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# AN ANALYSIS OF EMERGENCY RESPONSE COSTS DUE TO FALSE ALARM SYSTEM

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***ABSTRACT***

*Losses from fire events can be minimized if the fire detection and alarm system installed in an area function properly. The conditions will be different if an alarm that sounds is not the result of real conditions that can trigger a fire - also known as a false alarm. The false alarm condition gives a loss to the company. In this research, an analysis and comparison of costs in the detection and alarm systems conducted on the existing company fires with the same risk of false alarms, repairs fire detection and alarm system, and investment costs. The probability of a false alarm calculated in the existing condition, to know the potential losses charged to the company due to unnecessary emergency response activities. As well, investment costs were analysed to improve the performance of the system. Two alternative conditions were found to improve company's performance.*

***Keywords***: *Alarm systems, Cost analysis, Cost Comparison, False alarm, Fire Detection*

## 1. INTRODUCTION

A false alarm is a fire alarm signal resulting from any causes such as: a fire-like phenomenon that caused by environmental aspect, Accidental, Inappropriate human activities, or Equipment false alarms. These causes affect fire alarm that has resulted from a fault in the system (R Chagger & Smith, 2014). However, in practice, there is no term false alarm because all active alarms will be treated as if critical conditions occur until all conditions are confirmed to be under control. Due to it relates to emergency conditions and the safety of many people, errors caused by false alarms must be minimized.

False alarms are an attribute of the reliability and effectiveness of fire detection of the alarm systems (Thomas, 2002). The reliability of fire or smoke detection and alarm systems is not a pure property of the systems, but also it needs a function of the systems properties and the environment to operate (Yaping He & Nelson, 2008). A fire alarm system is develop to maintain and minimize any potential losses cause of undesired event by fire (Bin Bahrudin et al., 2013).

In other word, false fire alarms arise as the result of local environmental impact for the alarm systems. Moreover, a false alarms could affect the effectiveness and reliability of the fire alarm systems (Proulx, 2000). At the false alarm, automatic detections of the alarm systems sometimes react to triggers which are not necessarily a symptom of fire. In this case, steam, smoke of cigarette, aerosol sprays and smoke from cooking are all common causes of fire alarms going active are classified as a false alarm. In a building where evacuations are carried out following the activation of the alarm systems, false alarms can be extremely has high impact. The further-reaching consequences of false fire alarms may produce bad impact to the company.

It induces a sense of complacency with the public and, they become increasingly used to false alarms. Then, public are less willing to act quickly when the alarm

activates even it is a true alarm. Therefore, alarm in a company must be managed well. In this case, the reliability and the effectiveness of the fire alarm system has to be evaluated to know the reliability of the system to protecting peoples, employee in the building and safe the property (Qu et al., 2013). During the false alarm, employees have become idle, customer service stops, company reputation drops, lost sales potential, and other domino effects. From a financial perspective, there are two types of cost and loss that caused by a false alarm; the cost of losses that are consequential in nature, and the cost of losses that are responsive (Marks, 2014). Consequential costs are charged due to the consequences of a false alarm.

Even in an alarm sounding, the disaster mitigation Standard Operational Procedure (SOP) must be implemented. At the SOP of mitigation, the safety aspect is the top priority, all residents in the office must immediately go to a safe place. This condition leads the company to unproductive activities. Indirectly, due to the cessation of these activities, the company incurs losses every time. The consequential costs include employee idle-time costs, company loss-sales costs, hazard-monitoring fees, monitoring service provider fees, and fines imposed on companies due to applicable state regulations. The response cost is incurred by the company to respond to the danger signal by bringing in firefighters and their equipment. Naturally, the fire department will not take the slightest risk related to a fire disaster.

When getting a signal, the officers will immediately go to the location as soon as possible to immediately eliminate the source of the danger. Moreover, if the alarm signal is not a real event, the company will bear all forms of losses from the firefighters and the fleets that have come to the location. There is an opportunity cost from the fire department that is borne by the company. The response cost consists of several components, including fire service fees, extinguishing equipment costs, and resource costs. Previous research in fire alarm system: Ref. (Qu et al., 2013) analysed the failure of the false alarm system using a fuzzy model while (Jafari et al., 2020) evaluate the reliability of the alarm system using Bayesian network and fault tree analysis. Research application and fire alarm system model evaluation has been largely discuss, as found in (Cai, 1996) that proposed a fuzzy model for system failure analysis for fire alarm system.

Previous research in alarm system reliability evaluation has largely proposed and discussed. In this study, analyse a cost impact due to false alarm system at the company and propose recommendations to improve the system. Factors that require to be considered in quantification of the alarm system should be discussed in any situations. As an example, U.S. fire departments responded to 2.5 million false alarms in 2014 (Ahrens, 2016). This is almost twice the total number of reported fires and five times the number of structure fires.

Correlation of the number of false alarms with the number of detectors of the automatic fire alarm systems should be analysed and provide recommendation to improve the system (Chow et al., 1999). One of the biggest causes of an unwanted fire alarm is that of misapplication. This is where the wrong device is used in the wrong application or setting. In other case, installation practice is also found as the second biggest cause of the false alarm, as also found by (Colombo, 2018). An automatic fire alarm systems have become an important lifesaving technology in many human daily life activities (Anwar et al., 2017), therefore it should be reliable and effective.

Models have been developed to responds the false alarm, Ref. (Zafar et al., 2020) apply data mining technique to simulate fire alarm scenarios based on real-world data that organized by temperature, gas, and humidity data. The purpose of an automatic fire

detection system is to detect fire at the earliest practical moment and to give an alarm so that appropriate action can be taken such as evacuation of occupants, summoning the firefighting organization, automatic triggering of extinguishing processes (To & Fong, 2013). Moreover, a fire alarm is potential to produce a false alarm. As an example, during 2012 – 2015 U.S. fire departments responded to more than 2.5 million false alarms every year. This means that one out of twelve calls responded to by fire departments were false alarms (Karter, 2013). There are many ways of reducing false alarms, some of them are educating building owners, responsible persons and the general public and also flame monitoring (Cahill et al., 2020; Raman Chagger, 2012). This way may contribute significantly to false alarm reduction and risk mitigation. To solve the problem, it must to reduce the number of unwanted alarms that occur or improve the reliability and the effectiveness of the alarm system. This would also reduce alarm fatigue and complacency among the public (Ahrens, 2013).

Further, false alarms will also lead to the waste of fire brigade resources and reduction of the effectiveness of the system in the case of real fire. A transformation is needed to improve the alarm system. An analysis of the false alarm is required to provide recommendation in improving the alarm system. The objective of the study is to analyse the cost impact due to alarm system failure and propose improvement strategies. The rest of this paper is organized as follows: research method, result and discussion, and conclusion. In section 2, the Research Method is delivered to define the framework and methods. In section 3, the Result and Discussion analyse the data. In the final sections, the conclusion is described to answer the research objective.

## 2. METHODOLOGY

The research framework is depicted at Figure 1. A case study approach is proposed to detailly analyse the fire alarm system failure and its impact for the company. Therefore, a situational analysis is described at the first stage of the research to know current condition and identify the false alarm system failure. In this study, the quantitative analysis method is applied as a benchmark for calculating the costs incurred due to the false alarm. The data are collected from the historical performance of the alarm system in the XYZ company, as the case study. The data includes the frequency of alarms occurring in the area in the period of 2019. This historical data is required to analyse the factor to activate the fire alarm system.

In the implementation of this research, data was collected which included the frequency of false alarms, the frequency of what caused the false alarms, and the distribution of causal factors in each month during 2019. The causal factors of the failure alarm system are discussed further to find the potential cost impact for the company. The failure alarms system factors analysis is enriched by the in-depth interview with the stakeholders at the company. The interview is related to factors influence the failure alarm system and possible cost to prevent the problem. Further, this study also calculates the potential financial losses suffered by companies due to false alarms. This frequency is a multiplying factor of the amount of loss per false alarm event. The cost impact calculation analysis is described below:

Consequent lost = B + C + D+ E (1)

Response cost = G + I + J (2)

Total cost = Consequent Lost + Response Cost (3)

Total cost idle time per hours = salary for each person x total employee (4)

Which components data collected from department given as follows:

Company Loss Sales Cost (B) = USD 343.41/hours

Hazard monitoring cost (C) = USD 41.21/event

| | | |
|---|---|---|
| Monitoring Service fee (D) | = | USD 82.42/event |
| Regulatory fine (E) | = | USD 274.73/ event |
| Regulatory fine (E) | = | USD 274.73/ event |
| Fire Service Fees (I) | = | USD 2,022.66/event |
| Resource Costs (J) | = | USD 41.21/event |

After getting the value of financial losses due to false alarms, the amount of investment required is calculated to implement a newer fire alarm system. This calculation is based on a vendor that offers both system installation services and the provision of sensor devices. In this stage, the recommendation are formulate and proposed to improve the alarm system.

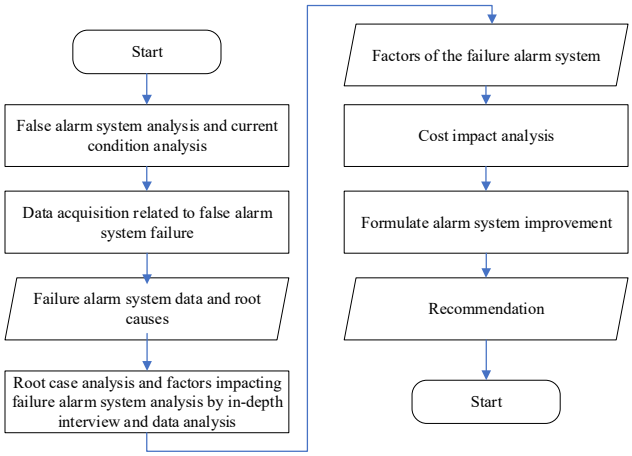



**Figure 1**. Research framework

## 3. RESULT AND DISCUSSION

### A. Current situation analysis and the frequency of the failure alarm system

The office area studied is in an XYZ company office building located in the Middle East. The building stands on land which has a 1,100m2 area with a two-story building. The number of employees actively working in the office are 124 people. This office has an office opening period of 8 hours per day, 6 days per week. Even so, activities in the office continue 24 hours a day. Even when the office is not open operationally, there are still guards on duty in the office area to carry out security activities every day. Common activities carried out in the office include administrative activities which include the use of electronic devices such as computers, printers, and photocopiers. The use of electric appliances also occupies a very significant number, including air conditioners, lights, automatic door systems, television screens, and kitchen appliances like coffee machines. In addition, the office area in the Middle East has two seasons, summer, and winter. During winter, temperatures have an average level of 10℃ which lasts from October to April.

Meanwhile, in the summer, temperatures can reach a level of 47℃ - during this time, the significant increase in temperature and dry air accompanied by dense dust increases the likelihood of false alarms. The total number of fire and gas detectors in the office area is 260 which are scattered throughout the rooms on the ground floor, first floor, and second floor. It is divided into three Zones, namely Zone-0 for the base, Zone-1 for the 1st floor, and Zone-2 for the 2nd floor. For equipment maintenance, it is carried out every 6 months and the company appoint a third-party company. Meanwhile, simulations or fire drills are carried out once a month.

| Category | Cause factors |
|---|---|
| Damage to the device | • The device battery damage.<br>• The sensor device is not functioning properly.<br>• Maintenance SOP is not going well. |
| Human negligence | • Smoke from the kitchen space due to cooking activities.<br>• Employee accidental activation. |
| Environment | • The ambient temperature heats up due to summer.<br>• Environmental dust is getting thicker.<br>• Aerosol particles in the air that can trigger the sensor. |
| Company System | • Electrical short circuit.<br>• Disaster mitigation simulation training schedule. |

**Table 1.** Causes of false alarm in XYZ company

| Consequence Costs | | Response Costs | |
|---|---|---|---|
| **Cost** | **Notation** | **Cost** | **Notation** |
| Employee *Idle-Time* Costs | A | Fire Service Fees | F |
| Company *Loss-Sales* Costs | B | Extinguishing Equipment Costs | G |
| *Hazard Monitoring* Costs | C | Resource Costs | H |
| Monitoring Service Fee | D | | |
| Fine | E | | |

**Table 2.** Components of Consequence Costs and Response Costs

From the data for the false alarm, there are several factors that caused the system to activate as shown in Table 1. Then, the data collection items for costs consequence and cost response are listed in Table 2. Sytems sounding during the period of 2019. In most of these cases, 109 of them were false alarms or about 95.6% of the total active alarm systems. Only 5 times the alarm system detected a fire, about 4.4%. When compared between false alarms and true alarms, the ratio is 21.8:1 as also found in (Marks, 2014). Figure 1 shows the data on the number of frequencies of fire detection systems each month in 2019.

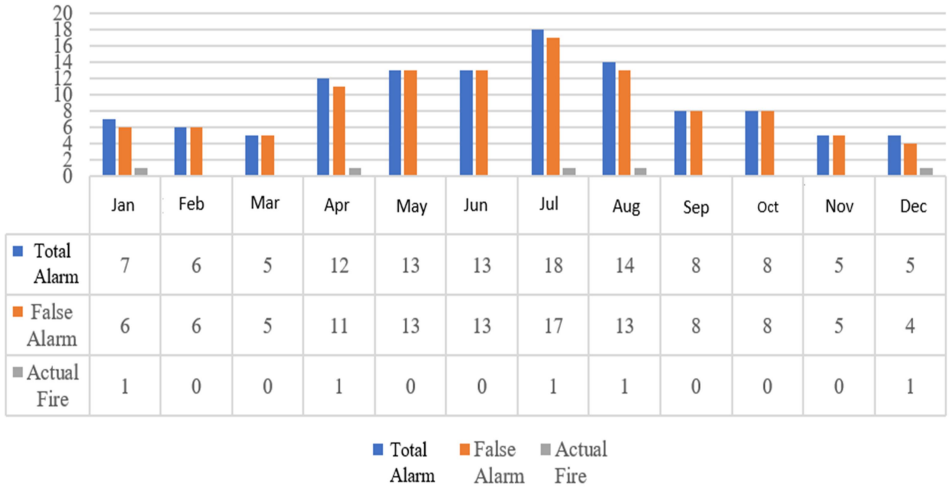
The data show that most false alarms was occurred in July. The period from April to August also shows a significant number of false alarms. In this case, the environmental changes in summer season has high impact for the alarm system failure. As we found that in summer at the middle east achieve it's warmest temperature up to 45℃. This condition affects the sensors in the fire detection system to be activated automatically even there are not appearance of fire at the office. Our analysis is also related to current condition as show at Figure 2. The data shows that device problems due to overheating have the largest number of frequencies, which is then followed by environmental dust and smoke from the activities at the kitchen.

False alarms due to sensor overheating have a correlation with the extreme environmental during summer season included sandstorm factor which has the second-highest number of cases which found There was a total of 29 cases in the 2019 period. Meanwhile, another contributing factor was the simulated fire mitigation training. This is a routine schedule from the company which is carried out once a month. Recorded 12 times these activities are carried out in a year. This activity is to maintain a level of employee vigilance against possible disasters that may occur.

The damaged device factor is recorded 5 times a year. From the information given by the maintenance team, the battery is not in the best condition which causes a short circuit to damage the battery charging system that needed to be replaced. In this case, a regular maintenance is required to maintain the battery condition and device service. The smoke factor from kitchen activities occurs due to cooking that produces excess smoke. There are 24 cases within a year. Human negligence has also been recorded in 5

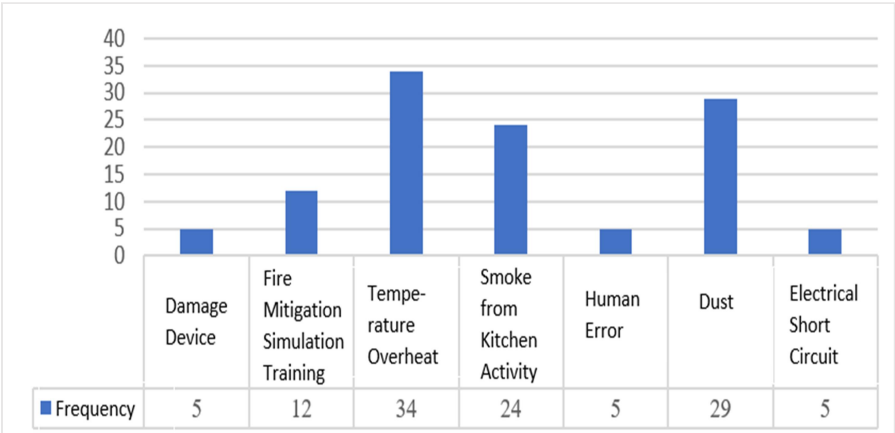
cases. The human negligence is an accidental activity that triggers an active system, usually because the manual activation button is pressed accidentally. Another cause is when doing maintenance, the system has not been shut down optimally. Lastly, the short circuit factor is the most dangerous because it has the potential to present a source of danger such as sparks that can spread to other objects and cause a fire. There were 5 cases recorded in a week.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Alarm | 7 | 6 | 5 | 12 | 13 | 13 | 18 | 14 | 8 | 8 | 5 | 5 |
| False Alarm | 6 | 6 | 5 | 11 | 13 | 13 | 17 | 13 | 8 | 8 | 5 | 4 |
| Actual Fire | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |

**Figure 2.** Frequency of activation of fire alarms in 2019 at the XYZ Company

Completely, Figure 3 shows the frequency distribution of the factors influenced the false alarm system during 2019. We know that the period with the highest number of false alarm cases occurred from April-September which goes into the summertime period. The temperature increases significantly, and the ambient air dries up. As a result, dust particles also increase which makes it difficult for the fire alarm sensor to maintain good performance.




| | Damage Device | Fire Mitigation Simulation Training | Tempe-rature Overheat | Smoke from Kitchen Activity | Human Error | Dust | Electrical Short Circuit |
|---|---|---|---|---|---|---|---|
| Frequency | 5 | 12 | 34 | 24 | 5 | 29 | 5 |

**Figure 3**. The frequency of each factors activate the alarms in 2019

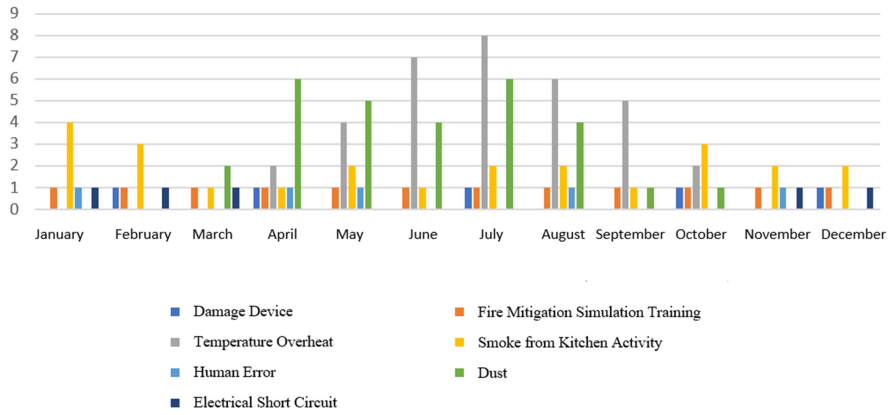



**Figure 4.** The Distribution on factors influence the activated fire detection systems for 2019

These two factors play an important role in the activation of the alarm system. The high temperature and the smoke-like dust coils trigger an active alarm system. The sensor uses the scattered image method, where it can confuse a collection of dust particles for the smoke. The smoke factor from kitchen activity increases during winter. An increase in cases was recorded in January and February. This is related to winter, which makes employees more active in using kitchen facilities to provide food while working. The use of higher cooking utensils triggers the accumulation of smoke in the room which then affects the fire alarm sensor system.

### B. Cost Analysis of the Failure Alarm System

With these several factors, it is highly potential to give a negative impact on the company. However, out of 109 cases detected as false alarms, 7 calls were recorded for firefighters and found that 5 of them were a response to true alarms. However, there were 2 firefighters arrival caused by false alarms which caused by environmental overheating and dust. The frequency of the alarms based on the factors are described in Table 3. The data has shown that the alarm system reliability is very low.

Further, as very high failure of the alarm system, this study calculates the cost impact and compare to another strategy to improve the system. Assuming the duration per event is 1 hour, the cost value can be determined as shown in Table 4. Then the total cost of consequences for 24 false alarm events during 2019 is USD 66,346.15. In the calculation of response costs, the component of the calculation variables is shown in Table 5. The total number of false alarm incidents that were up to the firefighters' summons were recorded twice. So, the total cost of response due to false alarm is USD 741.76. As a comparison, this study also analyses the idle cost up to USD 951.7/hour as shown at Table 6

| Description | Alarm | TRUE | FALSE |
|---|---|---|---|
| Calling the Fire Department | 7 | 5 | 2 |
| Other Alarms | 107 | 0 | 107 |
| Mitigation Training Activities | 12 | 0 | 12 |
| Other False Alarms | 95 | 0 | 95 |
| False Alarm leads to loss | 24 | 0 | 24 |

**Table 3**. The frequency of the number of alarms along with the factors and impacts carried out by the company

| Consequence Cost Component | Cost |
|---|---|
| Idle Time Fee | USD 2,022.66 |
| Loss-Sales Fee | USD 343.41 |
| Hazard Monitoring Fee | USD 41.21 |
| Monitoring Service Fee | USD 82.42 |
| Regulatory Fines Fee | USD 274.73 |

**Table 4.** Value of cost components in the calculation of consequential costs

| Response Cost Component | Cost |
|---|---|
| Fire Service Fees | USD 2,022.66 |
| Extinguishing Equipment Costs | USD 343.41 |
| Resource Costs | USD 41.21 |

**Table 5.** Value of cost components in the calculation of response costs

| Idle Cost Component | Cost |
|---|---|
| Idle Employee | USD 282/hour |
| Idle Contractor | USD 93.7/hour |
| Others Staff | USD 576/hour |
| Total Cost | USD 951.7/hour |

Table 6 The value of the cost components in the calculation of idle costs

**C. Recommendation for system improvement**

The factors and cost analysis to failure alarm system require a very high-cost impact to the company. This study proposed the investment analysis to implement in the current situation of the company. According to a benchmark, the cost charged to build a fire alarm security system in a commercial building, and has a complex security system, is estimated at USD 6 per m² while other costs include monitoring and repair costs are USD 60 per month (Durrel, n.d.).

Based on the cost and benefit analysis above, this research recommends using a system which has been standardized with NFPA62 (National Fire Protection Association) regulations, as well as general workplace safety regulations. It is including ADA (Americans with Disabilities Act), OSHA (Occupational Safety and Health Administration), IBC (International Building Code), and GSA (General Service Administration). This standards implementation at the company is possible to reduce fire alarm system failure and reduce cost of the operations. With an office building of 1,400 m², the total system repair cost is USD 8,400. Meanwhile, the annual monitoring and maintenance costs are USD 480. So, the total cost of building a new system is USD 8,800.

The solutions proposed replacement with a multi sensor is a simple, direct and effective way. The cost for a standard optical/heat multi sensor is reported between US $ 6.91 and US $ 13.83 which would make it a cost-effective solution to replace problem detectors or in areas where false alarm risks are higher. The estimated costs to businesses are ~US $ 4.01 k per false alarm. Based on research the number of false alarms by 45% over seven years has reduced, which amounts to an estimated cost saving of around US $ 622.6 k a year. This confirms that their strategies provide an effective means of reducing unwanted false signal and keeping them low as new buildings come “on-line”. Further, the most important factors that should be noticed to avoid a false alarm system is to develop and follow the safety rules, as suggested by Ref. (Wang et al., 2014).

## 4. CONCLUSION

With natural conditions that have two seasons, hot and cold, XYZ company needs to adapt to the fire alarm system in its office area. One form of adaptation that has been carried out is by implementing a better fire alarm system. From the results of research and calculations, the amount of potential loss caused by false alarms from fire alarm systems is USD 67,087.91 per year. Meanwhile, if the company wants to improve the existing alarm system, it requires an investment cost of USD 8,800. A comparison that has a very significant difference. Investment costs are 8x cheaper than the potential losses that can arise due to false alarms.

The investment costs are then used to make system repairs, especially improvements to the sensor device, which must be more efficient in detecting fire trigger factors correctly. Identifying the difference between dust and smoke, adjusting the temperature increase during summer needs to be considered to further improve the system. As all the installed fire detections system link to the control room, it is required to detect all activated fire alarms earlier by providing CCTV (Closed-Circuit Television) that is accessible to the control room operator who can confirm the emergency response team and employees whether it is real or false to avoid unnecessary loss of productive time and the fees of response cost component.

By reducing the intensity of false alarm responses, the company can minimize the number of losses that are mostly contributed by the idle time of company employees. With a minimized number of false alarms, the employee's productive time will also be disturbed less. Therefore, the fire safety system needs to be reconsidered for future repairs.

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