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### RESEARCH ARTICLE

#### EVALUATING THE FIRE PROTECTION SYSTEM AT LAMPUNG CITY MALL USING FAULT TREE ANALYSIS

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#### Abstract

This study evaluates the fire incident that occurred in the kitchenware storage area on the ground floor of Lampung City Mall, caused by an LPG gas cylinder. The study's objective is to identify the root causes of the fire, assess the adequacy of active fire protection systems, compare them to the applicable regulations and standards, and evaluate the communication hazard in Lampung City Mall. Recommendations for improving safety communication are provided. The findings indicate that the active fire protection system meets 88% of the required standards, which falls under the "GOOD" category, meaning all elements are functioning properly and in accordance with regulations. As for evacuation safety, the system meets 85% of the requirements, which also falls under the "GOOD" category. However, the study concludes that there are still several fire safety symbols that urge to be added in order to improve the safety communication at Lampung City Mall.

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#### Introduction:-

Fire safety has become a critical issue in large-scale buildings. Recently, alongside economic growth, the number of large-scale buildings and shopping centers has surged significantly [1]. Life safety is particularly essential in shopping center buildings, as fires in these large buildings not only pose a serious threat to life but also lead to substantial property losses and business disruptions, potentially delaying the provision of goods and services [2]. Despite various fire protection strategies or Hazard Communication systems implemented in shopping centers, fires can still occur [3].

In this study, the author selects Lampung City Mall as the research location. This shopping center is the first major mall in the city of Bandar Lampung, designed with a 6-in-1 Central District concept, integrating multiple facilities such as apartments, a mall, a hotel, an office tower, an exhibition hall, and a hospital. Last November, a fire broke out in the furniture warehouse on the ground floor. While there were no casualties, several restaurant warehouses suffered losses amounting to hundreds of millions. Therefore, safety concerns become paramount in fire emergency situations.

#### Methods:-

This study employs a descriptive research method, specifically a cross-sectional study, which aims to analyze the fire event using Fault Tree Analysis (FTA). The analysis also covers aspects such as fire exit corridors, directional signs, emergency exits, and assembly points, in accordance with the relevant regulations. Descriptive analysis is

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used to compare the facts found in the field with regulations such as the Ministerial Decree No. 26/PRT/M/2008 on Fire Protection Requirements for Buildings and Environments, Kepmen PU No. 10/KPTS/2000, Ministerial Regulation No. 04/MEN/1980, and National Fire Protection Association (NFPA) standards. Table 1 shows the score for safety system compliance.

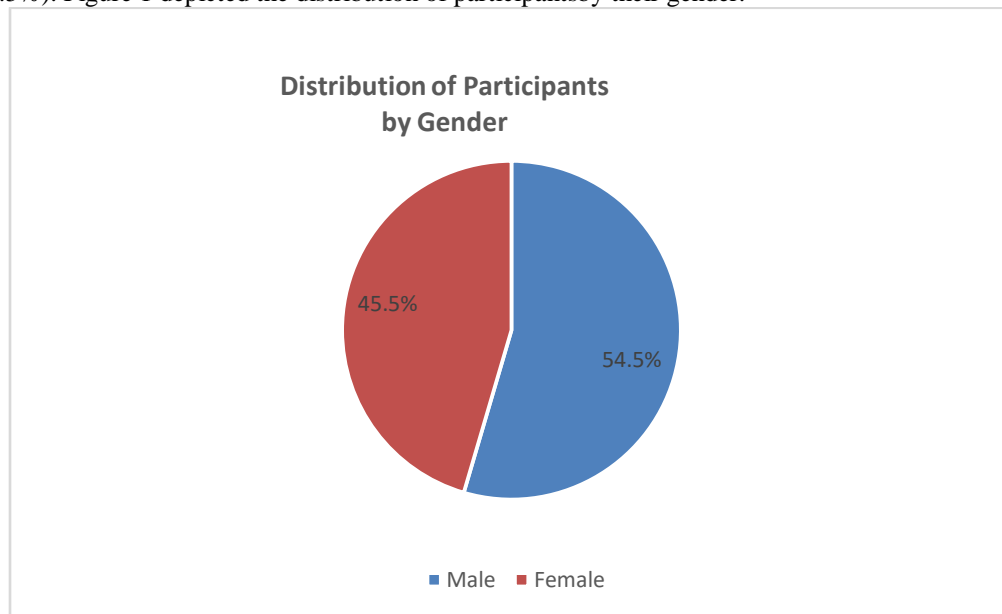
**Table 1:-** Safety system compliance.

Score	Compliance
Good (>80% - 100%)	Installation Fully Meeting Requirements.
Enough (60%-80%)	Installation Partially Not Meeting Requirements. Some parts of the installation do not fully meet the standards and may require minor adjustments.
Bad (<60%)	Installation Completely Not Meeting Requirements.

The participants in this study were 55 people, including visitors and employees of Lampung City Mall. Data was collected through an online questionnaire distributed to participants for two months. The collected data was processed descriptively, with the Fault Tree Analysis method applied to assess the fire incident, followed by recommendations for improving communication hazard.

### Results:-

Based on the responses from the online questionnaire, it was found that the majority of participants were male (30 people, 54.5%). Figure 1 depicted the distribution of participants by their gender.



**Figure 1:-** Distribution of participants by gender.

In terms of position, 29 employees (52.7%) and 26 visitors (47.3%) participated in the study. The study also conducted an analysis of the fire risk using Fault Tree Analysis (FTA), identifying the main causes of the fire as an LPG gas leak and electrical short circuits. Here is the chart showing the distribution of participant positions in the study:

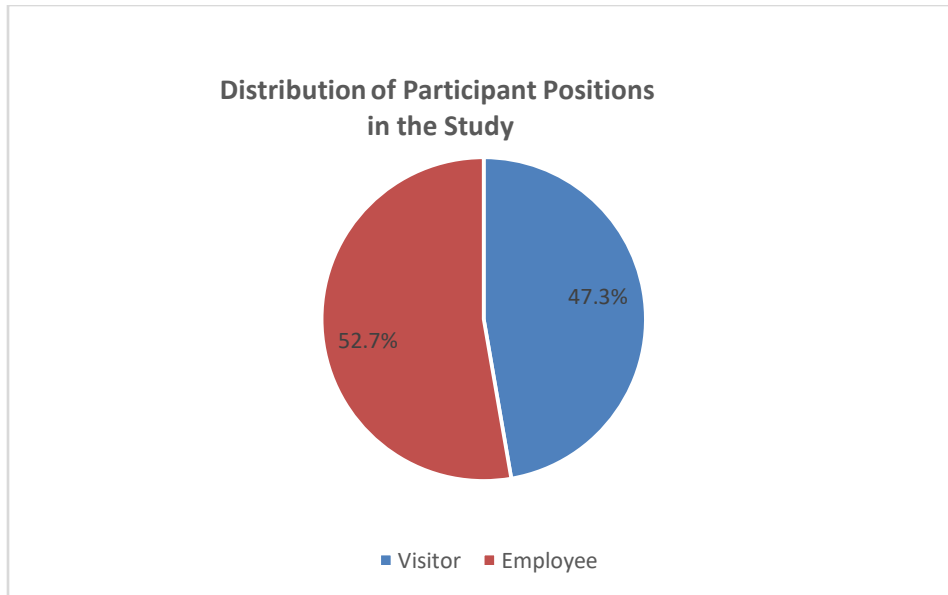



Figure 2:- Distribution of Participant Positions in the Study.

**Risk Assessment Through Fault Tree Analysis**

This stage begins by constructing a fault tree analysis chart that illustrates events leading to the top event: a fire at Lampung City Mall. The symbols connecting each event in the sequence are displayed in the table below:

Table 2:- Symbols of Fault Tree Analysis Elements.

Event	Symbol	Name	Description
Primary Event Symbols		Basic Event	Root of a problem that cannot be developed anymore
		Conditioninal Event	Event that is a condition of occurrence of another event when both have to occur for the output to occur
		Undeveloped Event	Events that cannot be developed due to lack of information
Intermediate Event Symbols		Intermediate Event	Problems that occur because one or more causes
Gate Symbols		And	Errors that occur due to several causes
		Or	Errors that occur due to one mistake

		Inhibit	Errors that occurs when a failure input occurs under conditions that make it possible.
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Sources: U.S. Nuclear Regulatory Commission “Fault Tree Analysis” Handbook NUREG-0492

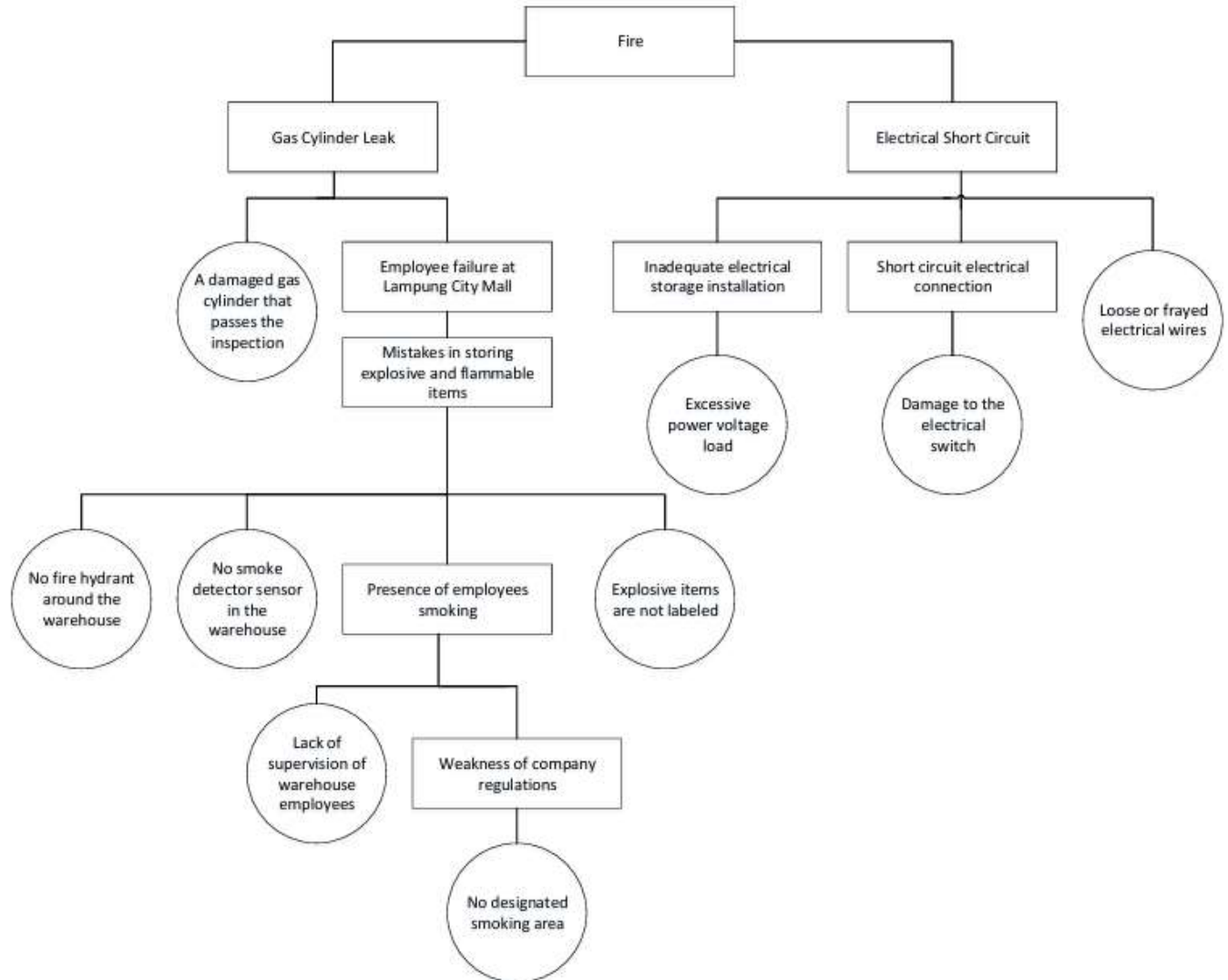


Figure 3:- The Fault Tree Analysis Diagram.

The Fault Tree Analysis diagram above explains that the fire at Lampung City Mall was caused by two main factors:

1. **Gas Cylinder Leak:** caused by a basic event of a damaged gas cylinder that passed inspection by the warehouse employees and an intermediate event of Lampung City Mall employee failure, or mistakes in storing explosive and flammable materials. Improper storage of goods led to the fire incident, compounded by the lack of a fire hydrant around the warehouse, no smoke detector in the warehouse, and employees smoking in the area. Another contributing factor was the absence of danger labels on explosive and flammable items. The smoking by employees was attributed to a lack of supervision over warehouse employees and weak company regulations at Lampung City Mall. This weak regulation was linked to the lack of designated smoking area.
2. **Electrical Short Circuit:** caused by an intermediate event of insufficient electrical containment installation that triggered by an excessive power voltage load, an intermediate event of short circuit electrical connection that led to damaged electrical switches a basic event of loose or frayed electrical wires.

### Active Fire Protection System at Lampung City Mall

The active fire protection system at Lampung City Mall includes alarms, detectors, sprinklers, portable fire extinguishers (APAR), and hydrants. These elements were evaluated through questionnaires and observations.

**Table 3:-** The Conformity Level of Active Fire Protection Systems at Lampung City Mall.

No.	Component	Percentage
1	Alarm	100%
2	Detector	85%
3	Sprinklers	95%
4	APAR	90%
5	Hydrant	75%
The Conformity Level		85%

Based on questionnaire results, it was found that the fire alarm system in Lampung City Mall is fully installed (100%) throughout the building, meeting the standard SNI 003-3985-2000. The fire alarm system at Lampung City Mall is integrated with the hydrant system.



**Figure 4:-** Fire Alarm and Detector Protection System.

Lampung City Mall has a total of 72 detectors, with 12 on each floor. However, these detectors have only been inspected once since installation, which took place during initial setup, and no subsequent inspections have been conducted.



**Figure 5:-** Fire Sprinkler Protection System.

Sprinklers comply with SNI 03-3989-2000 standards. Like the detectors, sprinklers are installed throughout each floor, although they are missing around the warehouse area and certain lower floors. The sprinklers have only undergone one inspection since initial installation.

Portable fire extinguishers (APAR) were assessed based on the Minister of Manpower Regulation No. 04/MEN/1980 and Minister of Public Works Regulation No. 26/PRT/M/2008. According to the questionnaire and observations, Lampung City Mall has 54 fire extinguishers, with nine located on each floor. These are inspected at least twice a year, and all inspection records are well-maintained.



**Figure 6:-** APAR Protection System.

Hydrants were assessed against the SNI 03-1745-2000 standard. Observations revealed that the hydrants include four outdoor hydrants and two indoor hydrants. Functional testing of hydrants is performed routinely once a year.



**Figure 7:-** Hydrant Pillar Fire Protection System Outside LCM Building.

The hydrant boxes at Lampung City Mall are easy to open, visible, and accessible. The hydrant boxes are painted red with the word “Hydrant” in white. However, there are no instructions for proper hydrant use inside the boxes, and the hydrant equipment in all locations is incomplete, which could impede emergency use.



**Figure 8:-** Fire Protection Hydrant Box Outside LCM Building



**Figure 9:-** Fire Protection Hydrant Box Inside LCM Building.

The evaluation of fire protection system elements at Lampung City Mall shows a compliance level of 88%, indicating that the systems meet regulatory requirements.

**Life Safety Facilities**

Life safety facilities at Lampung City Mall include emergency exits, stairwells, exit signage, emergency doors, and assembly points.

**Table 4:-** The Conformity Level of Life-Saving Facilities in Lampung City Mall Building.

No.	Component	Percentage
1	Exit Routes	60%
2	Emergency Stairs	100%
3	Exit Signs	100%
4	Emergency Doors	100%
5	Assembly Point	65%
The Conformity Level		85%

**Emergency Exits:**

The compliance of emergency exits was compared to NFPA 101 and SNI 03-1746-2000 standards. Lampung City Mall has two emergency exits that are unobstructed and connect directly to an open area outside the mall. Given that Lampung City Mall is the largest mall in Lampung, the adequacy of two emergency exits is assessed as 60% compliant, categorizing it as "adequate." This indicates that, while the exits are present, they do not fully meet the standard requirements for a building of this size.



**Figure 10:-** Life Safety Facility - Emergency Exit at Lampung City Mall.

**Emergency Stairs:**

Observations showed that emergency stairs are available on each floor, achieving a 100% compliance rate, meaning that these elements meet all regulatory requirements.



**Figure 11:-** Life Safety Facility - Emergency Stairs at Lampung City Mall.

**Exit Signage:**

Observations indicated that exit signs throughout the mall mostly meet NFPA 101 and SNI 03-1746-2000 standards, achieving a 100% compliance rate. The installed signs, including "EXIT" markings, are well-suited to guide visitors in an emergency.



**Figure 12:-** Life Safety Facility - Exit Signage at Lampung City Mall.

**Emergency Doors:**

Observations confirmed that Lampung City Mall has numerous emergency doors accessible to mall visitors. The compliance rate is 100%, indicating that emergency doors are installed according to requirements.



**Figure 13:-** Life Safety Facility - Emergency Doors at Lampung City Mall.



**Assembly Points:**

Compliance of assembly points was evaluated against NFPA 101's life safety code. Field observations show that Lampung City Mall has two assembly points.



**Figure 14:-** Life Safety Facility - Assembly Points at Lampung City Mall.

While the mall has designated assembly points, the number may be insufficient given that Lampung City Mall is Lampung's largest mall. For assembly points to be considered fully compliant, they must meet several criteria set by the NFPA 101 (2000), including:

1. Providing at least 30 m<sup>2</sup> of space per person, with a minimum height of 200 cm or more, able to accommodate all occupants.
2. Maintaining a minimum distance of 6.1 meters from potential hazards to ensure safety.
3. Ensuring accessibility to safer areas without obstructing emergency vehicles.

The current assembly points are located in open, safe spaces that facilitate easy evacuation. However, to meet full compliance, additional or larger assembly areas should be considered to accommodate all mall occupants safely during an emergency.

**Discussion:-****Fire Protection System at Lampung City Mall**

According to KEPMEN PU No. 10/KPTS/2000, the active fire protection system is a fire prevention system that operates automatically or manually. This equipment is used by building occupants or firefighters to assist in firefighting operations. The system includes alarms, detectors, sprinklers, fire extinguishers (APAR), and hydrants.

In the analysis of this active fire protection system, the average compliance level for the alarm, detector, sprinkler, APAR, and hydrant achieved a score of 88%. This result falls under the "GOOD" category, meaning all elements are functioning optimally and meet the applicable requirements. This level of compliance should be maintained to ensure no obstacles arise during evacuation.

**Life-Saving Facilities**

According to PERMEN PU No. 26/PRT/M/2008, every building must be equipped with evacuation facilities to allow occupants sufficient time to safely exit in an emergency. Life-saving facilities include exit routes, emergency staircases, directional signs, emergency doors, and assembly points.

Exit routes, as per SNI-03-1735-2000, should provide an unobstructed path leading to a public road. They must be protected from fire threats by fire-resistant walls, floors, ceilings, and doors.

In the life-saving analysis, the average compliance level for exit routes, emergency staircases, directional signs, emergency doors, and assembly points scored 85%. This is also categorized as "GOOD," indicating that all elements

function well and meet the required standards. Maintaining this compliance level is essential for smooth evacuation during emergencies.

However, two life-saving facilities fell under the "INSUFFICIENT" category: inadequate exit routes and assembly points. These deficiencies could harm the company in an emergency, as both elements are critical during a fire.

The non-compliant elements include exit routes, which are insufficient for a large, six-story mall. Lampung City Mall only has two exit doors. In the event of a fire, especially when crowded, visitors may panic and cause congestion as they try to escape.

Another element identified as non-compliant is the assembly point. Additional assembly points are needed to accommodate mall visitors, apartment residents, and other building occupants, as Lampung City Mall is integrated with other facilities.

### Participant Feedback on Fire Safety Symbols

Based on observations, participants offered several suggestions for adding fire safety symbols (emergency doors, emergency staircases, and emergency lighting) to help Lampung City Mall visitors better understand fire safety information:

- "These are essential because safety information like assembly points and evacuation routes should be available at multiple locations in the mall to prevent panic during emergencies." — Nita Aulia Tami
- "Yes, it is necessary so that visitors know how to save themselves without panicking." — Febri Saputra
- "Add symbols for emergency doors and staircases in several locations. Safety information is very important for mall visitors." — Rizki Fernando
- "Provide safety information lines, similar to those on airplanes, so that visitors can exit safely in case of a power outage." — Untung Saputra

### Recommendations:-

The following recommendations are proposed to improve fire safety and communication:

No.	Existing Condition	Expected Condition	Recommendation
1	Lack of Assembly Point Symbols and Accessibility Issues	The assembly point should be easily accessible from areas served by easily reachable exits.	It is recommended to add symbols and an assembly point near the building's exit doors so that mall visitors can easily evacuate themselves in the event of a fire hazard.
2	Emergency Doors Lack "PUSH" Signs, and Their Location is Hard to Reach from the Evacuation Corridor	Emergency doors should be easily accessible and visible.	Fire doors should be located in an easily accessible place, not convoluted or far from the evacuation corridor. Adding "PUSH" signs would help users to open emergency doors easily.
3	Lack of Hazard Symbols on Explosive and Flammable Items	There should be hazard symbols for items that are explosive or flammable.	It is advisable to add hazard symbols for explosive or flammable items stored in the warehouse and throughout the mall to prevent future fires.
4	Lack of Safety (OHS) Knowledge Among Warehouse Employees	Mall employees, including warehouse staff, should be knowledgeable about and trained in workplace safety (OHS).	It is recommended to conduct OHS training for mall employees every 6 months or once a year for both new and existing employees, ensuring they are prepared and responsive in emergency situations.

**Conclusion:-**

The study concludes that the active fire protection system at Lampung City Mall meets the required standards with an 88% compliance rate, while life safety facilities achieve 85% compliance. The main areas for improvement include adding more assembly points, improving access to exit routes, and increasing the visibility of safety symbols. Additionally, further training for staff on fire safety and emergency procedures is recommended to enhance overall safety and preparedness.

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