

Mapping Sensor Technologies and Fire Safety Data for Smart Firefighting



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Briab
The right side of risk



Summary

The work presented within this report is a part of the project "Utilization of Innovative Digital Tools for Efficient and Smart Fire Fighting". The project is financed by Vinnova and has been performed in collaboration with the division of fire safety engineering and Lund University.

The objectives of the project were to identify relevant sensors and data types, assessing their reliability and usability in real-time decision-making and predictive simulations to enhance the effectiveness and safety of fire and rescue operations. The project also aims to recommend sensors and a way forward within the area of Smart Firefighting.

To be able to do so a literature review, stakeholder interviews, a case study at the World Trade Center in Lund, and an inventory of sensors within buildings and sensors brought to the fire scene by the fire and rescue service were conducted.

The result showed that many modern buildings are equipped with numerous sensors within systems such as ventilation systems, security installations and fire alarms. Developments in sensor technology have also led to a significant increase in the range of portable sensors that the fire and rescue services can take with them to a fire scene.

Within the report identified sensors were categorized into four groups: those monitoring fire development (e.g., temperature, smoke, gas), those monitoring the status of fire protection systems (e.g., sprinklers, door status), those who monitor indoor environmental conditions (e.g., smoke spread, occupancy) and those monitoring the operational capability of fire services (e.g., wearable equipment, drones).

The result also showed that there are several challenges to fully utilize the possibilities when it comes to usage of the data that the sensors provide. These challenges include limited real-time data access, lack of technical standards, uncertainty in sensor performance under fire conditions, and concerns over data ownership and privacy.

Based upon the work conducted, the conclusions were that there are obstacles to overcome but also great potential to integrate sensor data into firefighting operations. Predictive simulations could potentially be used to generate data for decision support and the following sensor types were identified as especially relevant for providing input to such simulations:

- Temperature sensors in ventilation or fire alarms for real-time temperature monitoring,
- CO/CO₂ and VOC sensors for air quality and early combustion,
- Door position sensors for compartmentalization and spread modeling,
- Sprinkler flow and activation switches indicating activated systems,
- Thermal and optical cameras for scene analysis and verification.

Information from sensors that the fire and rescue services bring to the site is more suitable to be interpreted directly by the firefighters at the scene or in an incident and command center.



The fastest and easiest way forward to achieve improved conditions for the fire and rescue services was deemed to be:

- improving access to fire alarm data,
- enabling remote access to analyzed sensor data,
- integrating sensor data with digital twins,
- and fostering national standards and collaboration among stakeholders.



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1. Introduction

Fire safety is crucial in protecting lives, property, and the environment, as fires in buildings continue to pose significant risks. Modern building environments are increasingly complex, driven by technological advancements, innovative architectural designs, and the extensive use of new materials. These factors often introduce unique fire risks that go beyond the types of fires and fire development that we traditionally are used to. Major incidents such as the Grenfell Tower fire in 2017 underline this (Malagnino et al., 2022; Siddiqui et al., 2021).

The introduction of digital technologies, specifically Building Information Modelling (BIM), Internet of Things (IoT), and digital twins, presents a substantial opportunity to transform the landscape of fire safety. BIM and IoT systems facilitate detailed real-time monitoring and predictive analytics that can significantly enhance fire safety strategies (Bhargav et al., 2018; Lovreglio et al., 2021).

Based on the need to handle more complex fires and technological advances, a new field has emerged under the concept of “Smart Firefighting”. Smart Firefighting leverages these digital tools, enabling fire and rescue services to make informed, real-time decisions by utilizing integrated data systems (Johansson et al., 2024; Malagnino et al., 2022).

This concept is defined by NIST as follows:

Smart Fire Fighting provides a framework to:

- (1) collect and combine large quantities of information from a range of sources,
- (2) process, analyse, and predict using that information; and
- (3) disseminate the results and provide targeted decisions, based on those predictions, to communities, fire departments, ICs, and fire fighters, as appropriate” (Hamins et al., 2015).

However, the adoption of these digital systems within the firefighting and rescue services sectors is currently limited due to challenges such as fragmented data systems, lack of interoperability, and inconsistent standards in sensor technologies and data management (Abrahamsson & Svensson, 2025; Frånberg et al, 2023).

To advance research in this area, Lund University has initiated a research project called **Utilization of Innovative Digital Tools for Efficient and Smart Fire Fighting**. The project is funded by Vinnova and this report constitutes a part of the research project.

1.1. Acknowledgement

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1.2. Problem definition

Despite significant advancements in smart building technologies and digital fire safety systems, there remains a fragmented landscape of sensor technology integration and data utilization within fire safety practices.



Traditional fire safety systems do not adequately support seamless data sharing and interoperability, limiting the potential of advanced real-time monitoring and predictive capabilities essential for effective emergency response strategies. The fire and rescue service often lack timely access to comprehensive, accurate, and structured data, negatively impacting their ability to respond effectively to fire incidents (Abrahamsson & Svensson, 2025; Cowlard et al., 2010; Frånberg et al., 2023).

This fragmentation arises from several critical issues:

- Inconsistent sensor placement and operational ranges, resulting in unreliable data collection (Cowlard et al., 2010),
- Insufficient standardization in digital information management, hindering effective interoperability among various fire safety and emergency response systems (British Standards Institution, 2021; Strömgren et al., 2021a),
- Limited implementation of digital twin technology and IoT integration in building fire safety management systems due to fragmented standards and inadequate digital infrastructure (Bhargav et al., 2018; Volt et al., 2020).

Addressing these gaps is essential to fully realize the benefits of Smart Firefighting and significantly improve fire safety outcomes.

1.3. Goal

Based upon the problem definition above and the overall structure of the research project the goal of this project is to:

- Identify relevant sensors and fire protection data that can be integrated into a “Smart Firefighting” system,
- Assess the types of sensor data that can contribute to predictive modeling and real-time decision support, including but not limited to:
 - Temperature,
 - Gas concentrations (e.g., CO₂ and soot),
 - Video feeds,
 - Heat levels,
 - Motion detection,
 - Wearable sensors,
- Evaluate the reliability and uncertainty of the collected data to ensure that the information provided to rescue services is accurate and actionable,
- Assess the availability of the sensor data as well as the possibility to integrate the data into a combined system,
- Assess the usability of the sensors with regards to the concept: Smart Firefighting,
- Recommend sensors and data types based on their relevance for the prediction of fire growth.



This report aims to create a foundation for the selection of sensors to successfully integrate sensor data into predictive models and models for operational decision-making. This enhances the development of more effective and efficient firefighting strategies.

The work conducted focuses mostly on systems that are available on the market (i.e. the focus is engineering), rather than prototypes which appear in scientific literature.



2. Methodology

A multi-method approach was applied, combining a review of literature, categorization and structure of information, empirical inventory and case study, stakeholder interviews, sensor data reliability and uncertainty assessment.

2.1. Review of literature

The project began with a comprehensive literature review, intended to establish a theoretical and technical foundation for the study. The review focused on:

- The current state of Smart Firefighting sensor technologies, categorization of these technologies in fixed sensors in buildings and sensors brought by fire and rescue services to the fire scene,
- Possibilities and limitations with Smart Firefighting sensor technologies,
- Sensor types commonly integrated in building automation systems (e.g., temperature, CO₂, motion detection, video),
- Sensor types that are commonly brought to a fire scene by the fire and rescue service, (e.g., thermal imaging, gas detectors, motion detection, video),
- Relevant data streams for fire detection, prediction, and operational support,
- Standards and limitations related to sensor data quality, accessibility, and interoperability.

The literature review led to the development of a preliminary set of evaluation criteria for sensors, including measurement range, resolution, reliability, latency, and integration potential. These criteria were used both as a reference for the interview phase and as a baseline for analyzing empirical findings.

2.2. Categorization and structure of information

Based on the literature review, a categorization of information and sensor data was identified. The categorization was then used as a basis for the evaluation of sensors to structure and pinpoint type of data, type of sensors and how the data can be made available.

The sensors were categorized based on the type of information they can provide. The different categories identified were:

- Sensors to describe and predict fire development,
- Sensors to describe the status of the building fire protection system,
- Sensors to describe the conditions/environment inside the building,
- Sensors to describe the operational capability of the fire and rescue service.

Within each main category two subcategories were then identified as:

- Sensors that can be embedded in the building,
- Sensors that the fire and rescue service can bring to the site.



2.3. Empirical inventory and case study

As part of the project, a master's thesis was carried out (Abrahamsson & Svensson, 2025), including interviews, an empirical inventory and a case study.

The interviews were to validate and extend the insights from the literature and were held as a series of semi-structured interviews. Eleven stakeholders were interviewed across the following domains:

- Property owners and facility managers,
- Sensor and building automation experts,
- System suppliers.

The inventory mapped:

- Types and spatial distribution of sensors,
- Availability and structure of digital fire safety documentation (e.g., BIM, alarm schematics),
- Data logging intervals, access protocols, and system integration (e.g., BMS, SCADA),
- Conditions for using the data as input to simulation or real-time decision support.

This inventory was used to assess how buildings can contribute to the development of digital twins and to evaluate the practical applicability of available sensor data in simulated fire scenarios.

Summaries of the interviews can be found in Appendix C to Appendix M within the master thesis (Abrahamsson & Svensson, 2025).

The qualitative findings were then supported by an empirical mapping of the sensor infrastructure and fire safety information in a selected smart building.

The main case study focused on the World Trade Center in Lund, where on-site inspections were conducted in collaboration with technical staff and the focus was upon sensors that are embedded in the building.

2.4. Stakeholder interviews

To validate and extend the insights from the literature, the master thesis an additional series of semi-structured interviews were conducted with four different stakeholders across the following domains:

- System suppliers of fire alarms and switchboard services,
- System suppliers of fire and rescue services equipment,
- Research institutes.

The interviews were focused upon sensors that the fire and rescue service can bring to the site and structured around the identified evaluation criteria and tailored to each respondent's area of expertise. Topics included:



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- Practical experiences with sensor systems in buildings,
 - Perceived value and limitations of data for emergency response,
 - Legal and organizational barriers to real-time data access,
 - Perspectives on the use of digital twins and predictive modeling.

Interviews were summarized, (with informed consent), and returned to each respondent for verification. The validated summaries were analyzed thematically to extract common patterns, challenges, and opportunities.

Summaries of the interviews can be found as appendix A-D within this report.

2.5. Sensor data reliability and uncertainty assessment

A central task of this report involved assessing the reliability and uncertainty of the identified sensor data. This included:

- Evaluation of sensor performance under fire-related conditions (e.g., heat, smoke, humidity),
- Identification of technical limitations (e.g., measurement saturation, delayed signal, hardware failure),
- Analysis of spatial and temporal resolution for dynamic modeling purposes,
- Consideration of signal loss, interoperability issues, and maintenance needs.

This evaluation aimed to determine the extent to which real-time sensor data from existing building systems could provide actionable intelligence for fire response teams.

2.6. Way forward

Finally, the results of the inventory and sensor assessment were used to select types of sensors suitable to integrate into firefighting operations to improve safety and efficiency. The fastest and easiest way forward to achieve improved conditions for fire and rescue services were also identified.



3. Literature review

This literature review explores existing research on sensors and fire protection information that can support the development of a Smart Firefighting system. The aim is to identify key technological advancements, prevailing methodologies and gaps in the current understanding.

3.1. Sensor technology

Smart buildings deploy a variety of sensors that can significantly aid in both early fire detection and in providing firefighters with real-time information during emergencies.

3.1.1. Types of sensors for fire detection and building monitoring

Common sensor types include:

- **Smoke detectors:** These detect combustion particles or aerosols and are available as ionization, photoelectric, or multi-criteria detectors. Advanced units also perform continuous sampling to reduce false alarms (Almatared et al., 2023). Several smoke detectors also have thermocouples for measuring temperature built in as a part of their monitoring system (Abrahamsson & Svensson, 2025).
- **Heat detectors and temperature sensors:** These are often integrated into HVAC systems or standalone fire alarm devices. They detect fixed thresholds or rapid temperature increases. Some detectors report both alarm status and live temperature values, useful for tracking fire growth (Siemens, 2022).
- **Flame detectors:** Typically used in high-risk industrial environments, these sensors detect UV or IR radiation from open flames and trigger rapid alarms (Wehbe & Shahrour, 2020).
- **Gas sensors:** CO and CO₂ detectors provide insight into smoldering fires and air quality. VOC (volatile organic compound) sensors can detect early-stage combustion or chemical leaks. These use technologies like NDIR spectroscopy for precise measurement (Jiang et al., 2023; Almatared et al., 2023).
- **Occupancy and motion sensors:** Used for lighting or climate control, these can also indicate whether people remain inside a building during an evacuation. Entry/exit logging systems or badge-based counters offer insights into occupant count and location during incidents (Leucker et al., 2023).
- **Environmental sensors:** Pressure sensors (e.g., in stairwells), humidity sensors, or sprinkler flow switches provide data on fire suppression and smoke control systems. For example, sprinkler activation in a specific zone indicates where fire is active (Telit Communications, 2019).



- **Door status sensors and integration with fire safety systems:** Magnetic contact sensors, often referred to as door position switches (DPS), detect whether a door is open or closed. Such information is on many occasions vital in maintaining compartmentalization during fire incidents. These sensors are typically integrated with fire alarm and building management systems to ensure that fire doors, held open under normal conditions by electromagnetic holders, are properly released and closed when a fire is detected. Integration of door status sensors with fire protection systems improves safety by automating critical containment actions and enhancing situational awareness during evacuation and firefighting operations (SDC Security, 2023; Advanced Fire Systems, 2022).
- **CCTV and imaging systems:** With the addition of AI-powered image recognition, cameras can detect flame signatures or motion patterns, making them functional sensors in a broader emergency management platform (Zhang et al., 2021).
- **Crowd monitoring techniques:** Detectors through cameras or other sensors to monitor people flow as well as being privacy-preserving and require minimum public participation (Singh, U. et al, 2020).

As buildings become more sensor-dense, data volume increases. However, for firefighting purposes, the location and context of each sensor reading are crucial. Therefore, integrating these sensors into a mapped digital model (like a BIM or digital twin) enhances their utility (Khajavi et al., 2020; Abrahamsson & Svensson, 2025).

3.1.2. Role of sensors in decision support for firefighters

Sensor data plays a central role in supporting decisions under time pressure. As alarms are triggered, responders can pinpoint the likely origin of a fire and track its progression via temperature and smoke readings (Abrahamsson & Svensson, 2025).

Additionally, CO readings, Wi-Fi connections, motion or badge-entry sensors can help determine if occupants are still inside the building, which is crucial for prioritizing search and rescue operations (Appendix 8.1, Abrahamsson & Svensson, 2025). CO or VOC readings can warn of toxic environments, guiding decisions about protective equipment or safe ingress routes (Wehbe & Shahrour, 2020).

Sensor data also aids in predicting risk escalation. For instance, multiple temperature sensors showing rising values along a corridor can indicate the direction of fire spread. Flow switches and water pressure readings inform incident commanders if sprinkler systems and fire hydrants are active and functioning in the correct zones, see for example products from Siemens (2022).

Real-time insights like these help the fire and rescue service act faster, avoid unnecessary exposure, and allocate resources more efficiently, turning sensor data into actionable intelligence (Jiang et al., 2023).

3.1.3. Examples of real-time monitoring and data collection

Real-world examples include buildings with dashboards that display live sensor status, temperature trends, and whether fire safety systems are operational (Telit Communications, 2019). Some modern systems allow sensor data updates every 8 seconds, offering a near real-time picture (Abrahamsson & Svensson, 2025).



Other examples include firefighter tracking systems, using wearable sensors that monitor air tank pressure, body temperature, and location. These can be displayed within a digital twin interface, allowing commanders to follow personnel movements and issue evacuation orders when necessary (Leucker et al., 2023).

As these examples show, sensor data can be collected and visualized in near real time, but accessibility and integration remain key barriers. Making this data available to responders (securely and quickly) is essential to realizing the full potential of Smart Firefighting.

3.2. Digital twins in firefighting

In recent years, digital twins have emerged as a powerful tool in fire safety and emergency response. A digital twin refers to a dynamic, virtual model of a physical building that is continuously updated through real-time data collected from embedded sensors and integrated building systems. Unlike static representations, such as traditional 3D Building Information Models (BIM), a digital twin offers advanced capabilities for monitoring, simulation, and predictive analysis—enabling improved situational awareness, decision-making, and operational efficiency during fire emergencies (Abrahamsson & Svensson, 2025; Ask et al., 2021).

By aggregating data from systems such as HVAC, fire alarms, and environmental sensors, digital twins provide a real-time overview of building conditions (Bhargav et al., 2019). Over time, they learn from accumulated data with regards to the conditions within the building and can model complex scenarios, such as fire progression, smoke dispersion, and occupant evacuation. This predictive functionality supports both proactive fire prevention and tactical emergency response (Ask et al., 2021; Lovreglio et al., 2021).

The distinction between a digital twin and a static BIM model lies in the integration of live data and intelligent analytics. Digital twins enable real-time monitoring, automatic system control, and simulation of potential fire scenarios—all of which are crucial for supporting effective emergency interventions (Strömngren et al., 2021). This is made possible using open standards that facilitate the integration of BIM and Internet of Things (IoT) technologies, a combination that enhances both data interoperability and response coordination (Bhargav et al., 2019; Siddiqui et al., 2021).

During emergencies, sensor-assisted firefighting further strengthens operational safety. Sensors provide critical data on environmental hazards, which can be visualized within the digital twin to guide response teams on-site. This supports better resource allocation, improves firefighter safety, and enables commanders to make data-driven decisions under pressure (Cowlard et al., 2010; Blecha et al., 2018; Malagnino et al., 2022; Huang & Tam, 2024).

3.2.1. Applications across the firefighting lifecycle

Digital twins deliver substantial value throughout the entire firefighting lifecycle—from pre-incident planning and active response to post-incident evaluation and long-term fire safety management. During the planning phase, digital twins replace static paper-based plans with interactive 3D models that incorporate essential safety information such as hydrant locations, fire doors, evacuation routes, and the presence of hazardous materials (Dublin Fire Brigade & BIMcert Project, 2022).



A key enhancement to this process is the integration of a life cycle perspective on fire safety information. The concept of an “unbroken chain of information” emphasizes the importance of continuous, standardized data flow throughout a building’s life cycle—from design and construction to operation and maintenance. Current practices in the building sector often suffer from fragmented information management, resulting in inefficiencies, inconsistencies, and compromised fire safety implementation (Strömngren et al., 2021b; Bhargav et al., 2018; Svensson & Strömngren, 2022).

To mitigate this, structured approaches are being introduced to ensure that fire safety requirements, regulatory documentation, and quality assurance protocols are seamlessly connected across phases. Central to this approach is the use of digital tools such as BIM which acts as a comprehensive repository for fire safety data (Norén et al., 2018; Siddiqui et al., 2021). BIM also facilitates interoperability and improves access to verified, consistent information, greatly enhancing decision-making in both routine operations and emergency scenarios (Malagnino et al., 2022).

By integrating lifecycle-focused data management with real-time digital twin capabilities, stakeholders can significantly improve coordination, reduce response time, and enhance building resilience. This holistic approach not only contributes to more effective fire safety management but also promotes long-term efficiency, transparency, and collaboration across the construction and facility management sectors. And it should increase efficiency during fire and rescue operations.

3.2.2. Benefits and challenges of digital twins in emergency response

The primary advantage of digital twins in emergency response is the rapid access to accurate, real-time information. Rather than relying on outdated blueprints or verbal briefings, emergency teams can instantly access spatially mapped data, particularly valuable in large or complex structures (Dublin Fire Brigade & BIMcert Project, 2022).

Firefighter safety is also significantly improved. Digital twins can track personnel positions, monitor air tank levels, and detect hazardous conditions. These insights can trigger automated warnings and evacuation alerts, while providing incident commanders with a shared operational picture to improve coordination (Leucker et al., 2023).

However, several challenges remain. High-quality digital twins require detailed building data, extensive sensor networks, and ongoing maintenance—all of which involve substantial financial and technical investment (Khajavi et al., 2020). Additionally, interoperability issues persist, as proprietary platforms often lack standardized interfaces, complicating integration with emergency systems. Many existing buildings are also not digitally equipped, requiring retrofitting and collaboration between stakeholders. Finally, successful deployment depends on user training and trust—digital tools must be intuitive, reliable, and usable in high-pressure environments (Abrahamsson & Svensson, 2025).

3.2.3. Integrating sensors and information systems with digital twins

To fully realize their potential, digital twins must be supported by robust sensor networks and integrated with systems such as Building Management Systems (BMS), Fire Alarm Control Panels, and communication platforms. Sensor data mapped to 2D or 3D building models allows responders to visualize alarm locations and interpret spatial patterns in real time (Khajavi et al., 2020).



Middleware solutions, APIs, and standardized protocols—such as BACnet, Modbus, or OPC UA—can enable cross-platform integration, but proprietary systems still present barriers. Effective collaboration between facility managers and emergency services is essential to ensure data access during incidents.

BIM models following the IFC standard are particularly useful for storing metadata such as sensor IDs, types, and locations. These models can dynamically update as new sensor data is received (NFPA, 2022). To prevent information overload during emergencies, systems must prioritize and filter sensor data—highlighting only critical changes such as elevated temperatures, deteriorating air quality, or incomplete evacuations (Dublin Fire Brigade & BIMcert Project, 2022).

3.3. Wearable sensors

Smart-firefighting approach increasingly leverages mobile and deployable sensors, such as drones and wearable firefighter telemetry, to stream real-time data. These tools extend the commander's perception beyond line-of-sight: drones equipped with thermal or multispectral cameras provide overhead imagery, while wearable sensors report firefighter location, air-supply status, and vital signs. Visualizing these feeds inside a digital twin helps assess hazards and direct safe operations (Leucker et al., 2023; Codina et al., 2019; Papadopoulos et al. (2024).

Several studies demonstrate how these solutions are already working in practice. PROeTEX (Protective Electronic Textiles) was a European research project aimed at developing smart textiles for emergency responders, particularly firefighters. The project integrated sensors into garments to monitor vital signs, body movement, and environmental hazards in real time. The system featured wireless communication, GPS tracking, and IMU-based fall detection to improve safety, situational awareness, and coordination in high-risk environments (European Commission, 2010). Köse & Eren (2024) applied a multi-criteria decision analysis to rank commercially available firefighter wearables based upon the PROeTEX program and found that smart personal protection equipment with patches were most effective at mitigating physiological and mechanical hazards.

Augmented reality (AR) is increasingly used to overlay critical information, such as building layouts, hazard zones, evacuation routes, directly into firefighters' helmets or handheld displays. When driven by live data, AR provides real-time tactical guidance in smoke-filled or unfamiliar environments. Studies integrating BIM with AR have demonstrated faster, more accurate evacuations and improved navigation during drills (Kanangkaew et al., 2023; Almatared et al., 2024).

Together, these studies indicate that smart protective clothing can transform personal protection equipment from a passive barrier into an active sensing platform that supplies digital twins with high-resolution, real-time data, enhancing situational awareness and safety.

Recent research has been focusing on drones equipped with multi-modal sensor suites that are rapidly becoming an important asset for Smart Firefighting. A systematic review by Sun et al. (2025) shows that lightweight edge-computing boards now allow infrared, RGB and LiDAR feeds to be processed on board the aircraft, cutting decision latency. Sousa et al. (2020) found that uncooled micro-bolometer cameras mounted on small UAVs can detect early signs of fire and hidden heat sources long before they are visible from the ground, while on-board filtering delivers near-real-time alerts.

Moving beyond single-sensor payloads, recent work also focuses on forest-fire monitoring and AI-driven analytics. Liu et al. (2023), Yu et al. (2025), Khalaf et al. (2023).



3.4. Technical and organizational challenges

3.4.1. Data sharing and real-time access for emergency services

One of the main obstacles in realizing Smart Firefighting systems is ensuring that real-time data reaches the fire and rescue service. Despite the presence of rich sensor infrastructure in many smart buildings, this data is often siloed within internal systems like building management or fire alarm panels and remains inaccessible to external responders during emergencies.

Effective data sharing requires technical interoperability, including APIs or standardized protocols, and organizational agreements that define who can access what, when, and under which circumstances. Firefighters interviewed in several studies raised the fundamental question: *How does information from smart buildings actually reach the fire and rescue service?* (Abrahamsson & Svensson, 2025). Without clear mechanisms and infrastructure for this, data risks becoming operationally useless.

Cities such as Dublin have addressed this by deploying cloud-based platforms where building owners can upload structured buildings and sensor data in advance. The fire and rescue service then retrieve it on demand, either at dispatch or on route (Dublin Fire Brigade & BIMcert Project, 2022).

Moreover, latency is critical: sensor data must update in seconds, not minutes. This has implications for communication infrastructure, including 5G, edge computing, and backup systems in case of power or network failure (Leucker et al., 2023). A practical solution used in some jurisdictions is preloading static data (building layout, hydrants, exits) on mobile devices, with sensor updates layered in as connectivity allows.

3.4.2. Security aspects and data integrity

As access to building data becomes more open, cybersecurity risks increase. Unauthorized access to real-time data—like building layouts, occupant locations, or safety system status—could be exploited maliciously. Systems must therefore include authentication protocols, data encryption, and access control policies (Hamins et al., 2015).

In addition, firefighters need to trust the integrity of sensor data, especially under extreme conditions. Fire, water, and electrical damage can compromise sensors, potentially leading to false negatives (i.e., a sensor appears normal when it has failed). Thus, systems should include health checks and failure indicators, and possibly redundancy to confirm readings across multiple devices (Jiang et al., 2023).

AI and data filtering can help mitigate false alarms, but this too must be validated. Fire and rescue services are understandably cautious about automated decisions without transparent logic.

Policies must also define when and how data becomes available to the fire and rescue service. One model proposes “on-demand access” triggered by a fire alarm or dispatch, which grants the fire and rescue service temporary access to live feeds and historical logs. Outside emergencies, that data would remain restricted (NFPA, 2020).



3.4.3. Standards and guidelines for implementation

Currently, there is no global standard that mandates how sensor or building data should be structured for use by the fire and rescue service, but several emerging frameworks aim to fill this gap.

The National Fire Protection Association (NFPA) has published:

- *NFPA 950*: which defines data exchange standards for the fire and rescue service,
- *NFPA 951*: which provides guidance for using digital information (e.g., BIM models) during response (NFPA, 2020, 2022).

Internationally, ISO 16739 (IFC format) is a key standard for encoding building information in a machine-readable, geometry-aware format. The fire and rescue service can use this to extract floor plans, room metadata, and even sensor layouts, provided buildings follow IFC-compliant modeling.

Local guidelines, such as those developed in Sweden through Smart Built Environment, advocate for open data architectures, simplified interfaces, and consistent information presentation across different sites and buildings.

3.5. Future developments and innovations

3.5.1. AI and machine learning combined with digital twins

The combination of artificial intelligence and digital twins is one of the most promising future directions in Smart Firefighting. AI models can be trained to recognize fire patterns and predict fire behavior based on building data, sensor readings, and historical incidents. When connected to a digital twin and sensor data, AI can simulate how a fire might evolve and recommend tactical actions in real time (Zhang et al., 2021).

This may include suggesting optimal ventilation strategies, identifying hazardous zones, or advising on evacuation routes. Some systems already use real-time simulations powered by machine learning to show the spread of smoke and heat under different scenarios (Hamins et al., 2015). These forecasts can improve decision speed and accuracy for the fire and rescue service.

Moreover, AI can assist in sensor data interpretation, filtering out false alarms and focusing responders' attention on critical anomalies. For instance, a sudden spike in temperature combined with a drop in air quality might trigger a priority alert, while isolated readings outside normal patterns might be suppressed (Jiang et al., 2023).

There is also ongoing work on reinforcement learning, where AI agents "learn" optimal firefighting strategies in simulated environments, potentially training future firefighting robots or autonomous building systems. While not yet widespread in real responses, these developments illustrate how digital twins can evolve into intelligent, decision-support companions during incidents (Zhang et al., 2021).

However, efforts should be put into making sure that AI can make as correct a prediction as possible. This can be a major problem for predictions outside of the data used for learning. Faulty predictions might put firefighting personnel in high-risk situations, that might even be fatal. Also, this might be a problem when new risks that still have not been investigated are introduced in the built environment.



3.5.2. Advances in sensor technology

Sensor technology is rapidly advancing in both precision and resilience. Next-generation fire detectors combine multiple data types such as smoke, heat, gas levels and optical flame signatures into multi-criteria devices that generate fewer false alarms and provide richer data streams (Almatared et al., 2023).

New sensor types are also emerging. For instance:

- Distributed Temperature Sensing (DTS) via fiber optics can monitor heat along entire corridors or structural elements,
- Structural health sensors (strain, deformation, or vibration sensors) can detect weakening load-bearing components before collapse,
- Compact thermal imaging sensors may be installed like traditional detectors, providing continuous infrared feedback.

In parallel, the development of fire-resistant and self-powered sensors increases the operational lifespan of devices even in harsh environments. Battery-free sensors using energy harvesting (e.g., from heat or motion) are particularly promising to reduce the installation cost of such sensors (Telit Communications, 2019).

Furthermore, mobile and deployable sensors such as drones and wearable firefighter telemetry expand the sensing coverage during an incident, feeding live data back into the digital twin (Leucker et al., 2023).



4. Inventory of sensors

In addition to the literature review interviews were conducted. These interviews are summarized and can be found as appendixes to this report or in the master thesis (Abrahamsson & Svensson, 2025).

The sensors studied in this inventory are categorized based on the type of information they can provide. The different categories identified are:

- Sensors to describe and predict fire development,
- Sensors to describe the status of the building fire protection system,
- Sensors to describe the conditions/environment inside the building,
- Sensors to describe the fire and rescue service operational capability.

Additional to the sensors the data they produce must be collected and distributed to the recipient. This is discussed in the chapter on data collection and sharing.

4.1. Sensors to describe and predict fire development

Based on sensor data and advanced analysis with simulation tools or pre-simulated scenarios, the fire service can potentially be provided with a description of the fire and fire localization. Localization means physically positioning the fire within a building. Describing the fire can for instance include its size and growth rate.

4.1.1. Sensors that are present in the building

Within the HVAC system, there are normally a few sensors that can be used to describe a fire. Dependent on the level of sophistication the sensors can be centralized at the air handling unit or distributed throughout the system.

For a system with centralized sensors the level of details it can provide depends upon how big the system is. A small system can provide detailed information about the area it covers while a large system can provide information about the presence of a fire but not where it is located.

Sensors within this area that are included within all ventilation systems are (Abrahamsson & Svensson, 2025):

- Temperature,
- Flow,
- Pressure.



If the system is built to optimize the ventilation at a room level, there could also be the following sensors included (Abrahamsson & Svensson, 2025):

- Motion sensors within rooms,
- Carbon dioxide measurements within the room,
- Temperature measurement within rooms,
- Air humidity measurement.

In some buildings fire and smoke dampers are controlled through a control system. Some of these dampers have a temperature and/or smoke sensor as a part of the damper. This means that it would be possible to detect and monitor a fire on a fire-cell level instead of a room level.

The fire alarm system often has several sensors (detectors) distributed throughout the building. The number of sensors as well as type of sensors depends on the object, but it could be sensors in each room or sensors in corridors and larger rooms. Sensors connected to the fire alarm can be.

- Smoke detectors (Optical, aspirating or linear),
- Heat detectors,
- Carbon monoxide or Carbon dioxide detectors,
- Heat or flame detectors through cameras,
- Heat sensitive cables.

(Abrahamsson & Svensson, 2025), Appendix 8.1)

A sprinkler system often only relays information about whether it is activated or not. Additional flow monitors could be used to get more detailed information about which part of the system is activated (Abrahamsson & Svensson, 2025).

Within the security system, cameras are the most obvious sensor that can be used to describe the fire development (Abrahamsson & Svensson, 2025). Cameras can be used to visually see where the fire is but also the size and characteristics of the fire. Cameras can include thermal sensors as well as normal video feed. There is also a large development of software connected to cameras which allows them to analyze more of what happens in a room. (Appendix 8.1).

4.1.2. Sensors that the fire and rescue service may bring to the site

Sensors that the fire and rescue service may bring to the site such as thermal cameras and temperature sensors can be used to describe the fire development (Appendix 8.3). In addition, there are several gas detection sensors that can be used to detect gases and hence to some extent describe the fire development (Appendix 8.3).

Since the sensors are normally connected to the fire and rescue service's equipment, they only provide information about the conditions at the current location of the firefighter, and because they move around the accident site, such sensors makes it difficult to monitor continuous conditions at a specific position.



4.2. Status of the building fire protection system

The status of the fire protection system includes sensors that can describe what has happened within the fire protection system in a building. This for example includes whether fire compartment doors are open or closed, if smoke hatches have opened, if smoke ventilation or pressurization fans have activated or if the sprinkler has activated. Such information can be crucial for fire service decision making and when intervening in a building fire.

4.2.1. Sensors that are present in the building

As described previously, monitoring of several of the active fire protection systems can be done through the fire alarm system. This is typically done through an I/O-unit meaning that the fire alarm system sends an activation signal to active fire protection systems. For example, fire alarm can be used to activate a smoke ventilation fan. If needed, the fire alarm can also collect an I/O-signal as verification when the active fire protection system is fully operational.

Since the fire alarm only uses I/O units for communication it cannot collect precise values such as flow or pressure.

When it comes to active smoke ventilation fans often come with a control system where information about smoke ventilation can be collected. Depending on the level of sophistication this information can be limited to activation or not, or full information about achieved flow, pressure and temperature in the system.

There are several sensors that can be used and of interest to describe the status of the building fire protection systems within a security system. For example, door magnets can be used to indicate if a door or window is open or closed (Abrahamsson & Svensson, 2025). If this information is connected to where fire cells are in the building it can indicate which fire cells are intact.

Cameras can be used to monitor doors and sprinkler activation (Appendix 8.1).

Smoke dampers often have a control system that can be used to monitor if the dampers are closed or not, as well as the temperature or presence of smoke at the damper. (Abrahamsson & Svensson, 2025).

The sprinkler system also has sensors that detect changes in pressure, flow and the activation of any pumps. Other extinguishing systems, for example gas, also normally have sensors that indicate whether the extinguishing system has been activated.

4.2.2. Sensors that the fire and rescue service bring to the site

Visual feeds and images/videos from cameras provided by firefighters working inside a building are examples of sensor data that can complete or confirm data on the status of the building fire protection system.

4.3. Conditions and environment inside the building

Conditions and environment inside the building relate to sensors that describe the environmental conditions inside the building during a fire incident. It includes monitoring where people are moving inside the building, as well as seeing if smoke has spread outside the origin of a fire or if high levels of carbon dioxide are detected within the building. These sensors are focused on describing what is happening outside the direct origin of the fire.



4.3.1. Sensors that are present in the building

One of the main aspects within this area is if and where people are located within a building as well as crowd monitoring. There are several ways of measuring this. Within a ventilation system that is built to optimize the flow within each room there are often motion control sensors or carbon dioxide measurements on a room level. These sensors could be used to indicate whether there have been people in a certain room or part of a building (Abrahamsson & Svensson, 2025). The sensors will probably not work when there is smoke in the room but will give information up until that moment (Abrahamsson & Svensson, 2025). However, future studies could investigate the performance and reliability of such building sensors.

The security systems can be used to monitor if people are inside a building. To be able to get an exact number of people inside the building the system must be built with safe passages system to prevent several people from passing through a door simultaneously (Abrahamsson & Svensson, 2025). There are also buildings where you get a security batch when entering the building and then you cannot leave the building without returning the batch (Abrahamsson & Svensson, 2025). Such a system would give you detailed information about the number of people within a building.

Additionally, there are Bluetooth systems that monitor the number of people in each room. They use each person's mobile phone and Bluetooth connection to count the number of people within a room. If you have the right application on your phone, it can also indicate who is in each room (Abrahamsson & Svensson, 2025).

Finally, the use of cameras is increasing rapidly. More cameras are installed in buildings, and this is mainly due to technical development as well as cost reduction. The increased usage is also due to new software behind the cameras. This software is used to analyze video streams. (Appendix 8.1). Cameras can also include microphones which would give you audio from the camera position as well. (Appendix 8.1).

A comprehensive paper on various aspects of crowd monitoring techniques can be found in the paper Crowd Monitoring: State-of-the-Art and Future Directions (Singh, U. et al, 2020).

4.3.2. Sensors that the fire and rescue service bring to the site

There are number of different portable and fixed sensors that fire and rescue services can bring to the site, in order to collect data on the conditions and environment inside the building. Examples of such sensors include temperature sensors and sensors for indicating the existence and measuring concentrations of various gases (Appendix 8.2). Also, firefighters working inside a building can provide visual feeds and images/videos from thermal imagers.



In addition, the fire and rescue service can bring drones or robots to help them get an overview of the fire scene as well as carrying sensors to collect data. Some sensors and features that can be built around drones or robots are (Appendix 8.4).

- The use of thermal cameras, lidar depth cameras, laser range finder to help the fire and rescue service to get an overview of the fire scene.
- Connecting data measurement or camera pictures to a map through the drone or robots GPS for navigation and positioning. The geolocation can be crude but can also be more precise if connected to a map beforehand.
- Creating a map over the fire scene through Simultaneous Localization and Mapping (SLAM). The drone or robot will build a map as they go (laser range finder, camera)
- Multiple drones can be used to ensure data sharing from the fire scene through data sharing between the drones.

One example of how drones and robots can be used is the robot SPOT features a mapping, localization, and autonomous traverse system collectively known as GraphNav. This capability is being used today by Boston Dynamics customers in the construction, oil and gas, and utilities industries for data gathering and controls monitoring applications (Appendix 8.4).

Drones should not be seen as a sensor itself except for producing a map and providing a live stream or a photo over the fire scene. Instead, they can carry different types of sensors. This means that through drones it is possible to connect sensor data to a position (Appendix 8.4).

4.4. Operational capability of the fire and rescue service

The operational capabilities of the fire and rescue service are largely related to the status of the firefighters. But it is also dependent on their equipment, including pumps (flow rate), the use of fans, etc.

4.4.1. Sensors that are built into the building

There are normally no sensors specific to this area within a building but data from embedded sensors can potentially be used.

In specific objects that are prepared for this purpose receivers in buildings can be used in conjunction with sensors carried by the emergency services to facilitate positioning or the collection and transmission of data. An example of this is receivers for radio systems (RAKEL), which can be used to monitor the position of firefighters.

If you are to allow the fire service to connect their sensors to receivers built in to the building (a network to allow for positioning of the firefighters or radio communication) this must be known in the design phase to allow for a cost effective installation.

4.4.2. Sensors that the fire services bring to the site

Many sensors within this category are integrated with the breathing apparatus that the firefighters use. The breathing apparatus can carry a large number of various sensors, including sensors for air consumption, air pressure in the breathing apparatus and positioning of firefighters. As an example, Dräger has developed a concept around so-called healthy firefighters. The centrepiece of this is the Airboss Connect back plate. This measures the pressure in the cylinder and can activate an alarm or send an evacuation signal.



The system can also include GPS functionality (Appendix 8.2). The firefighting equipment can also measure the temperature (Appendix 8.3).

Thermal cameras can be used and connected to a screen visible to the firefighter (Appendix 8.2).

There are also sensors developed for personnel working alone that could be used by the fire service for alarm and positioning (Appendix 8.1).

Smart clothing/wearables is an emerging area. Such articles are the fusion of textiles and technology that include sensors for heart rate, muscle activity, speed, breathing patterns, skin temperature, core temperature, surrounding temperature, humidity etc., more commonly used for military and elite sports applications. Access to such data would put firefighters in a much safer position, since they can be monitored from the outside of the building. (Blecha, et.al.).

4.5. Data collection and sharing

To be able to collect and use data, sensors need to be connected to a control system. These systems could be at a system level (for example an HVAC system or a fire alarm) or at a building level (a building management system). There could also be several systems within a building as well as connections between them.

When it comes to sensors that the fire and rescue service bring to the scene, generated data needs to be collected and presented in a structured way. This means that sensors also need to have a control system or an information gathering system to be able to use the data.

4.5.1. Sensors that are built into the building

Sensors in HVAC systems are connected to a local air handling unit or a local control system for the complete ventilation system of a building. A more comprehensive Variable Air Volume (VAV) system has a local Programmer Logic Controller (PLC) system on each floor that collects the data from the sensors. VAV systems often have a display in each control unit where data from the system can be presented (Abrahamsson & Svensson, 2025).

Fire alarm systems and security systems are often standalone systems that collect their own data. Newly built systems often have an integrated real time control monitoring function which is a web client (Appendix 8.1).

The data from all sensors can also be integrated into a building management system as a more comprehensive control system for a whole building (Abrahamsson & Svensson, 2025). Creating a BMS system is complicated though since it is hard to gather information from different systems which often are manufacturer dependent (Appendix 8.4).

Larger manufacturers who offer products within a range of building systems often have their own integration system. One such example is Schneider where sensor data is presented on a 2D drawing. Large property owners instead often use an independent system and then implement it on all their buildings (Abrahamsson & Svensson, 2025).

When it comes to a full building management system it is often more easily understandable compared to a display from a specific system such as a ventilation system. This is due to the fact that a building management system is designed to combine information from different systems and sensors (Abrahamsson & Svensson, 2025) while a specific system such as the ventilation system often is designed for a technician.



There are security platforms that allow the user to integrate different security and safety systems into one graphical interface where security systems as well as fire alarm systems can be controlled and monitored (Appendix 8.1).

Finally, there are also specific systems for gathering and presenting data from sensors that are built as a visual representation of the building and not for controlling the systems (Abrahamsson & Svensson, 2025).

4.5.2. Sensors that the fire and rescue services bring to the site

Sensors that are brought to the fire scene by the fire and rescue service are normally a standalone system meaning that the fire and rescue service also will bring the controlling systems to the sensors.

Often the product forms its own wireless network for communication and positioning. Technically, it works by setting up a base station at the point of attack for the operation that each firefighter connects to. It is also possible to bring amplifiers into the building to improve the network.

The data from the devices is presented in an app that is downloaded into a tablet (Appendix 8.2). Data from this network can then be sent to a dispatch center.

Portable sensors can also be connected to a digital interface via Bluetooth to a portable device, which can then transmit the data to and present it on a portable device (Appendix 8.2).



5. Discussion

The results of this study confirm that current sensor infrastructure in buildings holds substantial potential for supporting Smart Firefighting. Through the literature review, stakeholder interviews, and inventory of building systems it is clear what types of sensors exist today, how their data can be structured and shared, and what role they can play in enhancing operational firefighting support.

When it comes to sensors within buildings these are often installed as a part of one of the main building systems. For this report interviews and reviews showed that the most interesting systems to gather data from are the:

- HVAC or lighting system,
- Fire alarm,
- Security system.

Information can then be gathered directly from these systems or through a Building Management System (BMS) installed to monitor and sometimes control these sub systems. Data from these systems can be used to describe the status of the firefighting systems and conceivably predict the fire development, and the conditions inside the building.

When it comes to sensors that fire and rescue service bring to the site, they are more focused on describing the operational capability of the fire and rescue service as well as creating an overview of the fire scene. These are often standalone systems with their own infrastructure for data transferring and presentation.

Also, it should be noted that Smart Firefighting and sensor technology can be important for the efficiency during other rescue operations not for fire events only. An example of such an event can be the accidental release of toxic substances at industrial sites. In such a case, monitoring the facility (which can be a building or outside of a building) including monitoring the work by firefighters, can be crucial to efficiency as well as safety.

5.1. Reliability of sensor data in fire conditions

Sensor performance under fire conditions varies widely. While many are tested and certified for building automation under normal operation - extreme conditions such as heat, smoke, humidity, can largely affect their performance. Some sensors, such as CO detectors and flow switches, provide reliable binary data ("on/off"), while others, such as temperature and other gas concentration sensors, depend on calibration and maintenance (Abrahamsson & Svensson, 2025).

The fact that these sensors often have a limited range where they provide reliable data, redundancy and cross-correlation of data streams (e.g., simultaneous CO₂ rise and flow changes) are crucial to increasing confidence in the readings. It is also important to acknowledge that absence of sensor activation does not equal absence of hazard.

Due to the limited reliability under fire conditions, system suppliers might be hesitant to provide sensor data to the fire service. Since the sensors often are not built for fire conditions the manufacturers will not guarantee their accuracy and reliability (Abrahamsson & Svensson, 2025).



When it comes to sensors that the fire and rescue service can bring to the site, they are more likely to be robust and endure harsh conditions, but they are not necessarily designed to withstand extensive heat and hence they will not work in high fire temperatures (Appendix 8.2).

Another challenge to the implementation of sensors in the fire service equipment are the strict regulations surrounding electronic equipment in explosive environments. Breathing apparatus full face masks are regulated through EN 137 as well as EN 136 and are subject to particularly high safety requirements with regards to explosion safety, with the current requirement level being Ex ia IIC T4. These requirements limit current consumption, voltage and the design of electrical circuits. In many cases, the requirements for breathing equipment are even stricter than for other portable equipment, making it difficult to integrate advanced electronics without compromising safety (Appendix 8.3).

5.2. Using data to describe and predict fire development

Sensor data can be used both to describe the ongoing fire (location, intensity, smoke spread) and to predict possible developments (e.g., flashover risk, corridor spread). Temperature gradients, door status, smoke damper positions, fire alarm activation, and sprinkler activation are strong indicators of fire behavior. When integrated into simulation environments or digital twins, these inputs could allow predictive modeling of fire growth scenarios and can potentially help firefighting services adjust their tactics accordingly.

The problem with extracting data from such sensors today is that they are not normally integrated into a system that also has an actual representation of the building geometry (Abrahamsson & Svensson, 2025). Data sharing and collection systems are more focused on visualization than on gathering a complete set of information needed for a prediction of fire development.

Sensors that the fire and rescue service bring to the site are even harder to connect to actual representations of total building geometry. This means that such sensors will be able to give the fire and rescue service a good understanding of the actual conditions where the sensors are located, and this can work as a source of information for decisions, but it will be hard to use the data for simulations of future fire development.

Another problem with these systems is that the sensors need to be placed in the right position at the time of a fire.

When sensors are carried by the firefighter, they will provide data from the firefighter's position but there will be no data from areas where the firefighters have not been yet. Using a drone or a robot would be one option to carry sensors to new places, but it would take a long time to get a good physical representation of a whole building except for a video stream from the outside.

5.3. Data presentation and operational use

Interviews confirm that fire and rescue services prefer simple, high-confidence data interfaces: visual dashboards, tablet-based maps, and alerts integrated with known tactical patterns. Information should support decisions, not overwhelm. Systems that replicate operational language—such as “door to stairwell blocked” or “Zone 2 smoke vent activated”—are more likely to be adopted than systems requiring raw data interpretation (Abrahamsson & Svensson, 2025).



This means that for firefighting purposes, sensor data must be presented in a simplified, spatially contextualized format—ideally overlaid on a digital floorplan or digital twin. Visual interfaces should highlight alarms, room conditions, fire protection system statuses (e.g., closed dampers, pressurized stairwells), and suspected occupancy. Filtering and prioritization are key: rather than streaming all available data, systems should surface only what is relevant, actionable, and trustworthy. This aligns with how fire services operate under time pressure and cognitive load.

Today control systems and building management systems are typically not built for such purposes (Abrahamsson & Svensson, 2025). The design of the graphical representation of these systems is also not carried out according to a specific standard or set of rules. This means that the design will vary between different systems and different buildings, which in turn makes it more difficult to absorb the information and use it correctly.

Unlike these systems, fire alarms have a uniform set of rules governing how the system should be represented digitally. The Swedish Fire Protection Association's standard specifies details of how the drawings should look, which symbols should be used and what information may be included in the drawings (Brandskyddsföreningen, 2021). These drawings are not allowed to contain detailed information about the building's fire safety systems or specific hazards within the building.

Information about fire safety systems or risks are instead usually included in a building's emergency response plan, if it has one. The Swedish Fire Protection Association also provides instructions on what these should look like in its publication *Insatsplan 2019* (Brandskyddsföreningen, 2019). However, this emergency response plan is not connected to any technical systems or their graphical representation. A potential development could be to provide digital emergency response plans to the fire service where the status of fire safety systems (e.g. location of activated detector) is presented.

When it comes to sensors that the fire and rescue service brings to the site such systems can be designed to accommodate the fire and rescue service needs and it is also possible for the fire and rescue service to train with the system. The likelihood of the system presenting a more understandable visualisation of the data is therefore higher.

5.4. Availability and ownership of data

Sensor data is often contained within building systems, such as building management systems, fire alarms, or security system with ownership retained by building operators or third-party service providers. This limits real-time accessibility for fire services, unless pre-configured interfaces or legal frameworks are in place (Abrahamsson & Svensson, 2025). In the absence of access, much of the sensor infrastructure remains unused at critical moments.

There are applications available today which send more detailed information to the fire and rescue service. These systems are integrated into the fire alarm and sometimes use manual handling at a dispatch center to share the information with the fire service and sometimes use e-mail (Abrahamsson & Svensson, 2025), (Appendix 1).

Sharing data with the fire service on site is a challenge. One way could be through the RAKEL system (Swedish system for radio communication for the emergency response units) but there is no way of sending for example a live stream or a building model (digital twin) through that system today. The RAKEL system is limited to distributing only a small amount of data. That said, a new version of this system RAKEL2 is under development which will enhance the possibility of data sharing through the system.



Today the fire and rescue service must use a mobile internet connection if this is available in their vehicles. These connections are often less secure and as soon as the system is connected to internet there is the possibility that the information will be accessible to unauthorized persons. It is a question of Internet security on both the property owners' side as well as the fire service's (Abrahamsson & Svensson, 2025).

Property owners might also be hesitant to give fire and rescue services full access to a building's sensor data since the fire and rescue service also act as a supervisory authority under the Civil Protection Act (2003:778) and they may suspect it could result in a more detailed regulatory visit.

There is also a problem for the fire and rescue service to access such information. They would need to have an account for each building that has the technique and then they would need to have enough knowledge to handle the different types of systems. Models for "event-triggered sharing" (e.g., upon fire alarm) or persistent cloud-based access for approved authorities instead offer feasible paths forward.

A system where data and information (presented in a form that is recognized by the fire service, e.g. according to the current practice for emergency response plans, see Section 5.3) are available through a screen or a data connection when the fire and rescue service enter the building could also be a possibility. This type of systems is also less sensitive from a security perspective since the data is handled locally within the building.

For sensors that the fire and rescue service bring to the site they will instead create their own local network which then could include the right level of security for the task, meaning that the risks of external persons retrieving the data should be lower.

5.5. Structuring sensor data across the building lifecycle

To be able to use sensor data in the context of Smart Firefighting sensor data must be structured from the design phase, stored using open formats such as IFC, and updated throughout the building's operation.

The sensors must have a structural layer describing where the sensor is installed, what building system it is connected to (ventilation, fire alarm, security). In addition to that sensors must have a data layer where metadata such as sensor type, measurement range, calibration intervals, should be documented.

To be able to use the data for predictions the frequency of which data is saved also must be addressed. Often the system will present the actual value of the sensor, but the values are then only saved every 10 minutes to limit the amount of data (Abrahamsson & Svensson, 2025). If a fire occurs, data every 10th minute is not good enough, and data needs to be stored more often.

Finally, there needs to be an interpretation layer. Integration with digital twins enables visualization, while building management systems can serve as the backbone for aggregating and delivering data.

From a lifecycle perspective it is also crucial to have an updating system in place to ensure that the data is correct throughout the building lifecycle. The sensors and data structures must be maintained when maintenance or replacement are conducted within the system as well as larger refurbishments. The lack of updates will make the data useless and possibly misleading to the fire service, which then could do more harm than good. Long-term maintenance of data integrity and compatibility is vital to ensure operational usability.



For fire alarms, there are regulations with regards to the reliability of the system from a life cycle perspective. There are also requirements linked to operation and maintenance, as well as independent audits.

It must also be recognised that the structuring of data and the maintenance from a lifecycle perspective comes with a cost. To be able to motivate building owners to invest and maintain the sensors and the digital twin the benefits from such an investment must be greater than the costs. The other way of motivating such costs would be a legal requirement or financial benefits from insurance companies (Abrahamsson & Svensson, 2025).

Since sensors that the fire and rescue service bring to the site normally are not connected to a predefined building visualisation the need for a life cycle perspective is not as high for such a system.

5.6. Sensor maturity and narrow availability

Most sensors discussed in this report are available today and in use within high-end building systems (e.g., smoke detectors, temperature sensors, door magnets). Others, such as Bluetooth occupancy tracking or AI-enhanced cameras, are emerging but not yet widespread in fire applications. Robotics, automated mapping, and integrated firefighter telemetry are promising research directions but remain in pilot stages. The digital twin concept is evolving quickly, but uptake is currently limited to large-scale or public-sector buildings.

This means that there are sensors available to describe and predict fire growth in buildings today. With emerging technologies, even more information can be gathered from a building.

The same can be said about the sensors that the fire and rescue services bring to the site. As technology advances more sensors will be available. New technology will also make it possible to transfer data from the sensors to a control system where it can be visualized.

5.7. Platforms for data aggregation and lack of interoperability

Platforms used to collect and present sensor data include vendor-specific BMS solutions (e.g., Siemens Desigo CC, Schneider EcoStruxure), cloud-hosted dashboards, and custom visual interfaces (e.g., Akademiska Hus). Interoperability remains a challenge. Middleware, APIs, and common ontologies are needed to bridge systems and make relevant data available to the fire service.

A comprehensive fire alarm system will also give a lot of information about a building and could be a more reliable source of information since it is built for that specific purpose. The fire alarm systems normally are not built upon open APIs but instead they have a clear regulation controlling both the data collection and sensor development. Furthermore, fire alarms also have clear regulations on how the data should be presented as well as how system drawings should be presented.

Systems that the fire service bring to the site could be expanded to integrate more sensors as well as cameras. They could also be used to transfer data out of the building. (Dräger) This said since the systems are built for a high reliability and should be easy to use manufactures have indicated that they might be hesitant to incorporate sensors from other manufacturers which could limit technology development.



5.8. Standards and guidelines (and lack of)

Standards such as NFPA 950 and 951, ISO 16739 (IFC), and National approaches provide a foundation for structured data management. However, they must be implemented consistently across sectors.

Additional to this, some systems such as fire alarms have their own standards and guidelines for data handling and presentation. Such Swedish standards for the fire alarm would be SBF 110:8 and SBF 1021.

The legislation related to connected sensors is being updated through the NIS 2 directive (DIRECTIVE (EU) 2022/2555 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 December 2022 on measures for a high common level of cybersecurity across the Union, amending Regulation (EU) No 910/2014 and Directive (EU) 2018/1972, and repealing Directive (EU) 2016/1148 (NIS 2 Directive). This will improve the security of connected sensors.

Regardless of examples given above, the lack of regulations and standards, not least for technology under fire conditions and specific needs during a fire event, implies a major limitation for the development and implementation of Smart Firefighting.

If a more uniform standard and regulatory framework, including the life cycle perspective, existed for all systems collecting sensor data that included their geographical location together with their measurement value, this would significantly improve the possibilities of using sensor data. If, in addition, there were a uniform regulatory framework for how the data could be made available to the fire and rescue services, this would also be a major enabler for future further development of technology.

5.9. Selection of sensors and relevance to continued work regarding prediction of fire growth

Based on the literature, inventory, and interviews, the following sensor types are deemed to be especially relevant for the fire model and experiments in the continued work within the project:

- Temperature sensors in ventilation systems or fire alarms for real-time heat development.

These sensors have been recommended because they can be widely distributed throughout a building, thereby providing good geographical coverage of the building. This is a relatively well-proven technology and is considered to provide direct feedback on the size and growth rate of a fire. The measured values can therefore also be used to predict possible fire development. The clear advantage of sensors in fire alarm systems is that they are specifically designed and standardized to function during a fire, which makes them more reliable in such situations.

- CO/CO₂ and VOC sensors for air quality and early combustion.



These sensors are also normally well distributed throughout a building, provided that the ventilation system is built for a room control function. These sensors make it possible to assess smoke spread before we see any impact on temperature and can therefore be used to detect the initial fire and how fire gases are spreading throughout the building. This information is valuable to the fire and rescue service in planning their response.

- Door position sensors for compartmentalization and modelling of the fire spread.

Whether a door in a fire compartment boundary is closed or open provides a clear indication of whether the fire can be contained within the initial fire compartment. Open doors, on the other hand, provide clear information that the fire compartments will not help to limit the spread of the fire to the desired extent. This information can therefore be of great help to the fire and rescue service in planning their response. This type of sensors is common in security systems.

- Sprinkler flow and activation switches for fire suppression feedback.

Receiving direct information about sprinkler activation and the functioning of other fire safety systems provides input for simulations of possible scenarios, but above all it gives the fire and rescue services an opportunity to assess the possible development of the fire and thus plan their response. Fire protection systems normally have sensors to indicate their function within them, and the information is often collected by the fire alarm.

- Thermal and optical cameras for scene analysis and verification.

Until it is possible to fully coordinate information from sensors, cameras are considered one of the best ways to understand how a fire is developing. A camera provides immediate feedback that fire and rescue services can use to assess and plan their response. Visual information is also considered to be very powerful, as it is easier to assess a visual image of a fire based on one's own experience than a temperature reading from a sensor in a room. Cameras are normally integrated in security systems

These sensors were thus selected for their availability, integration potential, and direct application in predicting fire development and validating the digital fire model scenarios.

None of the sensors that the fire and rescue services bring to the site are included within this recommendation. This is due to the problem with connecting them to a geographical position and a physical geometry that then can be used to predict future fire scenarios through a simulation. This does not mean that the sensors cannot provide valuable information to the fire and rescue services, but their information is more suitable to be interpreted directly by the firefighters at the scene or in an incident and command center.



6. Conclusions

This study confirms that sensor technologies and digital information systems already exist in many modern buildings, but their application in operational firefighting remains fragmented and underutilized. Through literature review, direct interviews, and sensor mapping, this work has fulfilled its stated goals and addressed all elements of its purpose:

- Relevant sensors and data types have been identified and categorized.
- Use cases for fire modeling and real-time decision support have been explored.
- Data reliability and uncertainty have been assessed.
- Integration potential has been reviewed.
- A clear set of sensors for the prediction of fire growth has been selected based on their relevance to predictive fire modeling.

The study highlights the significant potential of integrating sensor data into firefighting operations, while also exposing the many practical, technical, and organizational barriers and challenges that remain. Although numerous sensors are already present in modern buildings, their primary purpose is typically not aligned with firefighting needs. Instead, they serve other functions such as HVAC optimization, security, or energy efficiency. As a result, systems are rarely designed or structured to provide clear, real-time, and reliable insights to the fire service.

Based upon the results from the report a layered approach is essential

- **Structural layer:** Where is the sensor installed? What building system is it connected to (ventilation, fire alarm, security)?
- **Data layer:** What parameters are measured (e.g., temperature, pressure, CO₂)? What are the update intervals and reliability profiles?
- **Interpretation layer:** How can this data be translated into actionable insights (e.g., fire growth, evacuation needs, system failures)?

Understanding and combining these layers is necessary to transform data into operational value.

For certain systems, such as fire and security systems a structure as described above is partially available already, while other systems require major changes to their structure in order to be compatible.

When it comes to sensors that the fire and rescue service bring to the site, the study shows that there are major difficulties in using sensor values to simulate the growth of a fire. That said, since the fire and rescue services bring the system and the underlying system for information gathering and visualization to the site, many other problems are avoided, such as access to data, interface design and updates based on the building's life cycle.

This type of system is therefore an excellent complement to the sensors within a building and can provide fire and rescue service with a reliable base for decision-making. An important factor is that the information gathered from such a system is limited to the locations from which data can be retrieved.



6.1. Digital twins offer promise but require preparation

While digital twins provide a compelling framework for visualizing sensor data and predicting fire development, their effectiveness is only as strong as the quality of the underlying data. Without proper lifecycle data management, from BIM modeling to operational maintenance, digital twins risk becoming outdated or incomplete. Moreover, current implementations are largely experimental or site-specific. Broader adoption will require integration with national building registers and mandates for standardized fire safety metadata in digital models.

6.2. The fire and rescue services require structured, prioritized data—not raw data streams

Operational decision-making depends on clarity and speed. Sensor values must be contextualized, mapped, and filtered, in real-time. A raw data feed of all values from all building systems is unmanageable during an emergency. Instead, systems must highlight anomalies (e.g., smoke in multiple zones), support tactical mapping (e.g., where doors are open/closed), and confirm protection system status (e.g., sprinkler flow).

Sensors that the fire and rescue service bring to the site have a clear advantage here since the underlying system for information gathering and visualization are designed for this specific purpose. It will also be possible for the fire and rescue service to train with the system and hence be familiar with the visualization of the data.

6.3. Sensor utility is limited without clear data governance

Ownership and access are critical issues. Today, the building owner or system supplier controls most data—rarely is there a technical or legal path to provide this data to the fire and rescue services during an incident. Data availability must be clarified through pre-established agreements between stakeholders, on-trigger sharing mechanisms (e.g., access enabled upon alarm) or through cloud platforms that host non-sensitive building data in advance. Without this, Smart Firefighting remains more theoretical than practical.

This challenge does not apply to sensors brought to the site by the fire and rescue services, as they retain full control over both the data and its use.

6.4. Many sensors are mature—but not yet used for firefighting

Temperature sensors, smoke detectors, CO sensors, and door status sensors are standard in many systems. However, few are configured or integrated to support real-time emergency response. Some promising technologies—such as Bluetooth-based occupancy tracking, fiber-optic temperature lines, or AI-analyzed camera feeds—are available but not yet broadly implemented in this domain.



6.5. There is a cost—but also a value proposition

Developing and maintaining a smart sensor system or digital twin has a cost. It requires investment in system design, integration, data storage, and user training. However, this must be weighed against potential value: faster response, reduced property damage, fewer lives lost, and more efficient use of public resources. Particularly for complex, high-risk, or high-value buildings, such as hospitals, public infrastructure, or cultural heritage sites, this investment can be justifiable. Insurance companies, municipalities, and large property owners are likely candidates to drive implementation.

For some existing systems, part of this cost is already built into the current structure of the systems, such as fire alarms. This is because the regulations already require the implementation of the cost-driving measures mentioned above.

For sensors that the fire and rescue services bring to the site the cost and the value will be easier to evaluate since they are bought and used for solely one purpose. The sensors can also be used in all fires and are hence not connected to one property owner or one building. This means that the value will be higher and hence will the cost be easier to justify.

6.6. The future lies in collaboration and standardization

No single stakeholder can implement Smart Firefighting systems alone. Collaboration between the fire and rescue services, property owners, system vendors, regulators, and researchers are essential. Standards such as SBF 110:8, SBF 1021, NFPA 950/951, ISO 16739 (IFC), and national frameworks must be embraced, extended, and enforced. Digital fire safety must be built into procurement, construction, operation, and renovation.

The same can be said for sensors that the fire and rescue services bring to the site. If there were a framework for both visualization and sensor integration, new sensors and new technologies could be implemented and integrated into existing systems more rapidly.

Smart Firefighting is not about replacing human judgment; it is about providing decision-makers with better tools. A digital twin will not extinguish a fire, but it may guide the hose team more safely. A CO₂ sensor will not rescue a trapped occupant, but it may direct the search to the right room. The goal is not automation; it is augmented decision-making. With reliable data, structured systems, and strategic collaboration, Smart Firefighting can move from a vision to an operational reality.



6.7. Recommendations

To identify the fastest and most practical path toward improving conditions for the fire and rescue service, this report highlights the following steps. The bullets below are presented in a logical sequence, reflecting how these conditions can be progressively enhanced.

- Ensure that all information from the fire alarm system can be quickly and easily accessed by fire and rescue service personnel when they arrive.
- Make fire alarm information available remotely
- Expand remote access to include analyzed sensor information from other systems than the fire alarm. This could be from the security system or the ventilation system and include other sensor data, e.g. temperature, door status and camera feeds.
- Prioritize structured data, their context and visualization, i.e. highlight anomalies such as smoke or heat clusters, alarms and sprinkler system status
- Develop shared standards and interoperable systems by promoting frameworks such as NFPA 950/951, IFC (ISO 16739) and national equivalents, i.e. accelerating integration, vendor innovation and cross-stakeholder collaboration
- Integrate sensor information with digital twins and advanced analysis addressing firefighting needs and enable the use of AI to enable advanced applications.



7. References

Abrahamsson, O., & Svensson, S. (2025). *Smart insatsstöd - Data från smarta byggnader som ett stöd för räddningstjänsten* (Master's thesis). Lund University, Faculty of Engineering, Division of Fire Safety Engineering, Lund, Sweden.

Advanced Fire Systems. (2022). *Fire alarm system integration with building management systems (BMS)*. Retrieved from <https://www.advancedco.com/fire-alarm-system-integration-with-bms/>

Almatared, M., Liu, H., Abudayyeh, O., Hakim, O., & Sulaiman, M. (2024). *Digital-twin-based fire safety management framework for smart buildings*. *Buildings*, 14(1), 4. <https://doi.org/10.3390/buildings14010004>

Bhargav, D., Buda, A., Nurminen, A., & Främling, K. (2018). *A framework for integrating BIM and IoT through open standards*. *Automation in Construction*, 95, 35-45. <https://doi.org/10.1016/j.autcon.2018.07.022>

Blecha, T., Soukup, R., Kaspar, P., Hamacek, A., Reboun, J. *Smart firefighter protective suit – functional blocks and technologies*. (2018). 2018 IEEE International Conference on Semiconductor Electronics (ICSE)

Brandskyddsföreningen. (2019) *Insatsplan 2019*. Brandskyddsföreningen

Brandskyddsföreningen. (2021) *SBF 1021:3 Regler för orienterings- och serviceritningar för brandlarm, utrymningslarm med talat meddelande och gassläcksystem*. Brandskyddsföreningen

British Standards Institution. (2021). *Draft BS 8644-1: Digital management of fire safety information – Part 1: Design, construction, handover, asset management and emergency response – Code of practice*. BSI Standards Limited.

Codina, M., Oriol-Casals, A., Prats, M., & Amigó, V. (2019). *Augmented reality for emergency situations in buildings with the support of indoor localization*. 13th International Conference on Ubiquitous Computing and Ambient Intelligence UCAmI 2019. <https://doi.org/10.3390/proceedings2019031076>

Cowlard, A., Jahn, W., Abecassis-Empis, C., Rein, G., & Torero, J. L. (2010). *Sensor assisted fire fighting*. *Fire Technology*, 46(3), 719-741. <https://doi.org/10.1007/s10694-008-0069-1>

Dublin Fire Brigade & BIMcert Project (2022). *Digital Twin for Emergency Response (DTER)*.

European Commission. (2010). *PROeTEX – Protection e-Textiles: Micro-Nano-Structured fiber systems for Emergency-Disaster Wear*. Community Research and Development Information Service (CORDIS). <https://cordis.europa.eu/project/id/026987>

Frånberg et al. (2023). *IoT i hus och anläggning: Översikt och rekommendationer*. Smart Built Environment.

Jiang, L., Chaoyu, S., Wang, C., Pan, Z. (2023). *Intelligent control of building fire protection system using digital twins and semantic web technologies*, *Automation in Construction*, Volume 147, March 2023.



Johansson, N., Karlsson, B., & Svensson, S. (2024). Building fire dynamics and safety. In X. Huang & W. C. Tam (Eds.), *Intelligent building fire safety and Smart Firefighting* (pp. 3-23). Springer Nature Switzerland AG. <https://doi.org/10.1007/978-3-031-48161-1>

Kanangkaew, S., Asawatae, L., & Faiy, A. (2023). *A real-time fire evacuation system based on the integration of BIM and augmented reality*. Journal of Building Engineering, 67, 105883. <https://doi.org/10.1016/j.jobbe.2023.105883>

Khajavi, S.H., et al. (2019). *Digital twin: Vision, benefits, boundaries, and creation for buildings*. Automation in Construction, 118, 103226.

Khalaf, K., Choutri, K., Lagha, M., Meshoul, S., Batouche, M., Bouzidi, F., & Charef, W. (2023). *Fire detection and geo-localization using UAV aerial images and YOLO-NAS*. Applied Sciences, 13(20), 11548. <https://doi.org/10.3390/app132011548>

Köse, E., & Eren, A. (2024). *Multi-criteria decision analysis of firefighter wearable technologies*. Journal of Safety Research. Advance online publication. <https://doi.org/10.1016/j.jsr.2024.05.012>

Leucker, M., Sachenbacher, M., & Vosteen, L. B. (2023). *Digital twin for rescue missions – A case study*. In Proceedings of the Workshop on Applications of Formal Methods and Digital Twins, co-located with the 25th International Symposium on Formal Methods (FM 2023) (Vol. 3507). CEUR-WS.org. <https://ceur-ws.org/Vol-3507/paper4.pdf>

Liu, Y., Zheng, C., Liu, X., Tian, Y., Zhang, J., & Cui, W. (2023). *Forest fire monitoring method based on UAV visual and infrared image fusion*. Remote Sensing, 15(12), 3173. <https://doi.org/10.3390/rs15123173>

Lovreglio, R., Feng, Z., & Thompson, P. (2021). *Letter to the editor: Automation in fire safety engineering using BIM and generative design*. Fire Technology. <https://doi.org/10.1007/s10694-021-01125-x>

Malagnino, A., Corallo, A., Lazoi, M., & Zavarise, G. (2022). *The digital transformation in fire safety engineering over the past decade through Building Information Modelling: A review*. Fire Technology, 58(6), 3317-3351. <https://doi.org/10.1007/s10694-022-01313-3>

McKinzie, K., & Truthän, S. (2024, mars). *Enhancing fire-rescue and EMS operations with SMART systems*. Fire Engineering. <https://www.fireengineering.com/firefighting-equipment/enhancing-fire-rescue-and-ems-operations-with-smart-systems>

National Fire Protection Association. (2020). *NFPA 950: Standard for Data Development and Exchange for the Fire Service (2020 utg.)*. National Fire Protection Association.

National Fire Protection Association. (2022). *NFPA 951: Guide to Building and Utilizing Digital Information (2022 utg.)*. National Fire Protection Association.

Hamins, A. P., Grant, C., Bryner, N. P., Jones, A. W., & Koepke, G. H. (2015). *Research roadmap for smart fire fighting* (NIST Special Publication 1191). National Institute of Standards and Technology. <https://doi.org/10.6028/NIST.SP.1191>

Norén, J., Delin, M., Nystedt, F., & Strömgren, M. (2018). *Fire protection engineering in a BIM environment* (Teknisk rapport). Briab Brand & Riskingenjörerna AB. https://briab.se/wp-content/uploads/2019/04/SBUF_13316-FireprotectionengineeringinaBIMenvironment.pdf



Papadopoulos, G., Loupos, P., Tsoukalas, M., & Anagnostopoulos, N. (2024). *Integrating drone and wearable sensor data for live incident dashboards*. *Safety Science*, 174, 106061

. <https://doi.org/10.1016/j.ssci.2023.106061>

SDC Security. (2023). *EH Series electromagnetic door holder and releasing devices*. Retrieved from <https://sdcsecurity.com/EH-Series-Electromagnetic-Door-Holder-and-Releasing-Devices.htm>

Siddiqui, A. A., Ewer, J. A., Lawrence, P. J., Galea, E. R., & Frost, I. R. (2021). *Building Information Modelling for performance-based fire safety engineering analysis – A strategy for data sharing*. *Journal of Building Engineering*, 42, Article 102794. <https://doi.org/10.1016/j.jobe.2021.102794>

Siemens (2022). *Desigo CC: Integrated Building Management for Smart Safety*.

Singh, U., Determe, J. F., Horlin, F., & De Doncker, P. (2020). Crowd Monitoring: State-of-the-Art and Future Directions. *IETE Technical Review*, 38(6), 578–594.

<https://doi.org/10.1080/02564602.2020.1803152>

Sousa, M. J., Moutinho, A., & Almeida, M. (2020). *Thermal infrared sensing for near real-time data-driven fire detection and monitoring systems*. *Sensors*, 20(23), 6803. <https://doi.org/10.3390/s20236803>

Strömgren, M., Norén, J., Eriksson, E., Hiort, F., & Furenberg, A. (2021). *Kravställningsstöd för digitaliserad brandskyddsinformation i fastigheter*. Briab Brand & Riskingenjörerna AB.

Strömgren, M., Norén, J., Svensson, J., Furenberg, A., & Shisha, T. (2021). *Den obrutna informationskedjan för brandskydd*. Briab Brand & Riskingenjörerna AB.

Sun, H., Xu, R., Luo, J., & Cheng, H. (2025). *Review of the application of UAV edge computing in fire rescue*. *Sensors*, 25(11), 3304. <https://doi.org/10.3390/s25113304>

Svensson, J., & Strömgren, M. (2022). *Riktlinjer och principer för maskintolkningsbara byggregler*. Briab Brand & Riskingenjörerna AB.

Telit Communications. (2019, 20 februari). *IoT Devices for Firefighters: Key Certifications and Features*. <https://www.telit.com/blog/iot-devices-firefighters-certifications-features/>

Volt, J., Toth, Z., Glicker, J., De Groote, M., Borragán, G., De Regel, S., Dourlens-Quaranta, S., & Carbonari, G. (2020). *Definition of the digital building logbook*. European Commission, Executive Agency for Small and Medium-sized Enterprises (EASME).

Wehbe, R., & Shahrour, I. (2021). *A BIM-based smart system for fire evacuation*. *Future Internet*, 13(9), 221. <https://doi.org/10.3390/fi13090221>

Yu, B., Yu, S., Zhao, Y., Wang, J., Lai, R., Lv, J., & Zhou, B. (2025). *Intelligent firefighting technology for drone swarms with multi-sensor integrated path planning*. *Drones*, 9(5), 348. <https://doi.org/10.3390/drones9050348>

Zhang, T., Wang, Z., Zeng, Y., Wu, X., Huang, X., Xiao, F. (2022) *Building Artificial-Intelligence Digital Fire (AID-Fire) System: A Real-scale Demonstration*, *Journal of Building Engineering*. <https://doi.org/10.1016/j.jobe.2022.105363>



8. Appendix Interviews

8.1. Securitas System

8.2. Dräger

8.3. Interspiro

8.4. Linköping University



Summary interview
Smart Firefighting
Appendix 8.1 Securitas Systems



The use of sensors for “Smart Firefighting”

2025-05-27



Projektinformation

Project name: Using innovative digital tools for efficient and intelligent emergency services

Person leading the interview: Oskar Ekberg

Organisation: Securitas Systems

Project leader: Oskar Ekberg
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Simon Svensson

Date	Type of document	Written by	Controlled by
2024-10-22	Anteckningar möte	Oskar Ekberg	Nils Johansson
2025-05-27	English version (Summary of interview)	Oskar Karlberg	Oskar Ekberg



1 INTRODUCTION

1.1 Purpose

Notes from the completed interview are compiled in this document, and the interviewed person/organization will then have the opportunity to review their responses and make edits or additions if needed.

1.2 Scope

Handlingen omfattar intervjufrågor kopplade till inventering av sensorer som kan nyttjas för smart firefighting.

1.3 Interview occasion

The interview was conducted 2024-10-22.

1.4 Attendance

Representative: Jonas Jern (Head of Business and Offering)
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Other representatives Securitas

Tom Vetterlein	(Business Manager – Services)
Robert Törnkvist	(Product Engineer – Fire Alarms)
Carolina Lindros	(Offering Specialist)
Per Öberg	(Consultant manager - Fire)
Gustav	(Head of Video and IT)



2 BACKGROUND

The basic hypothesis of the project is that better use of data from sensors, in the building or sensors taken to the scene of an incident, can provide a basis for decision-making that leads to a more efficient and safer response to a possible fire.

The project will investigate how data from various types of sensors in buildings can be used together with a digital fire model (a so-called digital twin) to enable more effective fire and rescue services. This can be applied both in preventive work and in operational efforts. An important part of the project is to examine what types of data can be collected and how this data can be used to support better decision-making.

The current phase examines what sensors are currently available in equipment used by emergency services, what is under development and what is needed in the future.

One example of sensors currently in use is a smoke detector connected to a fire alarm system. When the threshold for optical density is reached, the detector sends a signal to the fire alarm control panel. The information obtained from this is the specific detector was activated. Using a building layout that shows the detector numbers and their locations, the fire and rescue services can then identify which room or rooms should be investigated.

There are four areas of interest to determine which sensors can be used for the project. These are fire dynamics, the status of the building's fire protection, the environment within the building and the capabilities of the emergency services.

In the area of fire dynamics, sensors are needed to help position the fire and determine its growth or spread. For the status of the fire protection of the building, sensors of interest are those that can help determine the status of both active and passive systems. Sensors that can help to determine the environment are those that can help to see if there are people in the building and their movement but also about the composition of the air, temperatures, etc. to assist the emergency services, sensors are needed that can monitor the status of the smoke divers and their positions.

The data obtained also needs to be presented and, if possible, aggregated in such a way that the person receiving the data can understand it. As an example, during an incident there may be an incredible amount of data available from sensors but for the emergency services it may be difficult to interpret the data and compile the data from different types of sensors.



3 INTERVIEW QUESTIONS

3.1 Sensors in Use/Available Today

Under denna punkt utgår frågeställningen från de sensorer som är aktuella och som finns att tillgå i dagsläget.

This section addresses sensors currently available and in use.

3.1.1 What sensors do you come into contact with today?

Sensors for fire dynamics:

Within fire alarm systems, there are currently various detectors used to assess fire development. These are primarily designed to detect fires and not necessarily tested for high temperatures. There are detectors available for smoke, heat, gas, and combination detection. Cameras that can be used are flame detectors and thermal imaging cameras.

Special sensors that were discussed:

Mobotix (camera with thermal and optical lenses,) approved for fire alarms (temperature, rate of temperature rise, time-controlled) – are being implemented in Insatscenter 24, though live streams are not yet active.

Sensorlaser Pro -Fiberdetection, linear heat detector and temperature sensor. Has been tested up to 750 °C for 2–3 hours.

The building's fire protection status:

It is possible to connect various components to the fire alarm system, such as monitoring of fire doors, etc., but it becomes more effective through a centralized system like UNISON, where different systems—such as access control and ventilation systems—can be integrated and linked together. The status of multiple systems can then be displayed through a unified interface.

The environment within the building:

Kameror är det givna förstavalet för detta.

People counting (via cameras) is available and used but is perceived to have major limitations. Facial recognition (which can be problematic due to privacy concerns) is under development, and suppliers are working to address these privacy issues. The technology was originally developed for retail stores to analyze what drives traffic to various areas. However, it does not yet provide completely accurate results due to network issues and the relatively new nature of the technology. Much of today's development focuses on software for existing cameras to enable new functionalities.



Cameras have the capability to stream live footage during an event, providing immediate verification of conditions on site. Some cameras may also include built-in speakers and microphones.

Access control systems can be used to measure flow through doors, but they do not provide accurate values unless it can be ensured that only one person passes through the door at a time.

Multisensors are becoming more common (detecting smell, heat, CO₂, humidity, people, vapor from e-cigarettes, air quality, sound, infrared—e.g., Motorola Halo). These are not designed for fire alarms but are integrated with security systems.

Abilities of the Fire Rescue and Services:

There are security systems/applications designed for lone worker protection that could also be used for tracking personnel.

A specific application has been developed for the healthcare sector, often based on WiFi within buildings. Wireless fire alarms still present challenges and are not yet fully reliable, but could potentially be used for monitoring movements within a building via WiFi.

3.1.2 What information do you get from the sensors you come into contact with today?

Everything we want – the problem is perceived more in how we interpret the data and how it can be communicated to the fire rescue services.

3.1.3 Are the updates real-time or do you only receive an activation signal?

Security systems always provide live updates, but in a superior system, the level of detail from the sensors can vary depending on the degree of integration between the subsystem and the superior system.

3.1.4 Are the signals you receive from the sensors addressable? Is the address system-based or location-based?

In a fire alarm system, the development is moving towards all components being addressable.

Sensors – the geographical connection is made via the sensor's technical number, and it's placement on the blueprint. UNISON then links this with the technical number that triggers the alarm in the system. The connection is thus made through unique numbers on the different devices, which are then geographically linked to a blueprint.

Modbus and Bachnet can be connected to UNISON and may require manual handling to associate with a physical location.

UNISON currently uses 2D models – 3D models are not widely used in security systems yet.



3.1.5 Through what system do you access the data collected from the sensors? Is it possible to forward this information?

The fire alarm system is currently connected to a standalone alarm center, from which information can be forwarded to the Fire and Rescue Service. Insatscenter24 was launched in 2007, and the first customer was connected in 2011.

Insatscenter24 (Securitas' in-house alarm center) offers two types of subscriptions: Basic, which transmits fire and fault alarms (same as SOS Alarm); Pro, which provides real-time information in plain text (sends this with floor plans) that can be sent directly to the fire and rescue service, provided they have a compatible system.

In a case study conducted by Securitas, it was shown that during a response at Västervik Hospital, 15 minutes were saved by being able to go directly to the building that triggered the alarm. The Pro service is designed for much more than just alarms – the customer pays for the subscription, and it is free of charge for the fire and rescue service to receive the information. Technically, SOS Alarm is used as the intermediary for this information. This means Securitas sends the data to SOS Alarm, which then forwards it to the fire and rescue service. There are also regulatory frameworks that govern how this communication must be conducted.

The challenge is perceived to lie in what the fire and rescue service can and/or is willing to receive, not necessarily what can be measured.

3.1.6 How do you use the information obtained from the sensors?

The technology is capable of a great deal – the limitations lie more in regulations, and the possibilities also depend on the technology available to the fire and rescue service. The development is considered to work well in places where the fire and rescue service has its own alarm center and is open to new technology.

Currently, there is great variation between different fire departments. For example, RSGBG (Greater Gothenburg Fire and Rescue Service) only wishes to receive alarms and faults, even though they could access more information.

A limiting factor is assessed to be that different fire departments operate differently and have different legal conditions. This means that for each individual organization, multiple separate agreements are required for data sharing with the fire and rescue service.

3.1.7 Do you consider the data from the sensors to be sensitive information? If so, how is security managed?

The requirements for connected sensors are being tightened through NIS 2 (a cybersecurity law that has been implemented in Europe and will become law in Sweden by the summer of 2025). CRA (Cyber Resilience Act) – sets product requirements based on cybersecurity standards and demands that products be upgradable.

All information is currently stored with the customer, not the fire and rescue service – i.e., the customer owns the data.



3.1.8 How reliable is the information collected from the sensors?

It depends on the application – the right type of installation and quality. The buzz around the Wi-Fi connected things has decreased, as the reliability is not always very good.

3.1.9 Do the sensors have any threshold values where the measurements become unreliable?

This varies depending on the specific sensor.

3.1.10 Do you experience any shortcomings with the sensors currently in use?

Videoanalys glapp i uppkoppling kan göra att man missar videorutor och personer, således inte 100%. Vikten av att säkerställa den personliga integriteten gör också att all teknik inte kan användas fullt ut.

Video analysis can suffer from connectivity issues, which may cause video frames and people to be missed, meaning it is not 100 % reliable. The importance of ensuring personal privacy also limits how thoroughly the technology can be utilized.

3.1.11 Other thoughts?

Inte så stort intresse från försäkringsbolag – Inte sugna på att driva. Affärsdrivna vill ha affären och de kan skriva egna avsteg.

Currently, there are 11 approved alarm centers in Sweden. As far as Securitas is aware, no other provider is currently able to transmit the same level of information as Insatscenter 24.

Property owners are not always interested in additional equipment, as they do not directly benefit from the fire alarm system – the benefit is primarily for the establishment. The users, in turn, are not always able to influence the purchase and installation of the fire alarm system. Ownership structures can therefore complicate matters.

There is not much interest from insurance companies – they are not eager to drive this forward. Commercially driven actors want to close deals and can write their own exemptions.

3.2 Sensors under Development / Upcoming Sensors

This section focuses on sensors that will be available in the near future but have not yet been put into active use.

3.2.1 What types of sensors are under development / upcoming?

Cloud solutions – sending links where information can be shared, possibly an app that enables this.

Web interfaces with screens to enable easier sharing of information.

Multisensors are being developed.

Video analyses and verification via video systems of detection coming from fire alarms.



Portable personal alarms that are also multisensors (carbon monoxide).

Tracking of people.

Mobile phones are increasingly useful for measuring and communication possibilities

Not necessarily many new sensors, but more coordination of different systems and more efficient data analysis

Development of fire alarms is a bit slower due to strict regulations. If the products have a classification – must be EN 54 – other products can be integrated if there is no classification, but it is not necessarily allowed to alarm the rescue service via these.

Many CO2 sensors in ventilation systems.

3.2.2 What information will be obtainable from these sensors?

There are very large possibilities with the technology, but we find it difficult to analyze the data and draw relevant conclusions.

Development will likely occur in data analysis.

3.2.3 How do you hope to use the sensors?

There is a lot of data today but we do not really the tools to analyze it. As this develops, data from sensors can be combined and more detailed conclusions/predictions can be made

3.2.4 Other thoughts?

There is a challenge in that the fire rescue service is municipal, and therefore there is no unified regulation regarding how detailed information should be delivered. This makes it cumbersome, supplier-dependent, and difficult to develop.

The visual aspect is considered important, and there is a desire to be able to see what is happening. Connecting and activating cameras via other sensors may become important.

DISTRUBUTION LIST

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Company	Name	Address
Securitas	Jonas Jern	jonas.jern@securitas.com



Summary interview
Smart Firefighting
Appendix 8.2 Dräger



The use of sensors for “Smart Firefighting”

2025-05-26



Project information

Project name: Using innovative digital tools for efficient and intelligent emergency services

Person leading the interview: Stefan Svensson (MSB), Nils Johansson (LTH), Oskar Ekberg (Briab)

Interviewed organisation: Dräger Sverige AB, Patrik Karlsson Almgren

Project ledader: Oskar Ekberg
oskar.ekberg@briab.se
08-410 102 50

Participants LTH/Briab Stefan Svensson (MSB)
Nils Johansson (LTH)
Oskar Ekberg (Briab)

Datum	Type of document	Written by	Controlled by
2024-11-08	Anteckningar möte	Oskar Ekberg	-
2025-05-26	English version (Summary of interview)	Oskar Karlberg	Oskar Ekberg



1 INTRODUCTION

1.1 Purpose

The purpose of this document is to serve as a basis for interviews for WP 1, smart firefighting.

Answers obtained during the interview are recorded in this document and the interviewee is then given an opportunity to read through their answers and edit or complete the answers.

1.2 Scope

The document includes interview questions linked to the inventory of sensors that can be used for smart firefighting.

1.3 Interview session

Interview has been conducted on 2024-11-08

1.4 Attendance

- Stefan Svensson, MSB
- Nils Johansson, LTH
- Oskar Ekberg, Briab
- Patrik Karlsson Almgren, Dräger



2 BACKGROUND

The basic hypothesis of the project is that better use of data from sensors, in the building or sensors taken to the scene of an incident, can provide a basis for decision-making that leads to a more efficient and safer response to a possible fire.

The project will investigate how data from various types of sensors in buildings can be used together with a digital fire model (a so-called digital twin) to enable more effective fire and rescue services. This can be applied both in preventive work and in operational efforts. An important part of the project is to examine what types of data can be collected and how this data can be used to support better decision-making.

The current phase examines what sensors are currently available in equipment used by emergency services, what is under development and what is needed in the future.

One example of sensors currently in use is a smoke detector connected to a fire alarm system. When the threshold for optical density is reached, the detector sends a signal to the fire alarm control panel. The information obtained from this is the specific detector was activated. Using a building layout that shows the detector numbers and their locations, the fire and rescue services can then identify which room or rooms should be investigated.

There are four areas of interest to determine which sensors can be used for the project. These are fire dynamics, the status of the building's fire protection, the environment within the building and the capabilities of the emergency services.

In the area of fire dynamics, sensors are needed to help position the fire and determine its growth or spread. For the status of the fire protection of the building, sensors of interest are those that can help determine the status of both active and passive systems. Sensors that can help to determine the environment are those that can help to see if there are people in the building and their movement but also about the composition of the air, temperatures, etc. to assist the emergency services, sensors are needed that can monitor the status of the smoke divers and their positions.

The data obtained also needs to be presented and, if possible, aggregated in such a way that the person receiving the data can understand it. As an example, during an incident there may be an incredible amount of data available from sensors but for the emergency services it may be difficult to interpret the data and compile the data from different types of sensors.



3 INTERVIEW QUESTIONS

Dräger is a global corporation in the fields of medical technology and safety technology.

Dräger develops and manufactures products in medical and safety technology. They protect, support and save people's lives around the world in hospitals, emergency services, government agencies, mining and industry.

Examples of equipment intended for rescue services are breathing apparatus, masks, helmets and gas detection equipment. Detection equipment are both fixed and portable.

3.1 Sensors available today

This section is based on the sensors that are currently relevant and available.

3.1.1 What sensors do you currently come into contact with?

Sensors for fire dynamics:

Within Dräger's product range, there are thermal imaging cameras designed for use in rescue operations. The product is called Dräger UCF Fire Core and is used by attaching a camera unit to the firefighter's helmet. This unit can then be connected to a display inside the mask via Bluetooth. The camera unit can also be detached to look around corners etc.

The environment within the building:

Dräger offers a range of portable and fixed sensors for gas measurement. Measurement equipment can be selected based on the gases that are relevant to monitor. Portable sensors can be connected to a digital interface via Bluetooth to a mobile phone, which can then transmit the data to provide both the location and measurement values of the portable devices.

Dräger offers portable gas detectors for most gases.

Abilities of the Fire Rescue and Services:

Dräger has developed a concept focused on the health of firefighters. At the core of this concept is the AirBoss Connect backplate. It measures the cylinder pressure (and can issue alerts) and can also send an evacuation signal.

The fire rescue service's radio devices can also be used to provide positioning within buildings.

3.1.2 Are the updates in real time or do you only receive an activation signal?

All sensors provide real-time data, and most of them can be connected to transmit the signal further. The connection is established through their own systems and software.



3.1.3 Are the signals you receive from the sensors addressable? Is the address system-based or location-based?

The product AirBoss Connect creates its own network for communication and positioning. Technically, it works by setting up a base station at the point of attack for the operation, which each firefighter connects to. Signal boosters can also be brought into the building to strengthen the network.

The data from the units is then presented in an app that you download onto a tablet (*Fire Ground*)

3.1.4 Through which system do you access the data received from the sensors? Can the information be forwarded?

The data is collected via the FireGround application, and it is also possible to forward it to an internal command center.

3.1.5 Do you consider the data received from the sensors to be sensitive information? If so, how is the security handled?

Dräger FireGround operates on an internal and secure local network which significantly reduces the risk of unauthorized access.

3.1.6 How reliable is the information from the sensors?

The portable gas detection equipment is designed to be robust and portable. However, the detectors are not built for extreme temperatures that may occur temporarily during firefighting operations, although they are expected to withstand such conditions for short periods.

In addition to portable sensors, there are also fixed gas sensors, which are designed for normal temperature ranges.

3.1.7 Do the sensors have any threshold values beyond which the measurements become unreliable?

All sensors are calibrated for a specific measurement range, and if they are not explicitly designed for high temperatures, there is a limitation in that regard.



3.2 Sensors in Progress / Under Development

This section focuses on sensors that will be available soon but have not yet been put into active use.

3.2.1 What types of sensors are in progress / under development?

The camera is also a thermal imaging camera, with the limitations this entails in terms of image representation.

3.3 Sensors for the Future

This section focuses on sensors that are expected to be needed in the future, based on the interviewee's free thoughts.

3.3.1 What types of sensors do you think will be needed in the future?

There are portable gas detectors today that can be connected to a phone – these should also be able to connect to AirBoss, which would then forward the signal. For example, this could enable real-time data transmission from the firefighters about temperature, carbon monoxide, and explosive atmospheres.

3.3.2 How do you hope sensors will be used in the future? (Both for preventive purposes and during rescue operations)

In addition to portable detectors, there are fixed sensors that can be wired or wireless. These can be connected to the platform Gas Detection Connect. The data and system are owned by the facility owner/organization but could be made available to the fire rescue service during an operation.

In the long term, digital solutions may enable the integration of multiple products and the presentation of results in a unified, needs-based interface.



3.3.3 Other thoughts?

Patrik emphasizes that implementing innovation in safety equipment takes time. The focus must always be on ensuring that the function is safe, reliable, simple, and robust.

Based on this, it seems difficult for Dräger to collect data from products other than their own within their digital solutions, but there should be possible to send data to another system.

DISTRUBUTION LIST

This document (the original, Swedish, version) was distributed by email on 2025-03-10 to the following distribution list:

Company	Name	Address
Dräger	Patrik Karlsson	patrik.karlssonalmgren@draeger.com>

Briab – The right side of risk



Summary interview
Smart Firefighting
Appendix 8.3 Interspiro



The use of sensors for “Smart Firefighting”

2025-05-26



Project information

Project name: Using innovative digital tools for efficient and intelligent emergency services

Person leading the interview: Oskar Ekberg (Briab)

Organisation: Interspiro

Project leader: Oskar Ekberg
oskar.ekberg@briab.se
08-410 102 50

Date	Type of document	Written by	Controlled by
2025-02-28	Svar på frågor	Thomas Storbacka	
2025-05-26	English version (Summary of interview)	Oskar Karlberg	Oskar Ekberg



1 INTRODUCTION

1.1 Purpose

The purpose of this document is to serve as a basis for interviews for WP 1, smart firefighting.

1.2 Scope

The document includes interview questions linked to the inventory of sensors that can be used for smart firefighting.

2 BACKGROUND

The basic hypothesis of the project is that better use of data from sensors, in the building or sensors taken to the scene of an incident, can provide a basis for decision-making that leads to a more efficient and safer response to a possible fire.

The current phase examines what sensors are currently available in equipment used by emergency services, what is under development and what is needed in the future.

There are four areas of interest to determine which sensors can be used for the project. These are fire dynamics, the status of the building's fire protection, the environment within the building and the capabilities of the emergency services.

In the area of fire dynamics, sensors are needed to help position the fire and determine its growth or spread. For the status of the fire protection of the building, sensors of interest are those that can help determine the status of both active and passive systems. Sensors that can help to determine the environment are those that can help to see if there are people in the building and their movement but also about the composition of the air, temperatures, etc. to assist the emergency services, sensors are needed that can monitor the status of the smoke divers and their positions.

The data obtained also needs to be presented and, if possible, aggregated in such a way that the person receiving the data can understand it. As an example, during an incident there may be an incredible amount of data available from sensors but for the emergency services it may be difficult to interpret the data and compile the data from different types of sensors.



3 ORGANISATION

Interspiro is a manufacturer of respiratory protection equipment for firefighters in the rescue services and in industrial facilities, among other things.

4 INTERVIEW QUESTIONS

4.1 Sensors Currently in Use / Available Today

This section is based on sensors that are currently relevant and available.

Questions related to sensors for describing a building's fire protection system have been excluded at this stage, as they are not considered relevant for Interspiro as a company.

4.1.1 What sensors do you currently come into contact with?

Sensors that can be used to measure variables related to fire dynamics:

-No

Sensors that can be used to measure variables related to the indoor environment:

- No

Sensors that can be used to measure variables related to the capabilities of the fire and rescue service:

- No

4.1.2 Are the updates in real time, or do you only receive an activation signal?

4.1.3 Is it possible to distinguish readings from individual sensors and place them geographically?

4.1.4 Is it possible to link the sensor readings to a floor plan or similar layout?

4.1.5 Through which system do you access the data collected from the sensors? Can the information be forwarded?



4.1.6 Do you consider the data obtained from the sensors to be sensitive (important that it does not reach external parties)? If so, how is the security of this data managed?

4.1.7 How reliable is the information from the sensors?

4.1.8 Do the sensors have any threshold values beyond which the measurements become unreliable?

4.2 Sensors in Progress / Under Development

This section is based on sensors that will soon become available but are not yet in operational use.

4.2.1 What types of sensors are in progress / under development?

We do not offer sensors for applications such as measuring fire dynamics or room monitoring. Our sensors are solely intended to measure pressure and temperature. At present, we have no plans to integrate other types of sensors into our equipment.

4.3 Sensors for the future

This section is based on the types of sensors that are expected to be needed in the future, according to the interviewee's own thoughts.

4.3.1 What types of sensors do you think will be needed in the future?

There are ongoing discussions in the industry about the potential for integrating biometric functions with breathing apparatuses. However, such implementation currently seems to be several years away, although it may become a possibility in the long term.

One of the biggest challenges is the strict regulations on electronic equipment in explosive environments. Breathing apparatuses is subject to especially high safety requirements, with the current standard being Ex ia IIC T4. These requirements limit power consumption, voltage, and circuit design. In many cases, the regulations for breathing apparatuses are stricter than for other portable equipment, making it difficult to integrate advanced electronics without compromising safety.

4.4 Other thoughts?



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This document (the original, Swedish, version) was distributed by email on 2025-02-28 to the following distribution list:

Company	Name	Address
Interspiro	Thomas Storbacka	

Briab – The right side of risk



Summary interview
Smart Firefighting
Appendix 8.4 Linköping University



The use of sensors for “Smart Firefighting”

2025-03-20



Project information

Project name: Using innovative digital tools for efficient and intelligent emergency services

Person leading the interview: Oskar Ekberg (Briab)

Organisation: Linköping University, Department of computer and Information Science

Project leader: Oskar Ekberg
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Date	Type of document	Written by	Controlled by
2025-03-20	Notes from interview	Oskar Ekberg	Piotr Rudol Mariusz Wzorek



1 INLEDNING

1.1 Purpose

The purpose of this document is to serve as a basis for interviews for WP 1, smart firefighting.

Answers obtained during the interview are recorded in this document and the interviewee is then given an opportunity to read through their answers and edit or complete the answers.

1.2 Scope

The document includes interview questions linked to the inventory of sensors that can be used for smart firefighting.

1.3 Interview session

Interview has been conducted on 2025-03-20

1.4 Attendance

- Oskar Ekberg Briab
- Piotr Rudol, Linköping University, Department of Computer and Information Science (IDA)
- Mariusz Wzorek, Linköping University, Department of Computer and Information Science (IDA)



2 Background

The basic hypothesis of the project is that better use of data from sensors, in the building or sensors taken to the scene of an incident, can provide a basis for decision-making that leads to a more efficient and safer response to a possible fire.

The current phase examines what sensors are currently available in equipment used by emergency services, what is under development and what is needed in the future.

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The data obtained also needs to be presented and, if possible, aggregated in such a way that the person receiving the data can understand it. As an example, during an incident there may be an incredible amount of data available from sensors but for the emergency services it may be difficult to interpret the data and compile the data from different types of sensors.

3 Interview questions

The Department of Computer and Information Science is one of the largest departments in northern Europe in its field. Research activity at IDA covers artificial intelligence, human-computer interaction, software and computer systems, and data science.

Mariusz and Piotr work with robotics for public safety. The basis for their work is that technological advances in artificial intelligence and robotics offer novel tools that first responder teams can use to shorten response times and improve the effectiveness of rescue efforts.

This interview is therefore more focused on the machines that can carry sensors to a fire scene compared to actual sensors.



3.1 Robotics that are available today

The machines that are used today are flying (drones) driven or walking. In general, all types of sensors can be applied to these machines and the main focus for Mariusz and Piotr's work is to enable the machines to work together and autonomously.

There are machines that are designed to work both indoors and outdoors and they all have cameras as well as other applications to control them as well as collect data.

Some features with relation to this is

- The machines use thermal cameras, lidar depth cameras, laser range finder to help them to move as well as creating a map of the area.
- The machines use GPS for navigation and positioning. The geolocation can be crude but can also be connected to a map
- The machines can use Simultaneous Localization and Mapping (SLAM) to build a map as they go (laser range finder, camera)
- The machines can be set up to share data between each other
- The spot robot SPOT features a mapping, localization, and autonomous traverse system collectively known as **GraphNav**. This capability is being used today by Boston Dynamics customers in the construction, oil and gas, and utilities industries for data gathering and controls monitoring applications.
- The machines could plot the sensor data in relation to a prepared map/plan drawing if they were prepared for that scenario beforehand.
- You can buy many machines of the shelf but the analysis programs that is necessary is often custom built. Of the shelf you often only get a live video stream.
- There is an issue with personal integrity which limits the usage of data analysis
- No integration of drones in existing systems first responder systems at this stage – they are normally standalone systems
- The machines are normally not designed for high temperatures
- The machines can carry different types of sensors and should not be seen as a sensor themselves but instead means to carry sensors as well as mapping of areas and connecting sensor data to a position.

3.2 More information

There is a community for Rapidly Manufactured Robot Challenge (RMRC) with has a subcategory for RESCUE robotics.

More information can be found here: <https://rrl.robocup.org/>



WARA-PS (WASP Research Arena for Public Safety), is a research arena in the Wallenberg AI, Autonomous Systems, and Software Program (WASP) supported by the Knut and Alice Wallenberg Foundation. As Sweden's largest individual research initiative, WASP fosters innovation and advancement in AI and autonomous systems.

WARA- <https://portal.waraps.org/page/about-us>

Within that project they are building a core system that combines information controls the robots and drones

<https://atlas.waraps.org/cesium/>

SENDING LIST

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Briab – The right side of risk