Design and Development of an Industrial Safety Mechanism Device to Track and Monitor Fire Extinguishers via QR Code Scanning Procedure

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Abstract: Fire extinguishers are mandated to undergo monthly inspections due to their indispensable function in the event of an emergency, which involves the suppression or suppression of fires. We verify the pressure, verify that the orifice is unobstructed, and examine for any indications of damage as part of the inspection. The data is documented after the examination using an aluminum badge and an inspection checklist. The paper introduces a novel ideology known as the Intelligent Fire Protection Strategy (IFPS) and conducts experiments with the appropriate infrastructure to evaluate its effectiveness. In order to evaluate its functionality, it is cross-validated with the conventional detection mechanism known as the Classical Fire Control System (CFCS). In order to enhance the accessibility of data and reduce the likelihood of errors in the recording of inspection findings, this proposed method, QR-based monitoring, was implemented by IFPS. The QR code that is included with each fire extinguisher provides crucial information regarding its type, pressure, propellant condition, expiration date, and next service month. The system will transmit an email or push message to the mobile app after the first month of service has elapsed. The fire extinguisher system adheres to standards such as IS15683, NFPA 10, and IS2190.

1 INTRODUCTION

A substance, generally a fuel, combined with gaseous oxygen, under the influence of heat, generates a rapid chemical reaction called fire. This phenomenon is known as combustion. In case the flaming, heating, and fuming characteristics of fire and flames are not controlled, the extent of damage thus caused may overwhelm its extreme limits (B Siregar, et al., 2017) (Gerard Goggin, et al., 2024) (Arkan Aslam Sanadi, et al.,2020). In summary, fire is a self-sustaining reaction in which a fuel source combusts rapidly with oxygen and which gives off heat, light, and a variety of chemical products (Sumitha C, et al., 2023). The following are the four things required for to start the fire:

- Fuel that which is combustible.
- Oxygen - to enable burning
- Heat to burn the gasoline
- Chemical reaction that is, the mechanism of combustion itself.

Among the several forms fire can manifest itself as flames, smoldering, spontaneous combustion, and electrical fires (Songkran Kantawong, 2022) (Devesh A. Patil, et al., 2022) (Sen Li, et al., 2023). Below are the stages of fire development being:

- The first development stage of a fire is defined by a little, isolated fire with minimum smoke and heat.
- As it spreads and uses the combustibles surrounding it to maintain its development, the fire generates rising amounts of heat and smoke during the stage of growth.
- Fully developed, is characterized by extreme heat, thick smoke, and the possibility of a flashover or back draft when the fire reaches its peak size and intensity.
- As the fire burns out or is put out, the heat and smoke output decrease, marking the beginning of the decay stage.

Depending on the fuel source and other fire-related factors, many types of fires can be

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distinguished (Mohsen Foroughi Sabzevar, et al., 2023) (Loay M. Aboud, et al., 2023) (Javier Pisonero, et al., 2023). Most fires fall into the following categories:

- Class A fires indicate for common combustible objects such fabrics, paper, wood, and trash.
- Class B flames need flammable gases or liquids such gasoline, oil, paint, propane.
- Class C flames demand wiring, circuit breakers, and electrical equipment including appliances.
- Class D flames need flammable metals including magnesium, titanium, and potassium.
- Class K fires use cooking oils and greases among other commercial tools.

The types of extinguishing are:

- **Cooling:** Reducing the fuel's and surrounding area's temperature will help to prevent re- ignition. This is the process used in water, foam, and dry chemical extinguishers.
- **Smothering:** This is used in foam, dry chemical, and carbon dioxide extinguishers as well as in oxygen deprivation to inhibit combustion.
- **Starvation:** Eliminating the fuel supply stops ongoing combustion, stopping the gas or flammable liquid flow.

There is a list of related works in Section 2. In Section 3, the recommended methods are presented. The findings are presented in Section 4. The conclusion is presented in section 5. The references are presented in further section.

2 RELATED WORKS

A fire extinguisher is a tool for putting out fires or controlling their spread in the event of an emergency. On a monthly basis, it is examined (NITHISH, et al.,2024). Verify that the pressure extinguisher is in good working order and that the nozzle is not blocked or broken. Please ensure that the data is recorded on the associated aluminum tag and inspection checklist after the inspection is finished. By using this QR-based monitoring system, officers will be less likely to make mistakes while collecting, locating, and viewing data on the results of fire extinguisher checks. Along with the kind of extinguisher, pressure condition, powder condition, expiration date, and next service month, every fire extinguisher has a QR code attached to it. The online application is set to automatically activate when the service month is up. The following fire extinguisher standards are in place: NFPA 10, IS15683, and IS2190.

A company's use of automatic portable fire extinguishers (APAR) is crucial for both fire prevention and suppression (Hasanusi Pane, et al.,2023). The procedure of inspecting fire extinguishers has recently been made easier with the use of digital solutions, such as the use of barcodes and android applications. The Waterfall model has been used in this research as a technical design model for software development. This study proposes an approach similar to tagging fire extinguishers with Andorite-based barcodes readable anywhere in the world via the Internet. With this barcode-based monitoring system, officers are less likely to make mistakes while recording data on fire extinguisher checks, searching for that data, and making it easy to read and retrieve. Barcodes are coded descriptions given to each fire extinguisher based on the specific conditions, which holds information of the type of extinguisher, weight, officer name, expiration date, and type. Given that this implementation of the method is slowly or gradually carried into effect, it may then be perceived that the resultant system will have a higher quality.

By improving catastrophe preventive capacities via the use of building technology, this study (Tzu-Wen Kuo, et al., 2025) sought to reduce the amount of time it took for firefighters to seek for survivors during interior fires. Tragically, firemen frequently fail to rescue persons in time from domestic flames, leading to fatalities. Thorough investigation and analysis are required to address the subject of how to maximize the likelihood of survival while concealed from rescuers. So, it's critical to find a way to make building door panels that can activate an emergency call system so that people may live in secure conditions. We identified the main challenges and limits of current search-and-rescue tactics by conducting a thorough literature study using the PRISMA approach. Afterwards, a notification system was developed to tackle this problem after the discovered major components were studied using the TRIZ technique to identify the essential aspects that impact the success of rescuing imprisoned persons. In order to provide the fire department with precise position information, we used a smartphone to scan a QR code, based on the idea that it is best to wait for rescue during a fire. We created a rescue notification door panel and got a patent for it after receiving a lot of input from firemen. Just imagine the search-and-rescue having been done quicker with the help of this particular technology in case of a fire. The test results

estimated that they managed one-third less of time of searching.

Flashovers cause fires to spread quickly, which can cause human deaths and substantial economic damage (Hyuk Lee, et al.,2024). In the midst of personnel shortages, the shipping industry is recognizing the importance of unmanned fire detection systems to streamline operations while decreasing staff. There is currently no dedicated AFDSS for unmanned autonomous ships, despite its importance in reducing false alarms and guaranteeing accurate fire suppression in the face of variable wave conditions. This is in contrast to the AFDSS that have found use in tunnels and building infrastructure. In this study, we provide a novel AFDSS that uses a reinforcement learning algorithm to optimize water spray in marine environments and incorporates RGB, IR, and UV sensors to decrease false alarms. We will present the system's design, integration, and trials of fire extinguishing, showcasing the improvements in fire safety in autonomous ships set in a simulated sea-state environment.

Fire modeling is often used, at great expense, to support analyses of building fire safety (Yanfu Zeng, et al.,2022). This Intelligent Fire Engineering Tool (IFE Tool) is an AI program developed in this study to accelerate building fire safety analyses, particularly to swiftly identify design limitations. Initially, a thorough analysis of the important building and fire factors to create a large numerical event atrium-fire database is conducted. Next, a model with an accuracy of 97% is fitted to perform a 9-year forecast of tenability with regard to smoke visibility, temperature, and CO concentration. Then the tenability decline profile is further considered when assessing the fire safety and available safe egress time (ASET) in atriums with geometrically complex roof designs and slab extensions. In a short amount of time, our AI design program can evaluate the planned atrium fire engineering design and provide helpful recommendations for possible enhancements. Atrium fire safety typical design chores are finally covered in the offered operation guidelines of IFE Tool.

3 METHODOLOGY

Due to developments in equipment inspection technology, digital tools such barcodes and Android applications may now help to test fire extinguishers. The advancement of technology has made all relevant to human action feasible. Using modern technology will enable one to finish those tasks faster and more readily than manual completion. The present fast expansion of mobile phone technology has made their requirement far more important in the process of finding information or seeking data. Though human work is still mostly done by hand, an organized system may speed up and ease it. Comparatively to the current approach called Classical Fire Control System (CFCS), the proposed way called Intelligent Fire Protection Strategy (IFPS) readily find out the pending and finished of fire extinguisher and decrease the mistake of fire extinguisher. The following figure Figure 1 shows the system architecture and the following figure Figure 2 shows the system flow diagram.

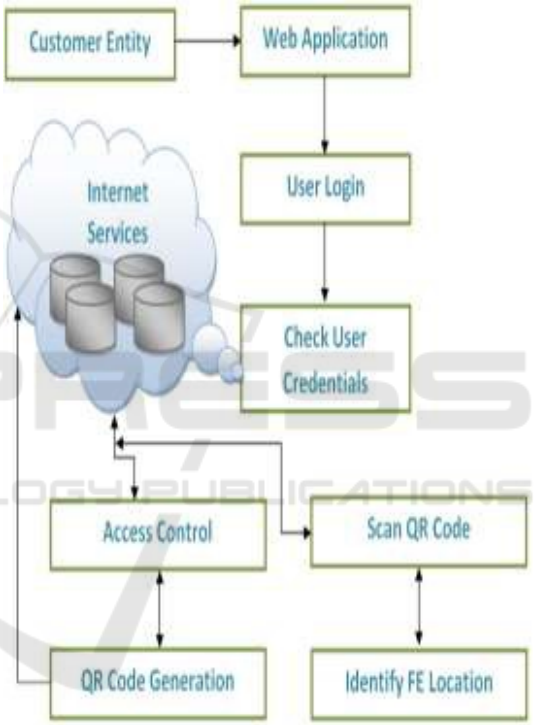

Figure 1: System Architecture.

Amongst other techniques, heat ascends transporting embers and sparks to distant regions facilitate fire spread.

(a) While in motion in the air, heat waves ignite adjacent combustibles.

(b) Condensed heat ignites encircling materials as it travels over solid structures.

(c) New fires may begin on surfaces or in the air by incandescent particles.

(d) Burning items like branches or trash that start new fires can be carried by wind or water.

(e) Fire can begin accidentally, through negligence or arson.

(f) Gusty winds help carry embers and sparks to

new areas and fan the flames.
(g) Fire can move very fast up slope or even across canyons and valleys.
(h) Like combustible materials or plant life, intact fuel supply might cause fire to spread.
(i) New fires may be started by many ignition sources, including lightning or electrical faults.
The following summary shows different forms of Fire Extinguishers in detail.

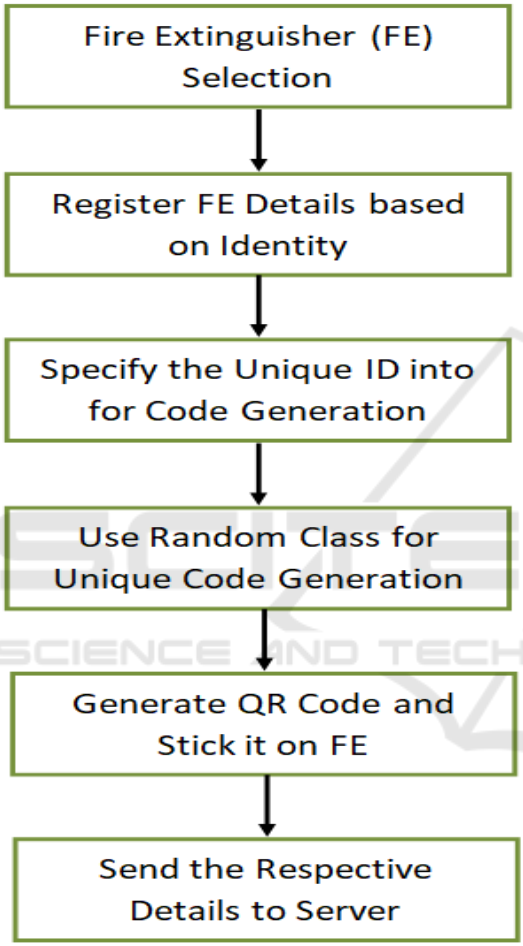

Figure 2: System Flow Diagram.

3.1 Water Extinguisher

The simplest and least costly are water extinguishers. Against Class A flames, which contain common fuels like paper and wood, they are efficient. Common types of fire extinguishers useful against Class A fires which contain regular flammable items such paper, wood, fabric, rubbish, plastics are water type extinguishers.

3.2 Foam Extinguishers

Against Class A and B flames, foam extinguishers are rather successful. For liquid-based flames, they work well; unfortunately, they are inappropriate for electrical fires. Common places where flammable liquids are present gas stations, garages, industrial environments, chemical plants, aviation rescue and firefighting (ARFF) operations are where foam extinguishers find application.

3.2.1 Carbon Dioxide Extinguishers

Against flammable liquid and electrical fires, carbon dioxide extinguishers are quite successful. They have a limited cooling impact; nevertheless, hence one should use prudence in restricted areas. Class C fires deal with electrical equipment including appliances, wiring, circuit breakers, and electrical panels.CO2 extinguishers cool the area with a temperature drop of up to -70°F (-57°C) by displacing oxygen, therefore starving the fire of fuel.

3.2.2 Dry Chemical Powder Extinguishers

Against Class A, B, and C flames they are efficient. The residue, nevertheless, may damage delicate machinery. DCP fire extinguishers are a kind of fire extinguisher whereby dry chemical powder (DCP) is used to suppress flames.

3.2.3 Wet Chemical Fire Extinguishers

Kitchen fires are generally handled with them. Designed to extinguish flames involving cooking oils and greases, a K type fire extinguisher is one type of fire extinguisher. First aid measurements in inhalation: Get sufferer moving toward fresh air. Get seen right away for any trouble breathing. Eye Contact: Keeping lids open, immediately flush eyes with plenty of water for 15 minutes. See a doctor if burning, redness, or itching develops. Wash everything off skin for at least 15 minutes using lots of water and soap. See a doctor if redness, itching, or burning results. Ingestion: Get medical treatment and dilute by drinking lots of water. Advice for doctors: Treat with symptoms. Usually regarded as harmless for the environment when applied sensibly in agricultural environments, MAP is not believed to be detrimental to aquatic life. Commonly used in fertilizers and fire extinguishers, mono-ammonium phosphates are white crystalline powders. It is a good supply of nitrogen and phosphorous, two vital minerals for plant development, and helps to put out fires very well. A fire hydrants main role is to give

firefighters rapid and easy access to water should a fire break out. Connected to a public water system, hydrants let firemen connect hoses to them, therefore supplying the required water to quell flames and stop their spread.

- Fire hydrants should always be easily seen and reachable. Clear the surrounding area of hazards such automobiles, trash, or overgrown plants.
- Open or close a fire hydrant only if you are a qualified professional or fireman else you risk tampering. Using a hydrant improperly could cause harm and lower its efficacy during an emergency.
- Fire hydrants should be easily found in an emergency by suitable marking with paint or placards.
- Safety Around Water Flow: operation caution around a hydrant in operation about water pressure. Dangerous high-pressure water streams released by fire hoses can cause injury.

3.3 Inspections

- Regular inspections of fire hydrants by municipal authorities or maintenance teams help to guarantee their functionality. Inspections ought to look for corrosion, obstructions, and damage.
- Hydrants should be checked for water pressure to guarantee they offer enough flow during a fire.
- The area surrounding fire hydrants should be evaluated to guarantee that there are no impediments and that firemen have easy access.
- Periodically doing flow tests will guarantee that the hydrant is connected to a trustworthy water supply and provides the right amount of water.

4 RESULTS AND EVALUATION

Quickly put out the fire with the help of the fire extinguisher. But these days, not all businesses check the cylinders thoroughly. Because he failed to adequately maintain the fire extinguisher inspection document. We are unable to locate the fire extinguisher on the factory floor in the event that the checklist is overlooked. In order to address this problem, a fresh approach is needed. This paper presents a new methodology called Intelligent Fire Protection Strategy (IFPS). To test its efficacy and performance, it is cross-validated with the traditional Classical Fire Control System (CFCS). On the other hand, fire extinguishers with QR codes can quickly locate a checklist that can be downloaded several times, and the data is stored on a server and updated monthly. We need to download a check-in form online in case we forget to bring one with us. This is a brief overview of the planned scheme's design, which calls for extinguishers to be stationed at every potential danger spot.

The fire extinguisher should be located so that the user doesn't have to walk more than 15 meters away from the fire. It is recommended to stay in the same spot on every floor. Additionally, fire extinguishers should not be left in one location for an extended period of time; if one becomes too hot or overused, it is imperative that the location immediately replaces it with a fresh one. There should never be anything in the way of a fire extinguishers access.

- Verify that the fire extinguisher is readily available and in its proper location.
- Verify that the pressure gauge is set to an operable range.
- Make sure the extinguisher is free of dents or rust before continuing.
- Fourth, make sure the tamper seal and pin are both intact.
- Make sure the fire extinguisher is full. 5.
- Look for indications of damage, corrosion, or manipulation when examining the extinguisher's overall physical condition.
- Make sure you sign and date the yearly maintenance tag.

4.1 QR-Code Fire Extinguisher Inspection

The QR code label is securely attached to the fire extinguisher and is equipped with a distinctive identifier that corresponds to the digital record of the extinguisher. The digital record must include the following information: User Manuals and respective Instructions, Extinguisher Type and Capacity, Location, Maintenance History, Inspection Records, Expiration Dates, Photos, and Videos. The following information must be included in the inspection process: Scan the QR code using a smartphone or tablet. To access the digital record, confirm the model and location of the extinguisher. Verify that the extinguisher is situated in the appropriate location. Review the inspection records and maintenance history. Confirm the expiration dates (e.g., recharge, hydrostatic test). Examine user manuals and

instructions. Add new inspection records, update the digital record, and capture photos or videos of the extinguisher. The QR Codes for the scanning and identification of the respective fire extinguishers are depicted in the following Figure -3.

Figure 3: QR Codes.

The benefits that can be obtained from the proposed model design include following:

- Rapid and effortless access to essential information
- Data precision preserved
- Increased precision and decreased errors
- Improved audit preparedness and compliance
- Improved maintenance and inspection scheduling
- Risk reduction and enhanced safety
- Errors are easily identifiable.
- Easily prevent the expiration of the cylinder on time
- To facilitate the communication of the issue to the user department
- Data can be readily surveyed online.

4.1.1 Web Application

A distinct web application is developed for the proposed approach, and the website's operation is user-friendly. The procedure is as follows:

- Access the website or application via the internet
- Provide the appropriate credentials, such as your username and password.
- Access the fire extinguisher portal by logging in.
- The Dashboard, which provides a comprehensive overview of the availability of extinguishers and their respective locations, can be readily accessed from there.
- A user-friendly interface that enables users to readily verify reports, fire extinguisher management details, and check the availability and count of extinguishers. This includes the ability to add or remove extinguishers.

The Dashboard with all available menus and the Login Page of the proposed web application are depicted in the following figures: Figure 4 and Figure 5.

Figure 4: Dashboard.

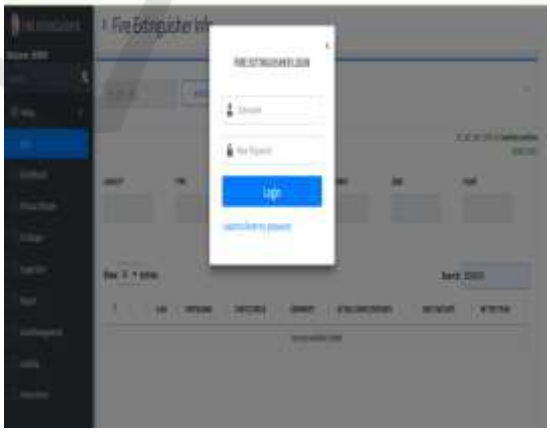

Figure 5: Login Page.

4.1.2 Details of the Fire Extinguisher Menu

Locate the fire extinguisher that was installed in the designated department and verify that it is still pending inspection. This menu is used to address any

overlooked or unresolved complaints, including the number, type, capacity, plant, and location of the fire extinguisher. The master page of the fire extinguisher web application, as well as the availability of the primary menus, is depicted in the following figures: Figure 6, Figure 7, and Figure 8. The subsequent page displays the available options for adding or removing fire extinguishers from the portal.

Figure 6: Master Page.

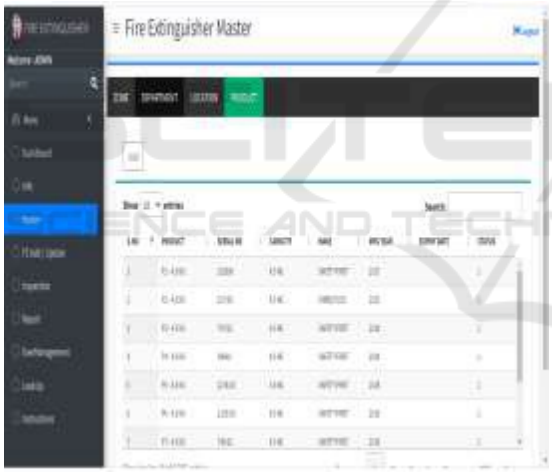

Figure 7: Availability of Main Menus in the Web Page.

Figure 8: Option to Add or Remove the Fire Extinguishers.

4.1.3 Inspection of Fire Extinguishers Prior to and Following Their Use

Before the inspection, we have a card or aluminum identifier that must be punched every three months. Occasionally, the card may be overlooked. In that event, we are faced with the challenge of determining the date and month of the inspection. In the event that a check document is overlooked, the fire extinguisher is not promptly located. Additionally, a manual inspection of the workplace is conducted. Upon completion of the applicable fire extinguisher inspection, it is necessary to affix the QR scanner to each fire extinguisher in order to facilitate inspection and expedite maintenance through inspection scheduling. This will enhance safety and mitigate risks. This is the most straightforward method for identifying the errors. The fire extinguishers before and after inspection views, as well as the Reporter Issue Page view of the proposed web application, are illustrated in the following figures: Figure 9, Figure 10, and Figure 11.

Figure 9: Before Inspection.

Figure 10: After Inspection.

Figure 11: Reporter Issue.

The QR code scanner efficiency of the proposed scheme, IFPS, is illustrated in the accompanying figure, Figure 12. This figure is cross-validated with the conventional detection mechanism, CFCS, to assess the QR code scanner efficiency of the proposed scheme. Table-1 is a descriptive representation of the aforementioned.

Table 1: QR Code Scanner Efficiency Evaluation between IFPS and CFCS.

Iterations	CFCS (%)	IFPS (%)
5	88.52	97.62
9	89.47	97.44
11	85.34	97.28
13	84.27	96.39
15	85.26	97.82
18	84.47	96.34
19	88.45	97.46
21	87.45	97.57
23	85.36	97.37
25	84.52	97.59

The fire extinguisher detection accuracy ratio of the proposed scheme, IFPS, is illustrated in Figure 13. This ratio is cross-validated with the conventional detection mechanism, CFCS, to assess the proposed scheme's accuracy. Table-2 is a descriptive representation of the same.

Figure 12: Analysis of QR Code Scanner Efficiency.

Table 2: Comparison of Accuracy Ratio between IFPS and CFCS.

Iterations	CFCS (%)	IFPS (%)
5	79.19	97.63
9	80.21	97.45
11	81.26	97.34
13	78.17	97.24
15	79.12	98.39
18	79.59	97.63
19	77.23	98.54
21	78.36	97.47
23	79.49	97.53
25	79.01	98.72

Figure 13: Accuracy Analysis.

5 CONCLUSIONS

The pending and completed fire extinguisher status can be readily determined using this QR code scanner method. To reduce the likelihood of fire extinguisher errors and the decal can be affixed to each fire extinguisher. Furthermore, to prevent the creation of review sheet data and in the event of a fire extinguisher malfunction, all individuals are required to utilize a mobile application to access the QR scanner and promptly notify the relevant department. Mail can be received by a fire or safety department, which can promptly replace the fire extinguisher and take corrective action. The implementation of QR code systems also enables improved compliance with safety regulations by guaranteeing that all maintenance and inspection activities are accurately documented and readily accessible. Furthermore, QR codes facilitate real-time communication and updates among safety personnel, thereby improving the overall level of safety preparedness.

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