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Assessment of Fire Safety Reliability in a Healthcare Facility Using the Building Safety Reliability Index

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ABSTRACT

Fire incidents in hospitals pose serious risks to patient safety, medical personnel, and the continuity of health services. Therefore, the readiness of fire protection systems is critical to enhancing safety in healthcare facilities. This study aims to evaluate the readiness of the fire protection system in the Pediatric Inpatient and Surgical Building of Ngudi Waluyo Wlingi Hospital, using the Building Safety System Reliability Value assessment method based on the Ministry of Public Works' Fire Protection Technical Guidelines. The assessment covers four main components: site equipment, life-saving facilities, active fire protection systems, and passive fire protection systems. Data were collected through direct observation, field measurements, and document review. The results showed that the building achieved an score of 79.23%, which falls within the sufficient category. Although the building is considered safe for use, several deficiencies were identified, particularly in active fire protection systems, life-saving facilities, and site completeness. Improvements in fire protection facilities, evacuation routes, and regular maintenance are recommended to enhance overall fire safety.

Keywords *: Fire Protection System ; Evaluation ; Hospital*

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INTRODUCTION

Fire incidents in healthcare facilities represent a critical public safety issue due to their potential to cause fatalities, disrupt essential health services, and result in substantial material and non-material losses (1). Hospitals are categorized as high-risk buildings because they operate continuously, contain complex electrical installations and medical gas systems, and accommodate vulnerable populations such as children, postoperative patients, and individuals with limited mobility (2). In the event of a fire, these conditions significantly complicate evacuation processes and emergency response efforts (3). Hospitals carry higher fire risk compared to other public buildings because of complex electrical installations, medical gas systems, intensive use of electronic equipment, and the presence of patients with limited mobility who require assisted evacuation. Multiple incident reports at both global and national levels indicate that hospital fires continue to occur, most commonly triggered by electrical failures and inadequate protection system performance (4).

Globally, hospital fires remain a recurring problem. Studies conducted in developing countries have reported an increasing number of fire incidents in healthcare facilities, particularly during periods of high service demand. A study by Sahu et al. documented at least 27 major hospital fire incidents between 2020 and 2023, resulting in 112 fatalities, with electrical short circuits identified as the primary cause in approximately 80% of cases (5). Data from the National Fire Protection Association (NFPA) also indicate that fires in healthcare facilities are frequently triggered by kitchen equipment, electrical installations, heating systems, and combustible materials, emphasizing the multifactorial nature of fire risk in hospital environments (6).

In Indonesia, fire incidents in healthcare facilities have also been reported across various regions. Between 2021 and 2025, multiple fires occurred in public and private hospitals, including major referral hospitals (7), highlighting that fire risk is not limited to small or outdated facilities (8). These incidents underscore the importance of systematic fire risk management and continuous evaluation of fire protection systems in hospitals.

Indonesian regulations, such as Law Number 28 of 2002 on Buildings (9) and the Regulation of the Minister of Health Number 66 of 2016 on Occupational Safety and Health in Hospitals (10), explicitly require healthcare facilities to comply with fire safety standards and implement comprehensive fire protection systems.

Fire protection systems in hospitals consist of integrated components, including site equipment, life-saving facilities, active fire protection systems, and passive fire protection systems. The effectiveness of these components determines the reliability of a building in preventing, controlling, and mitigating fire hazards (11). The Indonesian Ministry of Public Works has established technical guidelines for evaluating building fire safety through the Building Safety System Reliability Value as stipulated in the Technical Guidelines for Fire Protection Procedures in Buildings and the Environment or Pd-T-11-2005-C (12). In addition to providing healthcare services, hospitals must also ensure that their firefighting systems meet established standards. This includes the availability of fire extinguishers, safe evacuation routes, and staff training in emergency situations (13).

Ngudi Waluyo Wlingi Hospital Blitar is a regional public hospital that provides continuous inpatient services and accommodates a high volume of patients and healthcare workers (14). The Pediatric and Surgical Inpatient Building serves particularly vulnerable patient groups, making fire safety a critical concern. This research evaluates the fire protection system of the pediatric and surgical inpatient building of Ngudi Waluyo Wlingi Hospital using a quantitative Building Safety Reliability Index or NKSKB assessment instrument based on national technical guidelines. The method applies a structured weighted checklist covering four major components: site completeness, life safety facilities, active fire protection systems, and passive fire protection systems. This weighted checklist approach enhances assessment objectivity and enables precise identification of system weaknesses.

Scientifically, this research fills a gap in quantitative, standards-based fire protection evaluation studies within regional healthcare facilities. Practically, the findings are expected to support corrective recommendations, strengthen emergency preparedness,

and improve fire risk management in hospital environments. Therefore, this research holds strong relevance for both building safety research development and healthcare safety quality improvement.

METHODS

This research employed a quantitative descriptive observational design to evaluate the reliability level of fire protection systems in a hospital inpatient building. This approach was selected because fire protection assessment requires structured field-based technical measurement rather than perception-based survey data. Standardized observational audits are widely recommended in building safety evaluation to obtain objective performance indicators of both active and passive fire protection systems.

The research was conducted between April and August 2025 in the pediatric and surgical inpatient building of Ngudi Waluyo Wlingi Blitar Hospital, Indonesia. The unit of analysis comprised all building fire protection components, including site infrastructure, life safety facilities, active protection systems, and passive protection systems.

Since the unit of analysis in this study comprised all fire protection system components within the Pediatric Inpatient and Surgical Building, no sampling procedure was performed. Instead, this study employed a comprehensive building audit (census audit), whereby every observable component specified in the Building Safety System Reliability Index (NKSKB) guideline was assessed.

This approach is consistent with facility audit methodologies, where the objective is to evaluate the completeness and compliance of all system components rather than to estimate characteristics from a sample. Comprehensive technical audits are recommended for fire safety assessments because they minimize sampling bias and provide a complete representation of building safety performance.Primary data were collected through structured field observation using a Building Safety Reliability Checklist or NKSKB derived from the Indonesian Public Works technical guideline Pd-T-11-2005-C: Technical Procedures for Fire Protection Systems in Buildings and Environment.

This instrument provides a standardized technical audit framework integrating national fire protection standards.

The checklist evaluates four weighted parameter groups:

1. Site completeness
2. Life safety facilities
3. Active fire protection systems
4. Passive fire protection systems

Each component was rated using a three-level condition scale (Good 100, Moderate 80, Sufficient 60). Scores were multiplied by parameter weights to produce partial scores and a composite Building Safety Reliability Index (NKSKB).

The weighting values used in this study were adopted directly from the Indonesian Technical Guidelines for Fire Protection Procedures in Buildings and the Environment (Pd-T-11-2005-C), which provide standardized weighting coefficients for each fire protection component. Therefore, the present study did not perform an independent Analytical Hierarchy Process (AHP), pairwise comparison, consistency ratio calculation, or expert weighting procedure. The assessment focused on applying the nationally standardized weighting system to evaluate the reliability of the hospital fire protection system.

Secondary data were obtained from the hospital occupational safety unit, including maintenance records for extinguishers, sprinklers, detectors, and fire utility systems. Data triangulation was conducted by cross-checking field observations against maintenance documentation.

Data analysis was performed using descriptive quantitative scoring to generate total reliability values categorized as Good (>80), Moderate (60–80), or Sufficient (<60). This scoring approach enables identification of critical protection gaps requiring priority improvement. Weighting was applied to help determine which components are more important and therefore have a greater influence on the final performance score. Each component was weighted using the Analytical Hierarchy Process (AHP) method, which was chosen to minimize subjectivity in the assessment.

In short, the AHP serves as a tool for logically and transparently compiling weightings to ensure more accurate building safety system evaluation results. The AHP is a structured and systematic method for comparing. various options or alternatives. This method uses a hierarchical structure, a system that organizes elements into separate groups based on their influence relationships.

In this hierarchy, one element in one group can influence and be influenced by elements in other groups. Each element within a group is considered independent of the others.

Table 1. Building Safety System Component Parameters

Reliability of Building Fire Safety Systems Parameters	Reliability of Building Fire Safety Systems Parameters
Site Facilities	25 %
Lifesaving Facilities	25 %
Active Fire Protection Systems	24 %
Passive Fire Protection Systems	26 %

Source: Technical Guidelines for Fire Protection Procedures in Buildings and the Environment (Pd-T-11-2005-c), 2005

Field observations were conducted by two assessors with academic backgrounds in Occupational Safety and Health and fire protection. Before data collection, both assessors participated in a calibration session to standardize interpretation of each checklist item based on the NKSKB technical guideline.

Differences identified during the field assessment were resolved through joint verification. Observation findings were subsequently validated against supporting hospital documentation, including maintenance records, inspection reports, and fire protection equipment inventories, to improve data credibility through methodological triangulation.

RESULTS

The research was conducted in the pediatric inpatient and surgical building, one of the buildings at Ngudi Waluyo Wlingi Blitar Hospital is located at Dokter Sucipto Street, Number 5, Beru, Wlingi District, Blitar Regency, East Java, Indonesia. The building is 25 meters high and consists of 4 floors, the ground floor is used as a surgical inpatient room and several rooms on the second floor, on the second floor of this building is designated for a children's

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inpatient room, then on the third floor of this building is designated for a children's inpatient room as well, and on the fourth floor of this building is used as an auditorium and office.



Figure 1. Pediatric Inpatient and Surgical Building Ngudi Waluyo Wlingi Hospital

The evaluation results showed that the Pediatric Inpatient and Surgical Building achieved a total Building Safety System Reliability Value score of 79.23%, which falls within the sufficient category. The detailed component scores were as follows: site equipment (19.80%), life-saving facilities (16.35%), active fire protection systems (18.75%), and passive fire protection systems (24.33%).

Table 2. Table of Building Safety Component Parameter Result

Variable	Weight (%)	Weight (%)	Weight (%)
Site Equipment	25	19,80	Sufficient
Life-Saving Facilities	25	16,35	Sufficient
Active Fire Protection System	24	18,75	Sufficient
Passive Fire Protection System	26	24,33	Good
Total	100	79,23	Sufficient

Source: Primary Data, 2025

Site equipment and life-saving facilities generally demonstrated adequate performance, supported by the availability of environmental roads, yard hydrants, sufficient exit facilities, and appropriate exit construction, although water source identification was incomplete and helicopter landing facilities were not available due to building height limitations. Active fire protection systems showed mixed performance; fire detection and alarm systems, fire extinguishers, and building hydrants were functional, while several critical components such as siamese connections, smoke control systems, smoke exhaust systems, and fire elevators were unavailable or inadequate. The passive fire protection system performed relatively well, with building structure fire resistance, space compartmentalization, and opening protection generally complying with applicable standards.

The fire protection system evaluation of the pediatric and surgical inpatient building of Ngudi Waluyo Wlingi Hospital was conducted using the standardized Building Safety Reliability Index (NKSKB) checklist based on national technical fire protection guidelines. The assessment covered four major parameters: site infrastructure, life safety facilities, active fire protection systems, and passive fire protection systems using a weighted checklist approach.

The overall Building Safety Reliability Index score reached 79.23%, which falls into the Moderate (Adequate) reliability category. This score indicates that most core fire protection components are present, but the system has not yet achieved optimal reliability according to technical standards.

For the site infrastructure parameter, most components were rated moderate to good. Access roads and yard hydrants were available and reachable. However, water supply sources lacked proper identification and marking, reducing operational readiness during emergency response.

Within life safety facilities, exit routes and exit construction were generally available and usable. Evacuation paths met basic exit access requirements, although advanced smoke protection features along exit routes were not fully compliant. The helipad criterion was considered not applicable due to building height classification.

The active fire protection system parameter showed the greatest variability in reliability

levels. Fire detection and alarm systems, portable extinguishers, internal hydrants, sprinklers, emergency lighting, and emergency power supply were present and functional. However, several critical components were rated sufficient, including the absence or improper identification of siamese connections, inadequate smoke control and smoke exhaust systems, and the absence of a dedicated fire service lift. These deficiencies directly affect large-scale fire response capability and external firefighter operational support. For passive fire protection, structural fire resistance and spatial compartmentation were generally adequate. Nevertheless, opening protection elements did not fully meet fire-resistant closure standards at all vertical and horizontal openings, increasing the potential for smoke and fire spread between compartments. Score distribution indicates that moderate-rated components dominate the system, while sufficient-rated elements are concentrated in advanced active protection and smoke control subsystems. This pattern suggests that the building meets baseline fire protection requirements but still has critical gaps in advanced protection layers required for escalating fire scenarios.

Overall, the findings indicate that the building's fire protection readiness is at a basic- to-intermediate operational level and requires targeted upgrades in strategic components to reach high reliability standards for healthcare facility fire safety. The completeness of the Fire Protection System available in the pediatric inpatient and surgical building before the research was conducted was as follows;

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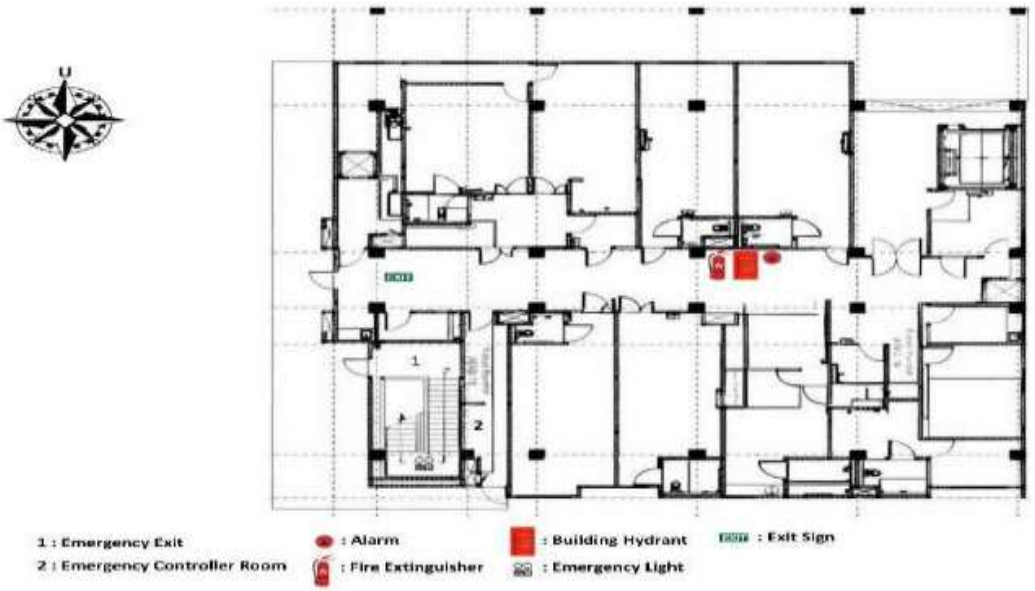


Figure 2. The completeness of the fire protection system on the 1st floor is available but is not optimal because routine repairs have not been carried out

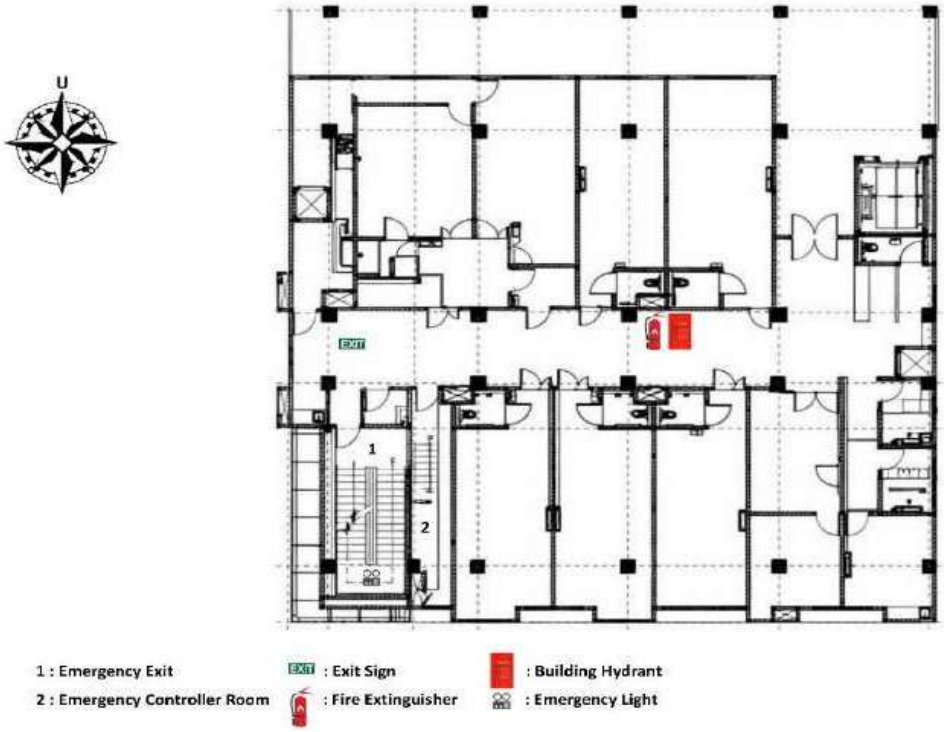


Figure 3. The completeness of the fire protection system on the 2nd floor before the research was that there was no alarm and periodic repairs had not been carried out

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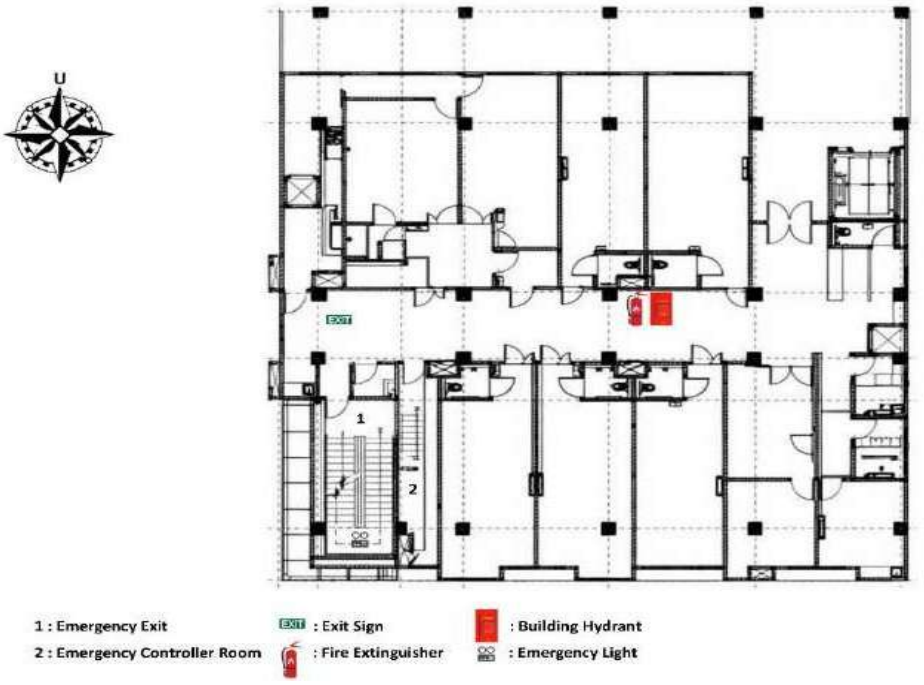


Figure 4. The completeness of the fire protection system on the 3rd floor before the research was that there was no alarm and periodic repairs had not been carried out

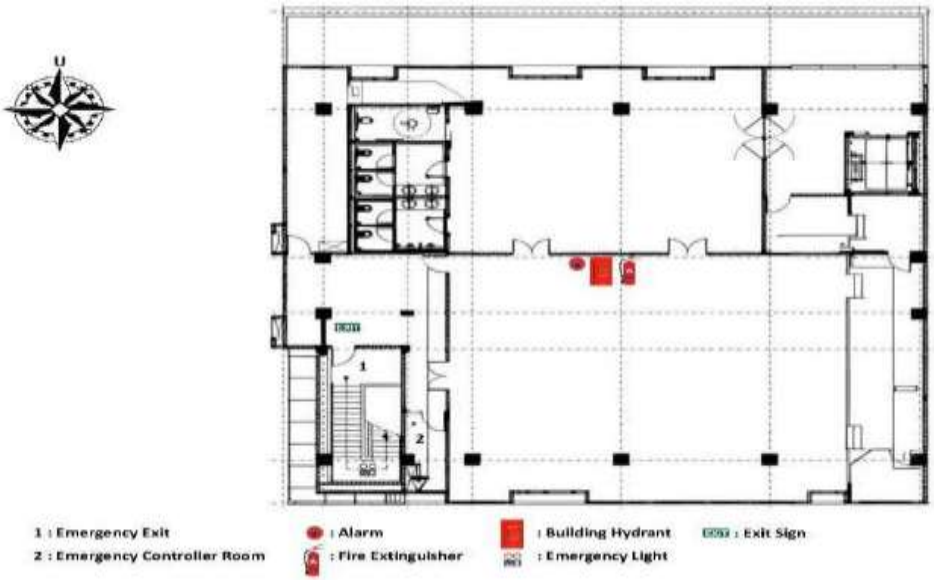


Figure 5. Completeness of the fire protection system on the 4th floor before the research, there were no fire extinguishers in the office and periodic repairs had not been carried out

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The following are recommendations from researchers regarding the completeness of the fire protection system that needs to be implemented in Pediatric Inpatient and Surgical Building of Ngudi Waluyo Wlingi Hospital.

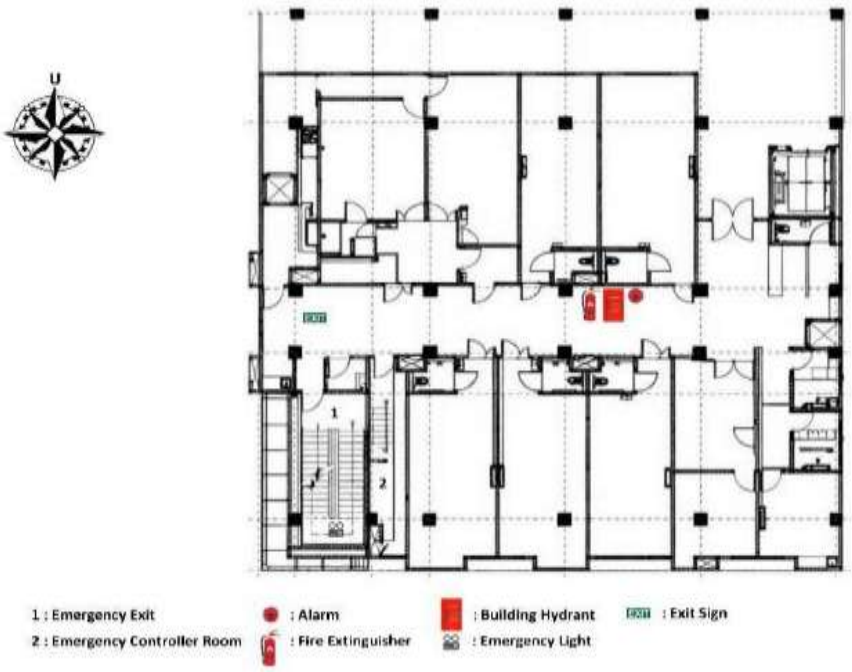


Figure 6. Recommendations for the completeness of the fire protection system on the 2nd floor of the pediatric inpatient and surgical building in the form of providing a fire alarm

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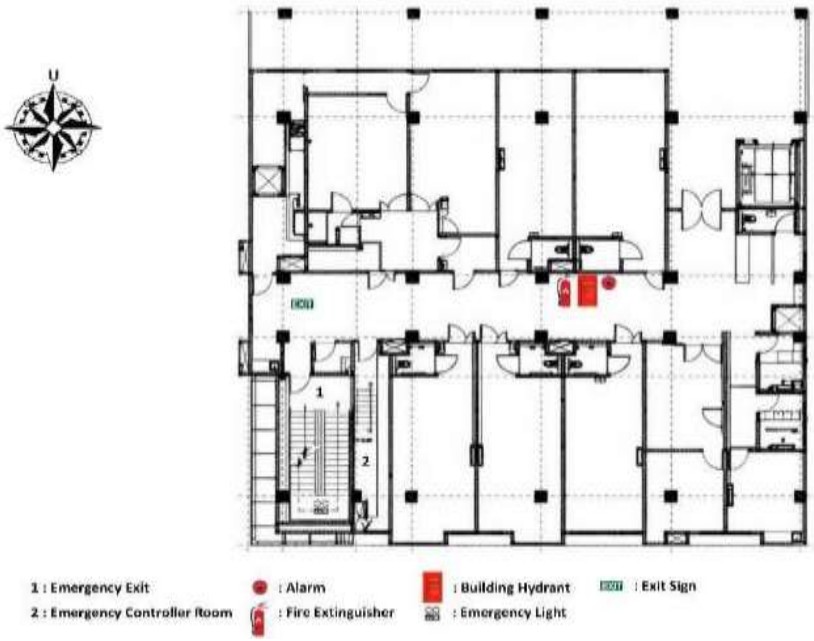


Figure 7. Recommendations for the completeness of the fire protection system on the 3rd floor of the pediatric inpatient and surgical building in the form of providing a fire alarm

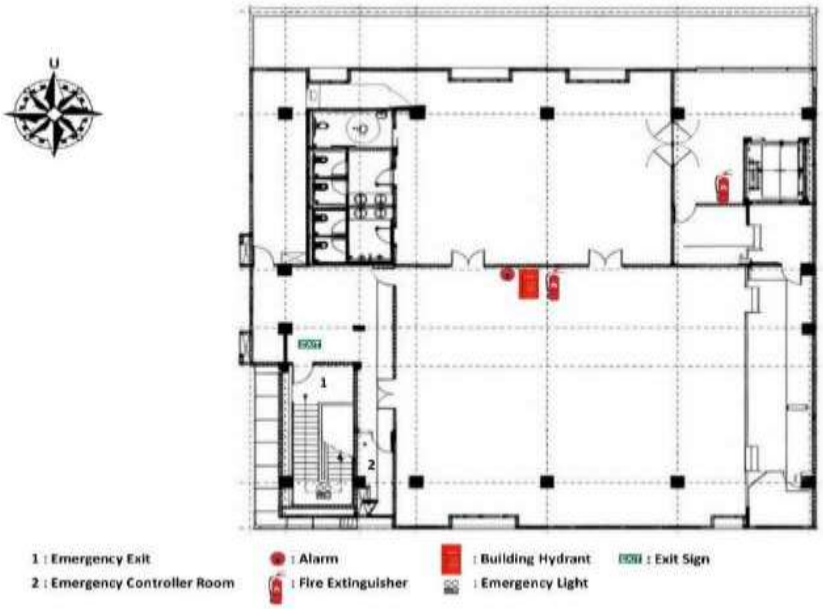


Figure 8. Recommendations for the completeness of the fire protection system on the 4th floor of the pediatric inpatient and surgical building in the form of adding fire extinguishers near the office

DISCUSSION

A hospital is a health service facility whose task is to provide health services, both for individuals and groups, providing emergency services, inpatient services and outpatient services (15), numerous studies have found that shift work is associated with a variety of health problems, including sleep disturbances, fatigue, cognitive impairment, accidents, injuries, depression, metabolic and digestive disorders, and an increased risk of diabetes, cardiovascular disease, and cancer, hospital facilities need to consider this (16), and than fire is one of the disasters caused by fire that can cause losses (17).

Occupational health generally refers to a state of freedom from physical and mental pain caused by the work environment (18), and occupational health and safety is a component of the hospital that must be considered by the hospital (19). The NKSKB score of 79.23% indicates that the Pediatric Inpatient and Surgical Building of Ngudi Waluyo Wlingi Hospital is classified as *sufficient*, meaning that the building is generally feasible for healthcare services but still has several deficiencies. This condition reflects partial compliance with fire safety standards and is consistent with previous studies in Indonesian hospitals, which generally report low reliability due to limitations in fire protection facilities (20). Fire cases are increasing in residential buildings due to short circuits, while in multi-storey buildings most are caused by human factors (21).

Fire safety ought to incorporate a comprehensive and harmonized array of measures, encompassing continuous fire safety education and awareness initiatives (22), and implementation in educational institutions is an effort to improve human resources (23). Active fire protection systems such as detectors, alarms, sprinklers, fire extinguishers, and hydrants are available and generally comply with applicable standards. However, the absence of essential supporting components, including siamese connections, smoke control and exhaust systems, dedicated fire elevators, and adequate fire water storage, reduces system effectiveness during fire emergencies and may hinder firefighting operations and evacuation processes (24), fire risk mitigation efforts are necessary to minimize the impact of the explosion (25).

Passive fire protection components largely meet minimum structural fire resistance and compartmentation requirements, but incomplete opening protection creates potential pathways for smoke and heat spread. While emergency lighting and exit signage function well and support evacuation under low-visibility conditions, limitations in environmental road access and yard hydrant performance may obstruct fire engine access and delay evacuation (26).

The present study primarily evaluated the technical reliability of the hospital fire protection system. Therefore, aspects such as fire drill implementation, inspection frequency, and staff preparedness were not directly assessed and should be investigated in future studies (27), one of the efforts to reduce the risk of occupational accident and occupational diseases is awareness regarding the importance of the safety and health of workers in hospitals (28), emergency management is critical to ensuring the safety and well-being (29). Occupational safety and health are conditions that provide workers with safety and health for their work, agencies, companies, as well as for the community and the surrounding environment (30).

All aspects of occupational safety and health, and it is recommended that workers comply with standard operating procedures for occupational safety and health (31). Although the hospital has partially complied with national fire safety regulations and technical guidelines, gaps persist in implementation and maintenance. Improving periodic inspections, completing missing system components, and integrating fire safety into the hospital's occupational health and safety management system are necessary steps to enhance protection, particularly for vulnerable patient populations.

CONCLUSIONS AND RECOMMENDATIONS

The fire protection system in the Pediatric Inpatient and Surgical Building of Ngudi Waluyo Wlingi Hospital has a sufficient reliability level, with an NKSKB score of 79.23%, indicating that the facility is generally suitable for healthcare services but still has several deficiencies. Although basic fire protection components are in place, the absence of key supporting systems and limitations in fire safety management reduce overall effectiveness

during emergencies. These findings emphasize the need for improved facilities, regular maintenance, and stronger integration of fire safety management to enhance protection, particularly for vulnerable patient groups.

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