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Assessment Strategies of Fixed Firefighting system in Residential Multi-Story Building for Improving Fire Safety: A Review

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ABSTRACT

A fixed firefighting system is a key component of fire safeguarding and reducing fire danger. It is installed as a permanent component in a structure to protect the entire or a portion of the building and its contents. The study aims to review the previous studies that deal with the evaluation of fire safety measures and their use in resolving problems associated with fire threats in buildings. For this reason, a number of previous studies in this field were reviewed compared with the NFPA code. The findings revealed that regulatory developments over the last several decades had created an atmosphere conducive to innovation. This has resulted in a growth in the number of fixed firefighting system types now obtainable. These solutions provide substantial distinction in terms of performance and hence safety. Not only is the availability of different fire risk alleviation systems important, but so is the election of the most convenient solution for the job. This is typically seen inside regulatory procedures and basics of thumb or heuristics and depends on the knowledge and expertise of divergent specialists. When several perceived danger and results thresholds are surpassed, fixed firefighting systems are frequently included as extra fire protection and resilience measures.

Keywords: fixed firefighting system**,** suppression, fire, Strategies for fire safety**.**

استراتيجيات تقييم نظام مكافحة الحرائق الثابت في مبنى سكني متعدد الطوابق لتحسين السلامة من الحرائق : مراجعة

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الخلاصة

يعد نظام مكافحة الحرائق الثابت مكونًا مهمًا للوقاية من الحرائق وتقليل خطر نشوب حريق ، لذلك يتم تثبيته كعنصر دائم في الهيكل لحماية كامل أو جزء من المبنى ومحتوياته. تهدف الدراسة إلى مراجعة الدراسات السابقة التي تناولت تقييم إجراءات السلامة من الحرائق واستخدامها في حل المشكلات المصاحبة لتهديدات الحريق في المباني. لهذا السبب ، تمت مراجعة عدد من

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الدراسات السابقة في هذا المجال مقارنة مع كود NFPA. اظهرت النتائج انه خلال العقود الأخيرة ، خلقت التغييرات التنظيمية بيئة مواتية للابتكار. وقد أدى ذلك إلى زيادة عدد أنواع أنظمة مكافحة الحرائق الثابتة المتوفرة حالياً. تقدم هذه الأنظمة مستويات مختلفة من الأداء وبالتالي تباين كبير في السلامة. جزء مهم من ضمان السلامة ليس مجرد توفر مجموعة متنوعة من أنظمة التخفيف من مخاطر الحريق ، ولكن أيضًا اختيار النظام الأنسب والملائم لهذا الغرض. يعتمد هذا على معرفة وخبرة المختصين بهذا المجال وغالبًا ما يقع ضمن الإجراءات التنظيمية والاستدلال أو القواعد العامة. تميل أنظمة مكافحة الحرائق الثابتة على اعتبارها أنها تدابير إضافية للحماية من الحرائق والمرونة عندما يتم اختراق عتبات المخاطر والنتائج المتصورة المختلفة.
الكلمات الرئيسية: نظام إطفاء ثابت ، إخماد ، حريق ، استراتيجيات السلامة من الحرائق.

1. INTRODUCTION

Fire is a natural and social occurrence that has an impact on both people and the environment **(Moshashaei and Alizadeh, 2016).** Among the many kinds of disasters, fire is a severe hazard to life and property in both rural and urban areas **(Xin and Huang, 2013).** The essence of the building's functioning was put to the test by shocking fire incidents. Uncontrolled flames are also a significant cause of building collapses, inferred damages, possible injury, and loss, among other things **(Wong and Jan 2003).** The costs of medical care, saving, disability, death compensation, and other damages are some of the other causes of destruction caused by fires in buildings **(Hai-yun, 2011).** Not just that, but fire-related emissions have a substantial influence on air quality and the environment on a local, regional, and global scale.

One of the most stressful factors for building owners is losing the building **(Caia et al. 2010).** Furthermore, individuals are often traumatized after a fire due to the loss of personal things**.** Over the last two decades, there have been growing fire size, intensity, and property loss trends. Today, there is a lot of discussion on ways to avoid fires and minimize property loss **(O'Laughlin, 2005)** Every year, (8) out of each (1,000,000) individuals in Europe are killed via fire, with numerous increased existence hospitalized. Therefore, governments have addressed this affair by modifying fire integrity tactics regularly. As a consequence, the numeral of fire fatalities in Europe has decreased by (65%) in the last (30) years **(Isiwele et al., 2018).**

Planning, design, installation, debugging, operating, maintenance, inspection, administration, staff disposition, and safety awareness are part of a fire integrity system. Fire technology, people disposition, and management were identified as three types of systems. As a result, the safety assessment of a fire system entails a thorough examination of technology, management, and personnel, followed by a determination of hazard resources, hazard control capability, and system safety. The theoretical safety control approach, which is based on the methodology, control mechanisms, and math models of new control theory, employs integrity checklist analysis, questionnaires, scoring methods, and other techniques to achieve dynamic and closed ring integrity system control **(Huang et al., 2011).** So, Therefore, fire safety rules should take into account all the variables of fire risk to reduce the community's concern about fire safety in buildings. As a result, this research aims to provide fire safety evaluation measures and their use in resolving problems associated with fire threats in buildings.

2. FIRE SAFEGUARD MEASURES CONCEPT

2.1 Codes of Fire

Ensuring compliance with required fire-safety laws and regulations is known as fire-code enforcement. Inspections are based on code enforcement, and the examination procedure is the spinal column of the fire prohibition scheme **(Diamantes, 2006).** The primary goal of the fire-code examination scheme is to identify and right hazards to people and property **(Hall et al., 2008).** The NFPA code contains special instructions for fire safety according to the type of each building, whether it is a government or commercial building or an educational institution and other

buildings, as there are special requirements that must be met in the building to provide adequate safety for the occupants of these buildings.

2.2 Reducing and Avoiding the Impact of Fires

Fire prevention first is the most basic technique to deal with fire threats. The human responsibility for preventing unintentional fires is an essential part of fire prevention **(Isiwele et al., 2018).** Vertical living is an apparent answer to the problem of housing for rising metropolitan populations. So the idea of high constructing structures is being public day after day and solving numerous urbanization problems. But the inappropriate design and arranging, in this situation, are causing fatalities and other losses. One of the significant aspects to consider in tall structure design is fire **(Cowlard and Bittern, 2013).** If the fire is not controlled, the consequences for human communities might be severe. Statistics demonstrate that earthquakes and fires have caused the most structural failures in tall structures in the past 30 years. A high number of steel structures fell during this time owing to earthquakes and fires. Tall structures are being built without planning norms and restrictions **(Chen et al., 2013).** Therefore, it is necessary to reduce the effects of fires on the population by fighting fires in their initial stages and providing safe escape routes.

2.3 Fire Safeguarding Supplies

Due to the occurrence of many unexpected factors inside the building, it is, therefore, necessary to achieve a perfect balance between fire Safeguarding systems and to have the best design, whether active or passive firefighting systems, to achieve the desired aim of fire safety **(Baker et al., 2013).** Building residents must be educated on how to use active fire systems installed inside buildings for the best use in the event of a fire, and it is necessary that they understand the purpose of these systems **(Chopade, 2020). Fig. 1** shows the types of these systems, and **Fig. 2** shows fire protection systems.

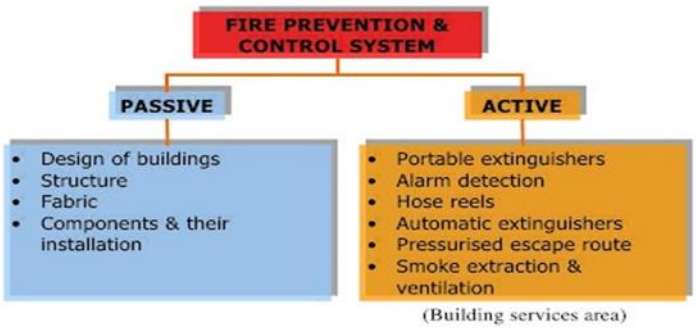

Figure 1. The firefighting system classification **(Kwon, 2014).**

Figure 2. Fire protection systems**.**

Fire Safety Provisions with Fire extinguishers are used in the earliest fire phase to put out the flames while they are still alive. If the fire progresses, the priority is to get everyone out of the building since inhaling poisonous chemicals from the fire may be fatal in only a few minutes **(Nelson, 1998, Alarie, 2002).** During this phase, active fire safeguarding measures, whether automatic or human, are used to manage the fire. It should be emphasized that the time of the activation of entire automated fire safeguarding systems is critical because any lateness in alarm of fire immediately jeopardizes life safety and diminishes the possibilities of confining a fire after it has increased in strength. As a result, all evacuation procedures should be finished before the fire escapes active fire suppression systems. **Eq. 1** shows how the time obtainable for elopement is linked to the fire development period :

$$Te + Td + Tsr \leq Ti \quad (1)$$

where (Te) is the period between inflammation and fire detection, (Td) is the time between detection and the commencement of elopement action, (Tsr) is the best time to travel to a proportionate integrity location, and (Ti) is the period between inflammation and the fire producing unsustainable circumstances. After a flashover, fire temperatures can reach 1,000°C, posing a major hazard to structural safety due to thermal widening and deterioration of a material feature. The primary purpose of passive fire safeguarding systems at this stage of the fire is to prevent fire from spreading by guaranteeing structural stability. To do so, all nonstructural and structural parts must meet fire safety criteria throughout the fire exposure. These passive fire protection devices permit safe firefighting and deportation operations and a reduction in ownership damage **(Venkatesh et al., 2019).**

2.4 Firefighting Brigade Station

If the active fire safety systems are unable to extinguish the fire, the firefighting department is responsible for managing or extinguishing the fire and guaranteeing life safety. A fireman is a rescuer who has received rigorous training in firefighting and is in charge of putting out severe fires that risk lives, ownership, and the environment, additional rescuing people **(Coulter, 2018).** Firefighters' job is close to other contingency response agencies, like the ambulance and police services. A fireman's responsibilities may be superposition with both. Fire investigators look into the cause of the fire. If the fire was sparked by arson or negligence, their efforts would make superposition with those of law execution **(Fire Academy, 2018).** The figure shows the most important elements that must be present when a fire occurs.
International standards for the efficiency of fire station service specify that when receiving a notification of a fire, the response time should not exceed 4 minutes because any delay causes great loss of life and property because the fire spreads very quickly within a short time. The other criterion is that the fire station should cover an area not exceeding 2 km, so the locations of the fire stations must be located in appropriate places and provide quick service to the area served by the fire station.

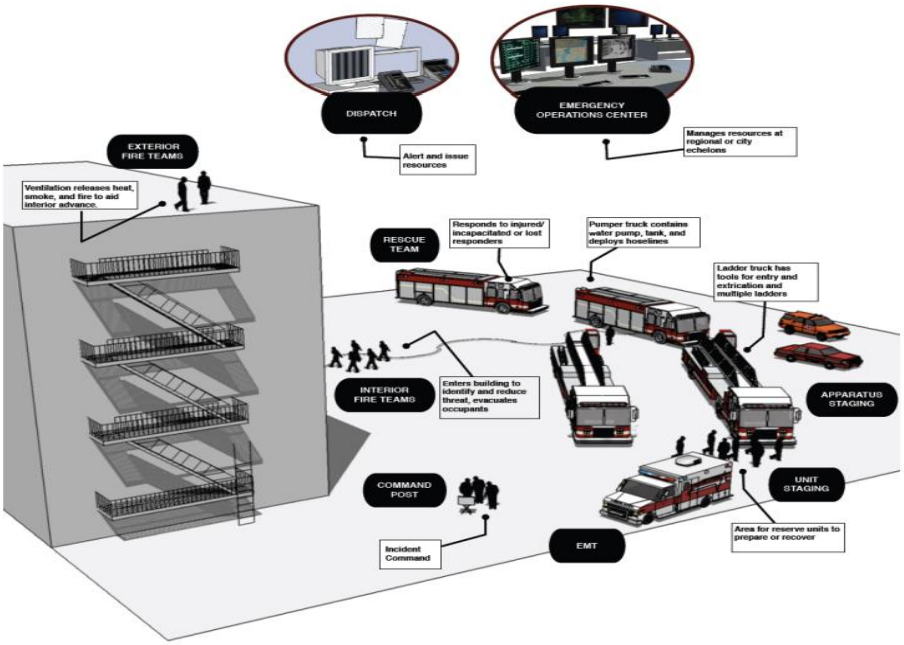

Figure 3. Essential elements of fire control (**Trent et al., 2008).**

3. FIRE SAFEGUARDING MEASURES EVALUATION

The Fire Safety Assessment Method is a parameter ranking approach for evaluating fire safety performance in which various fire safety parameters are assigned weighted points **(Park et al., 2014).** Fire safety methods have a variety of restrictions when it comes to dealing with today's fire risks.

3.1 Fire Safety of Building Materials

The building's high occupancy load is particularly in banquet halls and conference centers. According to **(Furness and Muckett, 2007),** where a significant number of people are concentrated in one place, the time it takes to exit the building is determined by the maximum flow

capacity of the escape routes. In the event of a fire, panic and pandemonium at the exits might dramatically raise the probability of injuries or deaths. A wide range of performance standards must be met by the building. Although there are minimal fire safety standards for single-family homes, they are important for commercial, industrial, and multi-family structures. Depending on the kind of materials and intended use, specific fire performance attributes of building materials are examined using various test techniques. When constructing a structure, one of the most crucial factors to consider is how it will react in the event of a fire. This ensures that the structure's parts will not collapse but will instead continue standing or holding back the fire for a specific time. The constructional components' standards and grade of fire impedance are fixed in the constructing codes **(Bertan, 2014).**

3.2 Effectiveness of Fire Safeguarding Systems

Fixed firefighting systems, such as any other system, are not 100 percent dependable; therefore, several or all of the potential advantages may be lost. It's normal to assume varying degrees of dependability from different firefighting systems with quite distinct sets of components and design philosophies. When various firefighting systems are utilized for safeguarding different circumstances, it's also acceptable to assume varying degrees of dependability **(Bird et al., 2019).** According to FM Global, installing automatic fire sprinklers in Europe reduced fire intensity by a factor of 4 to 5. However, if fire danger management is not implemented in the event of building improvements, the risk of fire will increase **(Gritzo et al., 2009).** A study showed that the use of automatic sprinklers helped reduce the materials that burn to 3%. At the same time, it was found in the test of homes not protected by automatic sprinklers that the consumable materials ranged between 62% to 95% **(Wieczorek et al., 2010).** According to the NFPA, automatic sprinkler systems are 91% reliable, provided they are correctly identified, installed, built, and maintained **(Hall, 2010).**

3.3 Focus of Firefighting

The focus of firefighting (property and business protection) differs from the typical function of firefighting and rescue in a fire-designed solution. In a fire-designed solution, numerous assumptions will have been made as well. These will have far-reaching consequences, and they may need certain adjustments in firefighting and fire engineering solutions. There is no requirement for the rescue action since it is considered that resident evacuation in a fire-designed solution does not rely on fire department assistance. Of course, it's impossible to rule out the potential that saving is required even in a fire-engineered structure. Still, it's fair to assume that the likelihood of someone being trapped within a fire engineered structure is very little. In any situation, fire service resource distribution should be carefully studied so that the firefighting crew does not participate in pointless and needless saving operations. Because the primary goal of firefighting in a fire designed structure is to preserve property, it's usually advisable to let the fire burn out when the chances of preserving the structure by firefighting are small **(Wang et al., 2011).**

3.4 Construction Law Provisions with Restrictions

One of the most typical occurrences in concrete and steel buildings is exposure to high temperatures caused by fires. Due to the differential in thermal expansion of its constituents, the concrete composition will self-degrade in this circumstance **(Shatha and Nada, 2016).** As the temperature of the concrete grew, its compressive strength fell. Failure occurs unexpectedly in a fast-moving process **(Amer, 2015).**

Therefore, there are similar concerns with regard to fire safety for buildings because there are problems that must determine their suitability with the materials used or the requirements of codes or approved design methods in order to achieve the desired goal and good organizational performance that leads to addressing the risks associated with fire as a result of the use of modern materials considered as a potential influencing factor On the safety of buildings from fires that occur in buildings **(Meacham, 2010).** For example, after the Grenfell Tower fire incident in England, all building codes were reviewed and re-examined again because they were not appropriate and allowed to reduce fire safety in buildings. Therefore, laws were prepared to provide safe buildings in England and their compliance with the laws and general objectives of the state and supporting infrastructure **(Hackitt, 2017).** Such issues will help implement better measures to regulate fire safety laws **(Oecd, 2015).**

3.5 Installation and Maintenance Phase

There is a range of sources of information, such as legislation, advice, and standards, that provide direction on the specifications of the system and the fundamental appropriateness of a system for a diversity of applications. This kind of advice is usually somewhat restricted **(Bird et al., 2019).** When putting the system in the location and once you've selected a fire extinction system that meets demands and prepared a fire protection design. Licensed distributors or implementation engineers are generally responsible for the installation proceedings. The complication of the equipment to be protected, the components to be installed, and the system itself all impact how long it takes to install a fire extinction system. An industrial fire extinction system, for example, will occupy longer to set up than a standard one.

Commissioning is the last stage after the fire suppression system has been installed. After the system has been fully commissioned, it must be meticulously maintained and inspected on a regular basis to ensure that it is operating at its best **(Thomas, 2020).** The final inspection, testing of all components, and activation of the system to its commissioned condition are all part of this process phase**.**

3.6 Non-compliance with fire-safety requirements

Historically, the United States has had a higher fire fatality rate than the rest industrialized world. This is true for both the number of people killed in fires. The reasons for the United States' strong position in this region are unclear and have been a source of controversy for some time. To make matters worse, the United States is a relatively safe country with one of the most sophisticated technology systems in the world. Having such high fire fatality rates is surprising for a nation that scores so well in those two categories. While the United States continues to have one of the worst fire fatality rates in the industrialized world, its position has improved significantly. The United States has dropped from being among the top three countries in terms of fire deaths two decades ago to having the tenth highest fire mortality rate per million inhabitants **(Topical Fire Report Series, 2011).** This decline in the number of deaths in full compliance with the laws related to fire safety, which building owners are obliged to provide in their buildings, and the continuous review of the laws related to the safety of buildings from fire accidents.

4. TECHNIQUES FOR DEVELOPMENT COMBUSTION INTEGRITY

4.1 Organizing and Implementation

Code enforcement is known as ensuring conformity with all codes, ordinances, laws, and other restrictions. Although this qualifier of code execution is correct, code fulfillment really refers to any conduct done to guarantee residents follow fire rules. Fire examinations to engaging with a citizens' set about burning garden garbage are all examples of code enforcement. Each of these activities aids in the education of residents on how to follow the code, which is, after all, what code enforcement is all about (**Coffman, 2009).** Fire prevention inspections are based on code enforcement, and the check process is the basic vertebral column of the fire protection scheme **(Diamantes, 2003).**

4.2 Resources of firefighting

For firefighters, balancing firefighting resources with the fires is a major challenge. Sometimes there is a shortage of materials in general, whether in the number of firefighters, vehicles, or other equipment. Therefore, fire officials must provide all observations about the provision of fire suppression materials to collect data permanently to have a comprehensive review of the resources on an ongoing basis and provide them at any time **(Gregory et al., 2003).** Failure to respond to a fire situation with appropriate people, equipment, specialized skills, and other agencies may result in delayed operational intervention, more remarkable fire development, and worse firefighter safety. Attempting to extinguish a fire with inadequate media might result in a partly effective incident plan and the danger of re-ignition. Crisis commanders should assess the resources available as part of their first strategy and if there is a chance to save lives or prevent the incident from growing **(NFCC, 2018).** Providing equipment and machinery to firefighters on an ongoing basis and in a sufficient number. It is a very important factor to eliminate fires in their initial stages and reduce deaths and injuries as little as possible.

4.3 Building Fire Integrity Lineaments

Building fire safety is a 'package' that includes building techniques, mechanical and electrical equipment, management technique, and an organized natural human reaction customized to limit the impact of fire on people, the construction, its contents, responding firefighters, and any nearby ownership. In the conditions of fire integrity in buildings, fire effect is described as any harm to life or property produced by smoke or heat and any adverse environmental effect from toxic items stocked on the site.

Constructing fire security cannot be classified as a single system; instead, it is comprised of several subsystems that work together to produce a complete package. Most of the time, removing one of the subsystems will cause the entire package to collapse, putting the people of the structure in intolerable danger in the case of a fire **(Metropolitan Fire Service, 2012).**

4.4 Occupant training

The teaching and training of residents on integrity issues is an integral part of any building fire integrity system (perhaps the most key part). Every possible device may be installed in a building, but if the residents have no idea what a blazing alarm sounds like, what safe and dangerous action practices are, or where the devices are located, the structure will not be fire safe. Too frequently, tenant exercise, fire drills, and safe action procedures are disregarded or just given a cursory glance. Suppose the entire fire safety system is to be effective. In that case, it will need a management strategy that addresses all of these factors in addition to what to do next the blaze has been extinguished to minimize its consequences **(Isiwele et al., 2018**). Evacuation during a fire is

very important because it depends on time and calculates the exit of residents in specific time frames because the residents inside the building are trapped, leading to the possibility of death. Sometimes the number of trapped residents is reduced through the efforts of civil defensemen **(Hadjisophocleous and Fu, 2004). Fig. 4** shows the training process for a population.

Figure 4. The training process for a population.

5. CONCLUSIONS AND RECOMMENDATIONS

According to the details offered above, the next conclusions and recommendations can be drawn:

a) It is essential to have a fire safeguarding system in place as part of a building's safety strategy. In the event of a fire, individuals within the building's life are put in grave danger.

b) Existing methods used to evaluate and formulate fire strategies for buildings need improvement. This research determined that a more comprehensive concept is necessary to provide adequate fire solutions in the field of fire safety.

c) Firefighting systems need constant monitoring and maintenance to ensure reliability in extinguishing the fire.

d) Major examination needs desiring to facilitate fire safety in buildings involve logical fire design approaches, Creating fire suppression technologies that are both cost-effective and efficient, developing performance-based codes, and characterizing new materials.

e) Existing fire safety methods result in an unquantified degree of building fire prevention, give the fewest options for reducing fire danger, and ignore modern fire danger challenges.

f) Main ways to reduce fire risk in buildings include raising public awareness, upgrading fire safety features in structures, using technology and resources correctly, and ensuring that building code rules are properly regulated and enforced.

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