Original Research Article

Intelligent Fire Detection and Suppression Systems in Compliance with Saudi Civil Defense and Vision 2030

Muhammad Fayyaz[1]*
[1]Kinan International Real Estate Development Company

*Corresponding Author
Muhammad Fayyaz
Kinan International Real Estate
Development Company

Abstract: Saudi Arabia's Vision 2030 initiative is stimulating numerous mega projects, logistics developments, airports, ports, industrial parks, high-density developments with mixed-use high-rise buildings, and large warehousing schemes with an unrelenting pace and scale. Such operation-critical developments have a propensity to cause enormous consequences in the event of fires: human casualties, sizeable losses of material wealth, and significant supply chain disruptions. Not only is the Kingdom of Saudi Arabia increasingly tightening its related compliance regulations, with the Saudi Building Code - particularly SBC 801 Building Code - and Saudi Civil Defense approval processes significantly impacting design and operational processes in Saudi Arabia, but intelligent fire detection and suppression systems incorporating multi-criteria detectors, video analytics, IoT monitoring, and data-driven maintenance-considering technologies of particular advanced scale and design as the next technology layer of protection. This paper synthesizes related literature on intelligent fire detection and fusion technologies and intelligent fire suppression integration and coordination technologies and technologies pertaining to Vision 2030 developments in the Kingdom of Saudi Arabia and Saudi Arabia-related requirements and directly translates the synthesized intelligence into Saudi Arabia-specific compliance by design requirements and processes from 2020 to 2025 and specifically translates intelligence into PRISMA-related requirements and suggests and reveals methodology - including PRISMA-related technology taxonomy and compliance by design - and implementation process and matrix for logistics and Vision 2030 developments.

Keywords: Saudi Civil Defense, Saudi Building Code, SBC 801, NFPA, ISO 7240, Intelligent Fire Detection, IoT Supervision, Edge AI, video Analytics, Multi-Sensor Fusion, Suppression Coordination, Vision 2030, Logistics Infrastructure.

1. INTRODUCTION

As said earlier in the essay on the background of the Vision 2030 program, the program is drastically transforming the infrastructure in the Kingdom at a speed and scale that the Kingdom has never seen before. Some of the programs include supply chain facilitation such as port, airport, inland logistics parks, and electronic-commerce facilities; tourism and entertainment such as the development of high occupancy facilities and environments; and diverse industry programs such as growing areas industry facilities like manufacturing factories, data centers, utilities, and many similar ones. In all the above-mentioned facilities and areas, as with many other similar fields and places, there can be no disruption whatsoever in order to maintain the fire

safety as a 'back office' since it is of immense importance and value in terms of proper continuation with minimal disruption in the process of supply chaining with insurance and trust. As repeatedly mentioned above in the context of Vision 2030, fire safety will always be at the focus of everything to do with life safety with proper and traditional ways of implementing fire safety in the right and perfect manner with perfect engineering, fitting, and maintenance. Next only to lack of funds in such ventures and studies in any field of choice and importance, proper detection times in fire safety and in many other fields and places of choice and importance can be of immense value in many ways in life in general. As with many other similar studies and places of choice and importance, proper detection times in the filed of fire safety provoke problems with every investigation and study as with every other place of choice and importance except detection times in fire safety in the context of Vision 2030 in general. As studied in the investigation and study carried out very recently with respect to this field of choice and importance in the context of Vision 2030 in general, there are many adequate and proper solutions under the title of 'intelligent detection.' More specifically, for Saudi Arabia, the promotion and control of IF technologies can be understood by observing the regulations developed for the country. The regulations can be summarized based on two main pillars. One of these pillars is the "Saudi Building Code"; matters falling under SBC 801 "Saudi Fire Protection Code" concerning detection, alarm, suppression, smoke control, egress, and many others, relating to design, installation, and documentation of IF technologies, among others, in the country. The second pillar lies in the issue of "Saudi Civil Defense Regulations" concerning inspection as well as the issuance of the necessary approvals for ensuring that any given IF technology meets the criteria of these regulations concerning the usage of "certified" products as well as engineering firms. The efforts of "Vision 2030" are geared towards the promotion of the uptake of data and AI technologies. The particular topics which this review, however, will be aimed at covering will be those that pertain to some form of intersection with intelligent fire technologies, while also covering related compliance issues that are particular to Saudi Arabia. Some particular questions that this review will be aimed at answering are: What form of intelligent fire technologies have been able to offer some form of benefit via the particular research studies that have focused on implementations up until 2020-2025? What form of intelligent fire coordination is able to offer some form of improvement to the capabilities pertaining to suppression? And how are government, testing, cybersecurity, and change control features able to offer improvements to this particular field, while also ensuring that it does not impede life safety within particular regulated environments that the implementations will be happening within.

2. Background: Saudi Arabia, Compliance and Standards
2.1 Saudi Building Code and SBC 801 SBC 801
Also includes the Saudi fire protection code, and basically, it has information regarding fire prevention, fire protection systems, life safety issues, and access of fire fighting forces within buildings. Concerning the implication of SBC 801 regarding the designing of the teams, innovation has to be correlated with the intention. It is possible to utilize intelligent analytics for innovation to detect and act upon detection; however, it is not possible to utilize intelligent analytics to ignore the necessity of initiating devices and is also not applicable to innovation for replacement of fire extinguisher devices. As a whole, generally, most of the designing work carried out is related to a combination of the SBC 801 code and general best practices globally that are internationally recognized and quoted globally around the world, (such as referencing NFPA publications related to fire alarms and sprinklers, ISO 7240 publications related to fire alarm components and testing philosophies and approaches) [9-12].

2.2 Civil Defense Approvals and Sector Rules
With regard to the approvals taking place for the Civil Defense, it is also anticipated that there is a level of compliance with respect to different stages such as fire strategies, drawings, calculations, along with the results obtained from the same. For example, with respect to some of the translated national regulations or guidelines as per the requirements for safety and protection of lives and properties, it has been mandated that buildings for specific populations should contain Automatic Fire Alarm Systems where there exists a necessity for the installation of heat and smoke detectors. In addition to this, for those buildings where there are higher populations, the necessity for the installation of Automatic Fire Alarm Systems and, along with this, the necessity for the installation of sprinklers also exists. As has been noted with regard to this document, "it is also important to note compliance with Saudi Standards and carry out and maintain it through authorized bodies" [6]. Furthermore, with respect to the different manual guidelines noting the different operations of the industry, with respect to different aspects of the industry, the operations along with the requirements and authority existing for the operations of the industry, such as to ensure that exit routes are clear, the pumps are prepared for operation, along with authority to stop the different operations of industry, among others [7-13]. The overall result being the establishment and maintenance of compliance with respect to a single stage of the building lifecycle with all other stages,

many of which are also very intricately linked to one another with respect to how they are examined.

2.3 Vision 2030 and Digital Transformation Drivers

Some of the programs include quality of life, safety, quality of services, and livability of urban areas, among others. The quality of life program for 2021-2025 has emphasized the importance of intelligent systems for services and smart cities for connected safety systems [14]. The National Strategy for Data and AI (NSDAI) has placed the concept of scaling up its data and AI applications as core to its concept of economic change, with a foreseen buildup in governance and capacity for achieving it [8]. In relation to fire safety, it seems that, for leveraging data-based supervisions for reduction in impairment time, analytics for faster verification, and data twins for securing compliancy, there has been an identified chance that has resulted in a number of conflicts, especially regarding challenges for ensuring that the intelligent system is auditable, that it is secure, and that life safety is no longer reliant on experimental analytics.

3. Aim, Objectives, and Research Questions

Aim

Extensively peruse the literature on Intelligent Fire Detection and Suppression Systems from 2020 to 2025, then develop a framework to align the system with the requirements set forth in SBC 801, along with the Civil Defense orders provided through Vision 2030.

Goals

O1: Intelligent detection modality types (sensor-based, vision-based, and hybrid) should be classified and information about each should be summarized based on its performance, especially concerning false alarm control/detection latency.
O2: Review intelligent suppression Intelligent suppression and coordination measures: supervision and preparedness monitoring, decision support, and connection to smoke control and evacuation.
O3: Describe architecture patterns such as Edge AI, Cloud Analytics, Digital Twin, and BMS integration, which are to be utilized in the regulated safety-critical deployment.
O4: The abilities of IFDSS would be matched with Saudi compliance in areas of Design, Commissioning, ITM, and Operational Governance.
O5: Defining a research agenda that is most relevant within the context of Saudi Arabia, with respect to issues dealing with logistics and on matters concerning large-scale projects.

Research Questions

RQ1: Which of the intelligent detection techniques clearly indicate improvement in comparison to traditional techniques in the studies carried out for 2020-2025?
RQ2: What is the effect of intelligent systems on suppression readiness, coordinating incidents, and recovery?
RQ3: What is needed in validation, reliability, security, and governance in order for the implementation of CBG adoption in Saudi Arabia to be successful?

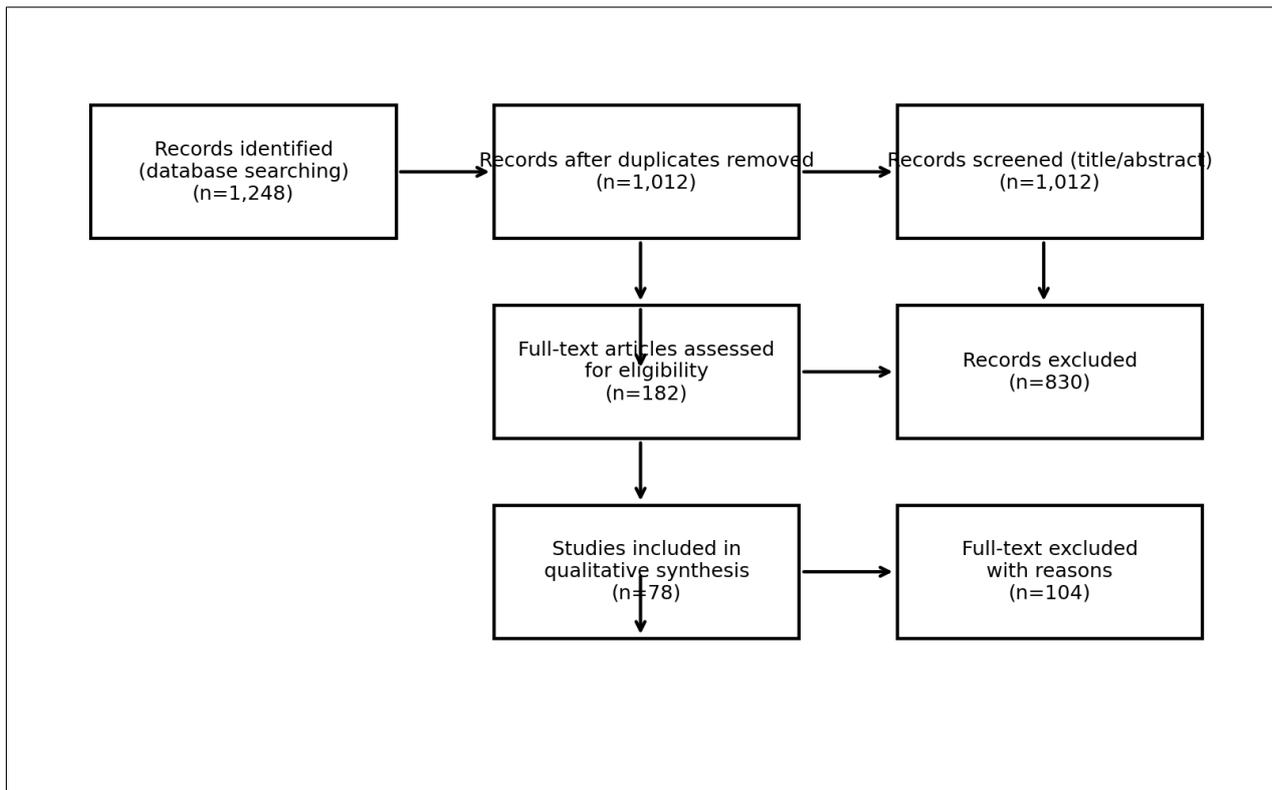## 4. Method the Paper is Informed by a Thematic Structured Review Method

Given that it has to be applied within a literature review format, which is normal within articles published in Scopus journals, as is the case with publications related to subjects like engineering and logistics, as well as informed by PRISMA, which stands for Protocol for systematic Reviews and meta-analyses concerning structured review methods.

4.1 Criteria Used to Select Relevant Articles:

The criteria used in selecting relevant articles include: (i) journal/conference papers published from 2020 to 2025: peer-review articles, (ii) standardization guide: official standardization, published from 2020 to 2025, covering fire detection, alarm system, fire suppression system, and AI governance, (iii) journal/conference papers published from 2020 to 2025: related to fire/smoke/flame, sensor fusion, IoT, edge computing, fire suppression system, coordination, and analysis, (iv) journal/conference papers published from 2020 to 2025: offering measurable results, with decision-making results such as delay and false alarm rate. On the other hand, articles to be excluded include: (i) journal/conference papers published before 2020, (ii) opinion articles/journal/conference papers related to fire but without sufficient methods, (iii) journal/conference papers published before 2020 without sufficient information, (iv) articles related to wildfires, with exceptions concerning buildings, constraints, and edge-based deployment.

4.2 Description of Search Strategies Used in Review:

The article makes use of different search strategies, which are: fire, smoke, flame, multi-criteria, ASD, beam, deep, yo-lo, YOLO, temporal, fusion, fire suppression system, sprinkler, supervision, terrorism, IoT, supervision, BMS, and many other connectivity, analytic, and suppression system-related terms. There are also different locations, as suggested by the likes of Scopus/Q1. Furthermore, many filters are applied, with three different sets of filtering approaches. The filters include title, abstract, full text, and eligibility validation.

```
┌─────────────────────┐      ┌──────────────────────────┐      ┌──────────────────────────┐
│ Records identified  │      │ Records after duplicates │      │ Records screened         │
│ (database searching)│─────▶│ removed                  │─────▶│ (title/abstract)         │
│ (n=1,248)           │      │ (n=1,012)                │      │ (n=1,012)                │
└─────────────────────┘      └──────────────────────────┘      └──────────────────────────┘
                                          │                                  │
                                          ▼                                  ▼
                             ┌──────────────────────────┐      ┌──────────────────────────┐
                             │ Full-text articles       │      │ Records excluded         │
                             │ assessed for eligibility │─────▶│ (n=830)                  │
                             │ (n=182)                  │      │                          │
                             └──────────────────────────┘      └──────────────────────────┘
                                          │
                                          ▼
                             ┌──────────────────────────┐      ┌──────────────────────────┐
                             │ Studies included in      │      │ Full-text excluded       │
                             │ qualitative synthesis    │─────▶│ with reasons             │
                             │ (n=78)                   │      │ (n=104)                  │
                             └──────────────────────────┘      └──────────────────────────┘
```

4.3 Methods Used to Compile Results

The quality of each above-deployed fire assessment was evaluated in terms of each system's evaluation. There was rigorous validation concerning journal/conference papers published, with some potential for narrative and thematic, through technology taxonomy and compliance, with validation being emphasized while discussing journal/conference papers with conflicting results.

5. Technology Taxonomy for Intelligent Detection
5.1 Multi-Criteria Detection and Smarter Initiating Devices

The majority of the compliant Saudi Arabian systems are expected to use code-recognized initiating devices that range from smoke or heat, flames, or the use of manual call points. It is important to note that the devices that are multi-criteria are those with intelligence, whereby devices are related to those with the detection ability of smoke, heat, or CO; additionally, there is the use of signal processing to ensure that no alarms are false. Other improvements may also be related to detection speed, as hghlighted by research that sought to use multi-sensor fire alarm devices whereby there is the use of fire devices with the capacity to carry out analysis of temperatures as well as humidity to control false alarms effectively. The improvement may be small, but it may also be significant, especially of a controlled environment from a perspective that builds a level of confidence but instead seeks to control unwarranted business activity. The perspective of what may be of most importance is

related to the fact that the devices installed are acknowledged as a 'listed product' just like those related to commissioning and ITM testing.

5.2 Aspirating & Line-Type Detection for Large Volume & High Value Assets

Aspirating Smoke Detector (ASD) and Line Type Beam Detectors are applicable for large open areas, data centers, and atrium areas. The areas for the development of the intelligence focus are the areas which are being considered by the multi-life cycle design. These areas are predictive maintenance for contaminants, blockages, and drift, and analytics which operate by combining results from the Aspirating Smoke Detector, air flow, and air conditioning context to understand and interpret the signature of the smoke. The performance test method standard for Line Type Detector/Multi Sensor Detector references the ISO 7240 standard, which could be referenced for justifying the design. Considering an environment which must take the Middle East into account they have a lot of dust and sand. The maintenance plan is a first-order factor for the design.

5.3: Vision-Based Fire and Smoke Detection

The field that is related to video-based detection, particularly related to fire and smoke, has undergone tremendous changes and growth from 2020 to 2025. In the year 2024, a research based on a literature review has been conducted and published by the researcher, along with a review of more than 130 publications related to the field of literature, so

that it can be proposed, keeping in view the importance of conditions and covers [1]. Along with this, research work has also been conducted related to developing model pipes, so that detection for flames and smoke can be made, particularly in different forms, and then implementation for the application is worked upon. When it comes to the detection of smoke plume/flame flicker for using models by employing deep learning algorithms, it has been witnessed that detection is performed before observations take place, particularly at such locations where detection is performed due to large volumes of smoke, particularly when the phenomenon related to the stratification of smoke becomes common and cannot reach fast enough towards detectors that were fixed on the top of structures. Some of the challenges that have become prominent, keeping in view the implementation of such models or activities related to these models toward detection include the phenomenon related to false alarms and challenges related to these alarms. In order to keep the necessary requirements particularly related to a specific geography, such as Saudi Arabia, it has been proposed that vision systems can be used secondarily.

5.4 Multi-Sensor Fusion as the Pragmatic Essence of Intelligence

There exists a mix of physical sensors, environment sensors, and even vision signals combined to process this information in order to achieve decision logic with ultimate aims of reducing false alarms and instituting an early warning system. This would be achieved with the use of logic that includes the use of sensors and even probabilities, with some even involving the use of machine learning in the process. There exists also the use of indicating information acquired from different sensors in an attempt to efficiently compute information to facilitate the computation of the decision with efficiency in mind in order to achieve the intention of detecting fire in an indoor environment, which had the objective of ensuring maximum accuracy, as recommended in an article published in 2023 by Sensors [17]. There exists an alternative option recommended in an article published in 2022 by Elsevier aimed at ensuring efficiency within an early warning system with the use of an intelligent system to enhance security in buildings with the use of forecasting and other factors considered in building security systems [18]. However, in order for the fusion logic implementation to be relevant to a regulated environment, a degree of determinism needs to be achieved through the logic, and then a basis for the alarms sequence as a result of the various devices and matrices that are itemized. Most often, the possibility exists for fusion analytics to assist with the scoring of this type of response.

5.5 Environmental Robustness as a Design Requirement

In addition, the environment in Saudi Arabia is most likely to provide a testing environment for these detectors. It is noteworthy that a high level of intelligence is needed for the particular detectors, such that they consider the environment in their analysis, hence using it as a basis for their decisions. Where the environment is high as a result of an increase in the level of dust, the system will fail, thereby indicating its confidence level. There is a possibility of having a multi-criteria carbon oxide level detector, heat level, smoke, etc. [15-17]. Video analysis should include consideration of lens cleaning, sun shades, as well as re-validation through analysis of previously created scenarios.

6. Intelligent Suppression and Control
6.1 Water-Based Systems:

Readiness Supervision and Analytics Automatic sprinkles are as central today as they ever have been to all fire safety initiatives and plans and strategies in the warehouse environment. The first piece of intelligence regarding the overall application and benefits of intelligence in the short term was and would be and remain the area of Supervisory Control, or, in other words, always maintaining a keen eye on valve conditions, water pressures, rates, pump on/off conditions, and tank levels. The singular and definitive standard on which one can and would safely rely and depend is included in and can and would be found throughout the standards on which one should rely and depend in the design and implementation of fire sprinkler systems, with a very clear and precise delineation of the legal requirements as articulated in the Saudi code and necessary to ensure compliance in the building with the requirements and regulations of the Civil Defense and to additionally ensure that the system is "operational and under the control of qualified entities." Data analysis feasibilities might also identify certainly impaired conditions before it is too late, as in the way of example, "trend" analysis might identify pump running conditions or pressures due to possibly leak-prone issues.

6.2 Fire Suppression System Materials and Their Functional Application
Include:
- Pipe materials: Black steel, galvanized steel, stainless steel, CPVC, HDPE as applicable
- Valve materials: Brass, bronze, ductile iron
- Materials for sprinkler heads: Brass, chrome-plated, corrosion-resistant coated sprinklers
- Tank materials: Steel, GRP/FRP as applicable
- Pump materials: Cast iron, bronze fitted, stainless steel
- Materials for agent cylinders: High-strength steel cylinders for clean agent systems

- Materials for nozzle: Brass/stainless steel as applicable

6.3 Selection of Suppression System Type by Area and Functionality

Area / Occupancy	Recommended Suppression Type	Typical Materials	Functionality
General warehouse	Wet pipe sprinkler	Black steel pipe, ductile iron valves, standard sprinklers	Fast automatic suppression for ordinary storage
High-bay warehouse	ESFR / in-rack sprinklers	Black steel / galvanized pipe, listed heads	Rapid suppression for high-challenge storage
Data center / electrical room	Clean agent	Steel cylinders, SS/brass nozzles	Fire suppression without water damage
Kitchen	Wet chemical	Stainless steel piping/nozzles	Suppresses grease fires, prevents re-ignition
Fuel storage / hazardous liquid area	Foam system	Compatible steel pipe, foam chambers/nozzles	Vapor suppression and surface fire control
Atrium / special spaces	Water mist / deluge where justified	SS tubing/nozzles	Fine water discharge, area-specific protection
Cold storage	Dry pipe / pre-action	Galvanized/steel pipe	Prevents freezing and accidental discharge

7. Architectures for Saudi-Ready Intelligent Systems

7.1 Layered Architecture: Certified Cores plus Intelligent Overlays

The most compliance-compatible architecture is a layered architecture. The components of this architecture involve a life safety core, which includes the listed detectors, panels, notification appliances, and suppression releasing logic, and is designed to be code and authority-approved. The intelligent overlay has edge gateways and analytics that, in turn, are concerned with subscribing to the events from the sensors and the video, but for the purpose of creating the advisory responses, including the probable location, confidence, and contexts of the incidents.

7.2 Edge AI for Latency and Resilience

Edge computing assists in latency reduction and minimizing dependence on wide area networks. Based on studies done around the applicability of running models on hardware with limited capability and running them on real-time streams, as mentioned in [2-16], Edge enhances the performance by improving the outcomes at the edges and during partial network outages. In relation to the issue of SA compliance, the segments created by the Edge Layer assist in monitoring segments operating on secure networks and authentic usage of the protocol for improved health checking.

7.3 Cloud Analytics, Fleet Management, and Digital Twins

Cloud-based platforms are vital in the analysis of multiple sites, which includes false alarms, contaminations, pump run hours, and impairments. Additionally, digital twin technology offers an opportunity to carry out a liaison between intent, design, and operational realities after including factors such as building geometry, HVAC zones, sprinklers, evacuations, and many more. In large projects, for example, digital twin technology is vital in meeting the training, scenarios, and report generation requirements. The main idea, however, is that after using cloud-based platform analytics, it should not replace the local decision-making process.

8. Evidence Synthesis: What 2020-2025 Studies

8.1 While Detection Performance Increases can be verified

They tend to be Results from recent reviews reveal that techniques such as deep learning and sensor fusion enable better detection results in terms of precision and latency for video feed detection than other vision-based heuristics [1-3]. However, generalization is still a problem in this area. The reviewed literature suggests that studies carried out on insufficient resources may produce varying results in different lighting conditions, angle changes, dusty environments, or industrial steam conditions. Hence, quality literature emphasizes the usage of temporal modeling approaches and scene datasets in improving this area [1-18]. In the case of Saudi Arabian logistics areas, "false alarm economics" is a serious issue. False alarm issues often bring about halting of conveyors, halting of entire systems, or even evacuations. According to the literature on this area, improvement is also required in terms of the reduction of nuisance conditions as well.

8.2 Multi-Sensor Approaches Reduce Nuisance Risk

Inside, the benefits related to the usage of EARWS, through the combination of the capabilities of smoke, temperature, and other sensors, can be obtained through operational experience via the utilization of cross-zoning detection techniques. The same can be done by incorporating logical

techniques, which are known to be effective. Intelligent analytics can be utilized to enhance the mentioned techniques depending on their ability to make use of increased context information and their trend detection capabilities. ISO-7240 standard is applicable to the component performance and requirements of multi-sensor detectors.

8.3 Supervision and Maintenance Intelligence Generates Immediate Values

A general thread that has been common is that the fire detection performance has a dependence on both maintenance and impairment. It is also possible that it can, with intelligent supervision, identify issues that may be experienced regarding devices that are impaired, drifting, contaminated, and networked before they are addressed appropriately. Further, it can be used to perform predictive maintenance, especially when the operation of the logistic hub is limited in terms of the 24/7 concept. This has to do with governance qualification and readiness [6, 7].

8.4 Suppression Intelligence is best in Readiness, not Adaptive Discharge

Adaptation studies are also carried out for suppression and decision-making. However, the rules regarding buildings, in most cases, require the application of deterministic activation logic for the suppression system. The readiness supervision, localization, and analytics, which follow the procedure, are very practical pieces of intelligence that require appropriate application.

8.5 Explainability and Inspection Acceptance

However, as far as it concerns accepting authority, for intelligent systems, it should be "explainable and auditable." Therefore, it can be noted that explainability for intelligent systems would necessitate that there is a storage requirement for storing snapshots or clips together with alerts to display where the region of interest is for intelligent systems to be validated by the operator. Additionally, it would necessitate a storage requirement for storing confidence scores and thresholds. In point of fact, within the literature, it seems that there is a consensus and agreement that explainability is not even an option but is part of the assurance itself.

9. Compliance by Design Framework for Saudi Arabia

Table 1: Compliance-by-design mapping for intelligent functions in Saudi projects (SBC 801 + Civil Defense)

Lifecycle stage	Compliance need (Saudi context)	Intelligent function	Evidence / standards anchor (2020–2025)	Implementation notes (fail-safe)
Design	Code-required systems and egress provisions defined per SBC 801	Layered design: certified core + advisory overlay	SBC 801-CR-2024 [5]	Overlay does not replace listed initiating devices or suppression.
Design	Sector rules: occupancy thresholds for alarm/sprinklers; Saudi standards (SASO) compliance	Requirements traceability matrix; product approval evidence	National regulation (translated) [6]	Trace requirement → device → test evidence.
Commissioning	Acceptance tests and cause–effect validation	Overlay validation: nuisance scenarios; camera calibration	NFPA 72 (2022) [9]; ISO 7240 (2022–2025) [11–13]	No life-safety outputs from non-certified analytics.
Operations/ITM	Periodic inspection, testing, maintenance; impairment control	Continuous supervision; predictive maintenance; exception reporting	CSL Guidance v12 (2021) [7]	Change control for software/model updates; staged validation.
Incident response	Rapid verification and coordinated actions	Advisory localization; SOP checklists; incident logging	Elsevier review + edge deployments [1–2]	Separate advisory alerts from certified alarm states.
Governance	Cybersecurity and auditability for connected systems	Secure logging; access control; segmented networks	NSDAI (2020) [8]	If overlay is compromised, isolate it; certified core continues.

"Compliance by design" takes a functional approach to regulations, with technology as the enabling factor. The framework of emerge is built upon four pillars, which include: i) preservation of certified life safety areas of buildings, ii) validation of intelligent layers within nuisance situations, iii) maintaining strict change control, and iv) auditability.

9.1 Design Phase Requirements

In terms of the usage, it is vital to describe the compliant base, which is defined as per SBC 801 and Civil Defense. The occupancy is also significant in terms of usage to determine technologized system technology. The requirements demand that each component shall feature confirmation, localization, situation awareness, supervision during maintenance, and compliance verification. It is also vital that these documents feature required definitions with regards to code required functions, like separate definitions, which are also safe in case of failure. At this point, the requirements concerning the purchase specification must also carefully consider approvals, cyber security, and maintenance, with regards to Saudi Arabia's demands [6, 7].

9.2 Commissioning and Acceptance Testing

The tests shall be conducted through traditional and intelligent overlay tests. In this case, traditional tests involve tests on devices, tests through cause and effect, tests on pumps, flow tests, and tests on audibility/visibility. There are tests to be conducted through intelligent tests, which include tests on camera calibration, intelligent tests on baselines, tests on nuisance through steam, dust, and tests on nuisances through glare. There are also tests to be conducted through drills to ensure tests on advisories of alarms do not affect results from tests on certified sequences.

9.3 Operations, ITM, and Change Control

There is also a requirement to conduct ITMs in Saudi Arabia, which should be done in periodic intervals. Regarding this, intelligent system management can also be implemented to optimize these tests. Firstly, it aids in fostering nonstop supervision. Furthermore, there are also checklist implementations through intelligent system management. Nevertheless, it is also vital to note that even with these demerits, it has to be implemented through software to generate such behavior. When it is upgraded, there is also evolution in the process. In this case, these processes have to be monitored. That implies re-validation. Concerning the operations organization, it shall have an 'AI Safety File' wherein a list of datasets shall be applied.

9.4 Performance Metrics Aligned to Operations

Moreover, words like accuracy, mAP, etc., are utilized in academia. This is not applicable in operations. The parameters that are applicable in Saudi Arabia are false alarm rates per month, time to verification, time to first action, impairment duration, and restoration time. Tests on intelligent overlays shall also be included.

9.5 Training, Competency, and Documentation for Regulated Operations

The intelligent overlay changes the skill set that's required by facility staff. The staff must be capable of analyzing the overlaid advisory alert, distinguishing this from certified alarm states, and utilizing application procedures that facilitate life safety. For a facility's maintenance staff, there is a skill set needed to clean cameras, sensors, networks, security infrastructures, etc. There is also a level of documentation that is needed if the facility is going to maintain approval level compliance. As a recommendation, it is advisable to construct scenarios that help with this, such as building a master cause and effect, schedules pertaining to camera/device locations, building a configuration baseline pertinent to analytics, etc. There could be a problem with staff changes, particularly within a logistic environment, but this ensures that staff changes do not cause any lapses that may eventually lead to a compromising level of compliance.

10. DISCUSSION: IMPLICATIONS FOR LOGISTICS AND VISION 2030 MEGA-PROJECTS

There are certain risk profiles related to the infrastructure and/or projects of logistics as well, which include fire loads related to packages in general, plastics used, traveling distances in general, heights of ceilings in general, and/or levels of automation in general. AI video analytics is viewed as particularly applicable to high bay environments with particular relevance to smoke layering effects. It is acknowledged that the ultimate best practice related to a cohesive intelligent safety system would include technologies related to detection/alarm technologies code compliance via control panels, followed by design and/or selection of suppression systems related to hazards used, and finally an intelligent system related to camera technologies, environmental data sensors, and/or other system supervision data used in an integrated operator information system. There are some practical scenarios that can be used to illustrate the understanding of such a definition. For a warehouse aisle ignition, it is possible to see faint smoke plumes approaching from the ceiling, where points are not above alarm level, with cameras. The overlay system can send early warning messages with possible

locations in the aisle, where supervisors can investigate and see sprinkler systems at work. For battery charging scenarios, there may be a stage following from a power anomaly detection process with pre-approved shutdowns before investigation. For areas such as concert halls, there is something called event mode, which can lower false alarm rates with the addition of a verification step. However, there needs to be a restriction, period, and requirement for audibility in this case, lest it is misused to block alarm.

11. Implementation Roadmap for Saudi Arabia Projects

The process for implementation of "Saudi Ready" can be divided into five parts. The first part is to develop a compliant baseline design according to SBC 801 and sector needs, which include system boundaries and definitions for cause and effect. The second part is to identify intelligent overlays that "enhance, rather than replace," functions that have already been certified. The improved functions include "video analytics for situation awareness, supervisory analytics for asset maintenance, and dashboards for reporting." The third part is developing an operational governance scheme that covers cybersecurity segmentation, access, maintenance, and an "AI Safety File." The fourth part is to validate an operational scheme through nuisance scenarios and joint drills with facilities personnel. The fifth is operationalization, where it includes "KPIs aligned to Compliance and Business Continuity," through "Continuous Supervision" that aims for a minimum "impairment time and false alarms."

12. Research agenda informed by Available Evidence up to 2020

R1: Custom datasets for Saudi Arabia: Design multi-modal datasets that can represent scenes which are associated with dust, sand storms, glare, steam from industrial sites, and low light scenes in warehouses. Similarly, design specific validation protocols for logistics scenarios.

R2: Methodologies for Building Safety Cases for AI Overlay: A set of safety case structures is proposed to cover safety concerns, mitigations, test outcomes, and safe failures.

R3: Interoperability

Define Security Integration Profiles for fire panels, BMSs, video platforms, and digital twins.

R4: Cyber-Physical Resilience Metrics: Measure how outages, cyber events, and sensor degradation impact detection latency and nuisance, as well as design fallback behavior.

R5: Readiness and Restoration Optimization: In this case, it would be important through analytics to improve readiness and restoration as well as the quality of compliance evidence, and at the same time

ensure that the suppression activation is code compliant and deterministic.

Updated R1 12.1 Limitations of the Evidence Base As this review has a narrow scope to draw upon considering the diversity of research conducted and published between the years 2020 and 2025, there is the fact that a number of papers conducting analysis on the efficacy of AI-based detecting fire systems use data that contains few nuisance sources that one might actually expect to encounter, such as welding arc, steam, dust, headlight from a forklift, sun reflection, and stage effects. In fact, there is a greater number of laboratory-based testing and analysis of the results than there is actual fieldwork within a populated space regarding false rate alarms over a substantial period of time. Furthermore, there are a number of reasons why it is best to consider this process as more of a general guide than a strict set of best practices and why it is best to deal directly with authorities regarding the matter. These can be found within the fact that code requirements tend to change over a number of years and can vary considerably within the nation of Saudi Arabia. 12.2 Implications for logistics performance and continuity From a logistics standpoint, the issue of fire safety can be related to other aspects of continuity of operations. "Downtime can propagate through the availability of inventory, transportation schedules, and customer service levels promised." Intelligent overlays can be vital tools in reducing the "time to certainty," what this term means being the period of time that transpires between first noticing that trouble has begun to develop and being sure that something needs to be done. "If done right, this can potentially reduce unwarranted evacuation due to nuisance alarms and can speed resolution and recovery from legitimate alarms, reducing localization of trouble and reporting alarms, and restoring facilities more quickly than before." To the users, what would be the most important areas for justifying the investment for them would be the areas which could be measured and maximized: business downtime reduction, reducing insurance costs, increasing auditability, and increasing the confidence of the workforces would be critical to attaining excellence goals outlined by Vision 2030. 13. Con Advanced technologies in detecting and suppressing fires may help make Saudi Arabia's increasingly popular and expanding infrastructure for logistically heavy projects an even safer place by helping prevent, detect, and deal effectively with fires. According to 2020-2025 discourse on the matter, the safest way to make this happen is by employing safe-guarded certified safety cores and adding explainable intelligent function overlays which may be engineered to possess unique characteristics for safe failure. To satisfy SBC 801 and Civil Defense certification requirements for such Saudi Arabian

projects, safe-guarded role definitions, deterministic matrices of cause and effect, methodologies for change control, and audit trails must be part of the intelligent system's design process. Advanced intelligent fire safety systems in Saudi Arabia help to satisfy the goals outlined by Vision 2030 by providing safe life, safe business, and utmost confidence in the safety and integrity of Saudi Arabian projects about to be launched into the Internet of Things infrastructure revolution. Future work to be conducted in the field should focus on Saudi Arabian field trials in areas of logistics, venues, and utilities.

REFERENCES

1. Gragnaniello, D., et al. Fire and smoke detection from videos: A literature review. Expert Systems with Applications, 2024. (Elsevier).
2. Chan, Y.W., et al. Flame and smoke detection using Kafka on edge devices. (Elsevier), 2024.
3. Elhanashi, A. Early Fire and Smoke Detection Using Deep Learning: A Comprehensive Review of Models, Datasets and Challenges. Applied Sciences, 2025. (MDPI).
4. Amjad, A., et al. Dynamic fire and smoke detection module with enhanced multi-sensor fusion. Pattern Analysis and Applications, 2025. (Springer).
5. Saudi Building Code (SBC). SBC 801—Code Requirements (SBC801_CR_241224-FA). 2024.
6. National Center for Archives and Records (KSA). Regulation of Safety & Protection Requirements (translated). 2021.
7. CSL. Guidance for Best Practices in Fire Protection "Do"s & "Don't"s, Version 12. 2021.
8. SDAIA. National Strategy for Data & AI (NSDAI) – "Realizing Our Best Tomorrow". 2020.
9. NFPA. NFPA 72: National Fire Alarm and Signaling Code, 2022 edition. 2022.
10. NFPA. NFPA 13: Standard for the Installation of Sprinkler Systems, 2022 edition. 2022.
11. ISO. ISO 7240-12: Fire detection and alarm systems—Line-type smoke detectors. 2022.
12. ISO. ISO 7240-9: Fire detection and alarm systems—Catalogue of test fires. 2022.
13. ISO. ISO 7240-1: Fire detection and alarm systems—General and definitions. 2025.
14. Vision 2030. Quality of Life Program Delivery Plan 2021–2025. 2021.
15. Choi, W., et al. Multi-Sensor Photoelectric Fire Alarm Device with Dynamic Thresholding. Applied Sciences, 2024. (MDPI).
16. Deshpande, U.U., et al. Real-time fire and smoke detection system for diverse critical scenarios. Frontiers in Computer Science, 2025.
17. Deng, X., et al. An Indoor Fire Detection Method Based on Vision and Multi-Sensor Information. Sensors, 2023. (MDPI).
18. Huang, P., et al. A combined real-time intelligent fire detection and forecasting framework for building fire safety. Process Safety and Environmental Protection, 2022. (Elsevier).
19. Morchid, A., et al. Integrated IoT solutions for early fire detection: architecture and evaluation. Smart Agricultural Technology, 2024. (Elsevier).
20. Yang, S., et al. Advancements in remote sensing for active fire detection: a critical review. Science of the Total Environment, 2024. (Elsevier).
21. Zhuang, Y., et al. A multi-sensor based fire detection technique (BP neural networks + fuzzification). ACM, 2025.
22. [Jia, Y., et al. A Fire Detection Model Based on Vision and Multi-Sensor Data (multi-source dataset). ACM, 2024.
23. ISO. ISO 7240-31: Multi-sensor point fire detectors (smoke + CO + optional heat). 2022.
24. Sharobiddinov, D., et al. Edge-based autonomous fire and smoke detection using lightweight CNNs. Sensors, 2025.
25. Panahi, F.H., et al. A reinforcement learning-based fire warning and suppression system using UAVs. 2023.
26. Lexis Middle East. Saudi Arabia: Fire protection companies must implement new Civil Defence controls. 2022.
27. SDAIA. National Strategy for Data & AI web briefing (official strategy page). 2023.
28. Saudi Building Code Authority. SBC portal and SBC 801 publication listings. 2024.
29. ISO. ISO 7240-1:2025 entry (official ISO catalog). 2025.
30. ISO. ISO 7240-12:2022 entry (official ISO catalog). 2022.