in delivering water to fight fires.
4. Providing the building's design plans for all its floors and specifying the locations of the various exits and emergency points for each floor, as in Figure (1.3)

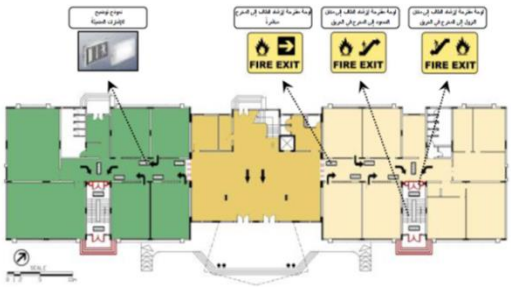

Fig. 3 The direction of escape movement for the occupants of the building at the time of the fire
Source : Al-Nimra, Nader Jawad, 2009

2- Early Warning Systems: The main benefit of these systems is the speed of responding to a fire and then converting this early response into an audio and visual signal to alert hospital users to the presence of a fire, Among the steps that are taken are the following.

1. Correctly sign "Alarms" in distinct places and out of public hands to avoid tampering with them or misuse, and they must be clear and known by hospital staff.
2. Providing the alternative energy needed to operate the system in the event of a power outage (Binggeli, C, (2003).
3. Providing emergency communications systems such as: public address system, portable radio unit, and other means to inform workers in emergency situations and contact the fire department.

Smart Systems Used to Detect and Extinguish Fires

1- **Sprinkler System**: This system is considered one of the most common and effective extinguishing systems. The system consists of spray nozzles distributed on the ceiling or walls and connected to a pipe system filled with water. When a fire is detected, the water valve in the respective nozzles opens and water spraying based on heat or electricity begins to extinguish the fire in the burning area(Hamood Alqourabah1 & Amgad Muneer).

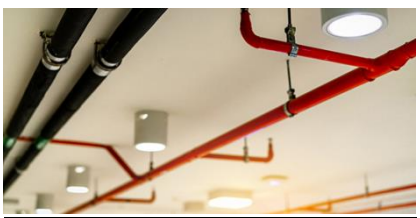

Fig. 4 Sprinkler System
Source: http://www.experience-mark.com/Fire_Systems.php

2- **Automatic Foam System**: This system uses foam as a means of extinguishing fires. The foam is automatically released when a fire is detected and is directed to the burning area to form an insulating layer that prevents the spread of flames and extinguishes the

fire. This system is used in areas that contain rapidly flammable materials or require specific suppression methods such as liquid fuel fires (Fire Systems, Inc).

Fig.5 Automatic Foam System
Source: https://2u.pw/ngK7sz0

3. **Automatic Water Mist System**: This system uses a fine spray of water to put out fires. Small, high-pressure sprayers are distributed that generate a fine mist of water. This system cools the burning area and reduces the oxygen concentration in it, which leads to extinguishing the fire (Liu & Kim 1999).

Fig 6: Example of Water Mist System Discharge
Source: Raia & Gollner,2014

3- **Electrical Fire Suppression Systems**: These systems use linear detection tubes to detect and extinguish fires. It is installed throughout cables and attachments. In the event of high temperature or a fire, the pressurized pipes explode and the extinguishing agent is released to extinguish the fire directly. Since the pipes explode at the temperature point, the extinguishing agent is released at exactly the correct location for the fire. A switch is also added to the system, so in the event of a pipe explosion A signal is published to isolate the power and issue an alarm (Business Watch.Inc).

Fig.7: Electrica Fire Suppression Systems
Source: https://www.businesswatchgroup.co.uk/fire-services/fire-suppression/electrical-fire-suppression

4- **Novec 1230 Fire Suppression**: It is a rapid, environmentally clean, safe to use fire suppression agent that is non-conductive and non-corrosive. The Novec 1230 has a discharge time of less than 30 seconds and discharges through a similar piping network to the FM200. It is stored as a liquid under pressure with nitrogen as the propellant gas (Business Watch.Inc).

Fig.8: Novec 1230 Fire Suppression
Source://www.businesswatchgroup.co.uk/fire-services/fire-suppression/gas-fire-suppression

5- **VESDA Detection Systems**: VESDA smoke detection solutions with continuous air sampling provide possible early warning of an impending fire. VESDA smoke detectors save critical time needed to verify the alarm and initiate the appropriate response to prevent injury, property damage or business disruption. Because VESDA detectors have a wide range of sensitivity and multi-level warnings, even minute levels of smoke can be detected before a fire has time to spread.

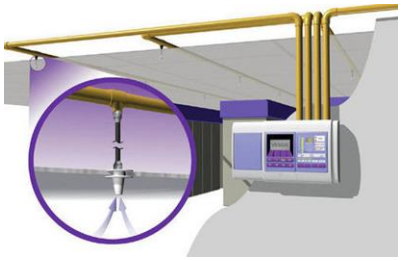

Fig.9: VESDA Detection Systems
Source: https://www.businesswatchgroup.co.uk/fire-services/fire-suppression/electrical-fire-suppression

6- **Explosion-proof system**: Explosion-proof fire safety barrier- This system does not affect the normal operation of electrical equipment under normal conditions, but when the system fails, it can limit the electrical energy that is transferred from a dangerous place to a safe place. This system can be used with a variety of fire detectors. This product uses advanced double resistance transistor electronic switching circuit, fast start-up speed, ultra-small output resistance, and automatic recovery. When the input current or voltage exceeds a predetermined value, the system starts working, so that the output voltage is almost zero, the current is reduced to a safe value (ASENWARE.Inc).
7- **Weather Proof Fire Alarm System**: A system that protects fire alarms in the event of water leakage on the floor or wall. It consists of a box with a transparent, waterproof plastic cover.

Conclusions

- Fires pose a major risk in hospitals due to the presence of patients who have difficulty moving and depend on medical equipment. The application of smart systems can contribute to early detection of fires, allowing rapid intervention, reducing damage, and protecting the lives of patients and hospital workers.
- Intelligent early fire detection systems integrate a range of technologies such as advanced sensors, early warning systems, wireless networks, and integrated emergency management systems. These technologies work together to improve the hospital's response to fire incidents.

- The lack of significant use of smart technology and smart building materials in our society; Due to the high cost and lack of specialized experience in smart systems and smart building materials, and the lack of an intellectual background among a large number of architects and engineers in the construction sector about smart architecture technologies, the extent of their importance, and how to employ smart building materials in architectural design.
- The necessity of a balance, overlap and interaction between smart technology and architectural design standards and the application of security and safety standards and principles that lead us to achieve the highest levels of safety and security in hospitals.
- The research focused on the fact that by relying on smart technologies and the integration between design and safety systems, the response can be improved and the safety of buildings and individuals can be enhanced. However, these systems must be implemented in accordance with applicable safety standards and guidelines and in cooperation with specialized experts in the field of safety and security.

Recommendations

1. Recommendations related to design determinants to increase the performance of the building itself:

These recommendations include all the design specifications that ensure containing the fire and limiting its spread In various ways, means and equipment, through:

1. Paying attention to the general architectural composition of the building, by not following imported architectural templates and applying it unconsciously, or making buildings without windows to achieve an aesthetic architectural form only, or Excessive application of contemporary architectural theories without taking into account security and safety factors.
2. Preparing architectural studies for the possibility of achieving safe design, through knowledge of the program.The architect of the project and its various elements.

3. Work to control and contain the fire and limit its spread, through:

- Dividing the building into spaces to remain under control without collapsing during the expected duration of the fire.
- Creating partitions that operate automatically when a fire occurs, which are vertical fire-resistant walls.
- Installing fire-resistant doors, especially for escape exits and dangerous spaces.
- Use of fire-resistant finishing materials (ceilings, walls, floors).
- Installing comprehensive fire alarm and extinguishing systems (automatic and manual).

2. Recommendations related to design determinants to raise the performance of building occupants:

These recommendations include all the design specifications that ensure rapid evacuation of the building. Its occupants are safe at the time of fire, through:

1. Provide a number of escape-exits and distribute them throughout the building so that there is no conflict in directions of movement.
2. Clarifying the locations of escape exits and explaining the method of opening their doors.
3. Make sure there are no obstacles in the escape corridors and exits.
4. Installing fire-resistant partitions and doors that prevent the leakage of smoke in the roads leading to the exits Escape.
5. Place information signs to guide escape corridors and exits easily.

6. Escape corridors and exits must be continuously lit while the building's occupants are present. The lighting is coordinated and regular to ensure that no part of it is exposed to darkness in case of One of the lamps burned out.
7. Taking into account all the design principles of internal and external escape stairs.

3. Orienting the architectural reality to the necessity of adhering to the application of security and safety standards in hospitals through the use of smart technology:

1. Promoting the idea of applying smart technology in architectural design among architects, researchers, and students and supporting them in applying smart architecture in their architectural projects and using it as solutions for applying security and safety standards in hospitals to achieve the highest efficiency.
2. Using the latest smart systems available in the local market and integrating them into the architectural design of the hospital to obtain a smart building that operates with high efficiency.
3. Constant communication with local and international companies to learn about the latest smart systems and the latest smart technological systems that the design requires.

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