\

112 Indoors: Improving Emergency Response with Indoor Location and Indoor Maps

June 2026

000000

112 Indoors: Improving Emergency Response with Indoor Location and Indoor Maps

Version: 1.0
Publication date: 02/06/2026
Status of the document: FINAL

Author(s):
Brooks T. Shannon, Vice-Chair, EENA Tech & Ops Committee

Contributor(s):
Dan Craigie, GeoComm
Cristina Lumbreras, EENA

European Emergency Number Association EENA
Avenue de la Toison d’Or 79, Brussels, Belgium
T: +32/2.534.97.89
E-mail: info@eena.org

Table of contents

Executive summary

Emergencies can occur anywhere, and many occur indoors. As a result of the transition from fixed telephones to cellular telephones, a growing percentage of calls to 112 from within buildings originate from mobile phones, where determining a caller's location is challenging. While standards like Advanced Mobile Location (AML) enable the transmission of handset-based location data that has significantly improved the accuracy of mobile locations, particularly outdoors, indoor environments continue to present challenges. Even when indoor location data is available, if its accuracy is low, multi-story buildings and those with complex layouts can make it difficult for responders to quickly locate individuals when time is of the utmost importance.

Accurate indoor location is critically important, but accurate locations alone are not sufficient. To support effective emergency response, location must be interpreted within the context of the environment. Indoor maps provide this context by translating coordinates into meaningful, operational information - such as floor level, room location, and accessible routes. When indoor location is combined with indoor maps, emergency services can move from a place of potential ambiguity and lack of knowledge to actionable intelligence, enabling faster navigation to incident locations, improved situational awareness, and more coordinated response across agencies.

Harnessing this potential requires more than just advances in indoor positioning technology. Public Safety Answering Point (PSAP) and first responder systems must be able to receive, interpret, and operationalize indoor location data, including vertical (Z-axis) information, within the context of indoor maps. This requires integrating indoor maps into operational workflows, adopting interoperable standards, and establishing governance frameworks that support secure data sharing. Together, indoor location and indoor maps represent a significant opportunity to improve emergency response outcomes across Europe and beyond.

Purpose of the document

- Discuss the importance of accurate indoor location
- Learn why indoor maps are useful, especially when combined with indoor location
- Share ways that indoor maps can improve emergency response
- Detail practical considerations for implementation and governance

1. List of acronyms

- **AED**: Automated External Defibrillator
- **AGL**: Above Ground Level
- **A-GNSS:** Assisted Global Navigation Satellite Systems
- **AML**: Advanced Mobile Location
- **BLE:** Bluetooth Low Energy
- **CAD**: Computer Aided Dispatch
- **CPR**: Cardiopulmonary Resuscitation
- **ETSI**: European Telecommunications Standards Institute
- **FTM**: Fine Time Measurement
- **GDPR**: General Data Protection Regulation
- **GIS**: Geographic Information System
- **GLONASS**: Globalnaya Navigazionnaya Sputnikovaya Sistema
- **GNSS**: Global Navigation Satellite Systems
- **GPS**: Global Positioning System
- **HAE**: Height Above Ellipsoid
- **HVAC**: Heating, Ventilation, and Air Conditioning
- **IMU**: Inertial Measurement Units
- **IoT**: Internet of Things
- **LiDAR**: Light Detection and Ranging
- **NFC**: Near Field Communication
- **NG112**: Next Generation 112
- **OTDOA**: Observed Time Difference of Arrival
- **PDF**: Portable Document Format
- **PIDF-LO:** Presence Information Data Format = Location Object
- **PSAP**: Public Safety Answering Point
- **RF**: Radio Frequency
- **RFID**: Radio-Frequency Identification
- **RSSI**: Received Signal Strength Indicator
- **RTT**: Wi-Fi Round-Trip Time
- **SLAM**: Simultaneous Localization and Mapping
- **UWB**: Ultra-Wideband
- **VPS**: Visual Positioning Systems

2. Introduction: The Changing Nature of Emergency Response

Emergency communications are evolving. For decades, emergency response systems were designed around fixed-location devices, such as wireline telephones, where the location of the caller could be reliably associated with a known address. In that environment, determining where help was needed was relatively straightforward.

Today, that paradigm has shifted. Mobile devices have become the primary means of communication. People carry them everywhere = into homes, offices, schools, transport hubs, large public venues, and myriad other places. In an emergency, individuals are far more likely to reach for whatever telephone is close at hand = which is very likely a mobile phone, and not a fixed device. As a result, a significant percentage of emergency calls to 112 now originate from mobile devices, and many of those emergency calls originate from within buildings.

This shift introduces new challenges. Unlike fixed devices, mobile phones are not tied to a predefined location. Their position must be estimated in real time, often using a combination of satellite signals, network data, and onboard sensors. While these methods can provide accurate location information outdoors, indoor environments make estimating indoor location challenging. Buildings are complex environments that vary widely in size, design, and materials used in their construction. All these factors can impact the accuracy of estimated indoor locations.

In addition, buildings can contain multiple floors, interconnected spaces, restricted access areas, and features that are not visible from the outside. These factors can make it difficult to quickly reach a caller when responding, especially if a caller's indoor location accuracy is poor. In many cases, even when responders arrive at the correct building, they must still search for the person inside. This can involve navigating unfamiliar layouts, identifying the correct entrance, and moving through corridors, stairwells, and rooms without clear guidance. Each of these steps introduces delay. In emergency response, time matters. Delays of even a just few minutes can have tremendous consequences.

Next Generation 112 (NG112) represents a major evolution in emergency communications. By transitioning to an IP-based, packet-switched approach to communications and enabling the exchange of rich data - including location, text, images, and video - NG112 creates new opportunities to improve situational awareness and coordination. However, to fully realize these benefits, location information must be both accurate and actionable - especially indoors. This is where indoor location and indoor maps play a critical role.

3. Why Indoor Location Matters for 112

Location is one of the most important pieces of information in any emergency. When a call is placed to 112, call-takers must quickly determine where the incident is occurring so they can dispatch appropriate resources. In many cases, callers can describe their location verbally. However, there are situations where this is not possible. For example, a caller may be unable to speak due to injury or medical distress. They may be in a situation where speaking could put them at further risk. They may not know their exact location, or they may be in an unfamiliar environment. Language barriers can also make it difficult to communicate location information clearly. In these scenarios, where a caller cannot verbally relay their location, the ability to automatically determine a caller's location becomes critically important.

Historically, this was relatively straightforward for fixed-line devices. The location of a wireline telephone could be stored in a database and associated with a known civic address. When a call was made, that address could be delivered to the PSAP along with the call. Mobile devices, however, require a different approach.

Outdoors, technologies such as Global Navigation Satellite Systems (GNSS) and network-based positioning can provide location estimates. Advances in smartphone technology, including the use of multiple sensors and hybrid positioning methods, have significantly improved accuracy in recent years. In many cases, outdoor location accuracy can now be within a few meters. Indoors, the situation is more complex. Building materials such as concrete, steel, and energy-efficient glass can block or degrade GNSS signals. As a result, satellite-based positioning may be of poor accuracy, unreliable, or wholly unavailable inside buildings. Network-based methods can help, but their accuracy can vary widely depending on the environment and the strength of cellular signals within buildings.

To address these challenges, modern devices use a combination of techniques, including Wi-Fi signals, cellular measurements, barometric sensors, and inertial sensors to estimate location indoors. These capabilities can provide more accurate location information to emergency services using location conveyance standards like AML. These advancements represent a significant improvement over older position estimation methods that only relied on satellite and network-based positioning. In some cases, indoor location estimates can achieve accuracies of tens of meters on the horizontal plane, and a few meters vertically. However, in other cases, indoor location accuracy can be much worse given environmental conditions that can lead to signal degradation or a lack of available position methods, such as in places within buildings where no Wi-Fi is available. Location technology continues to improve, addressing these issues, and Appendix A provides further technical detail on commonly used methods to estimate indoor positions, as well as more novel methods.

Even with improved accuracy, challenges remain. Knowing that a caller is located within a particular building – or even within a certain area of that building – does not necessarily provide enough information to guide responders directly to them. In multi-story buildings, vertical location becomes especially important. A difference of just a few meters in vertical accuracy can represent multiple floors. Understanding not only where a caller is located horizontally, but also their position vertically (Z-axis), is essential for effective response. Standards such as NG112 and AML provide a pathway for delivering this information and making it actionable and interoperable. The inclusion of vertical location data opens the door to estimating a caller's floor level. But location accuracy alone does not solve the problem. To be truly useful in an operational context, location must be interpreted and translated into information that responders can act upon quickly.

4. The Indoor Location Gap

Despite significant advancements in location technology, a gap remains between knowing a location and being able to act on it effectively. This gap is most evident indoors. When a 112 call originates from within a building, location information may indicate the general area of the caller. It may even provide a reasonably accurate estimate of their horizontal and vertical position. However, without additional context, that information can be difficult to interpret, or in the worst case, completely useless.

For example, a location estimate may indicate that a caller is in the northwest portion of a building, approximately 30 meters above ground level. While this information is helpful, it does not answer several critical questions: Which floor is the caller on? Which room or space are they in? What is the best way to enter the building? Which stairwell or lift provides access to that location? Are there obstacles or restricted areas along the way?

Without answers to these questions, responders need to expend time and effort to manually search for the caller. In large or complex buildings, this search can take a very long time. Responders may need to move from floor to floor, check multiple rooms, and navigate unfamiliar layouts. In high-risk situations such as fires, medical emergencies, or security threats, these delays can have serious consequences.

This is not simply a technical challenge; it is an operational one. Emergency response depends on the ability to quickly translate information into action. Location data that cannot be easily understood or applied within operational systems can limit its effectiveness, even if it is technically accurate. In other words, location is only valuable if it can be used. Bridging this gap requires more than improved positioning technologies. It requires systems and data that provide context and support decision-making in real time. This is where indoor maps become essential.

5. From Location to Actionable Intelligence Using Indoor Maps

To support effective emergency response, location information must be transformed into actionable intelligence: information that can be immediately understood and used to make decisions. In the context of emergency communications, this means enabling call-takers, dispatchers, and first responders to quickly determine where an incident is occurring, how to respond, and how to arrive on scene as quickly as possible.

When a 112 caller's location is displayed on a map that only shows a building footprint or an empty space, it can be difficult to determine where the caller actually is. A location estimate might indicate that the caller is in the northwest corner of a building and approximately 30 meters above ground level. However, without additional context, responders must still interpret what that means in practice, including which floor corresponds to that height, which rooms are located in that area, and how to navigate to that location once they arrive.

Indoor maps provide the context necessary to transform indoor location into actionable intelligence. At its most basic level, an indoor map represents the layout of a building.

It can show rooms, corridors, stairwells, lifts, entrances, and other structural elements. When location information is overlaid onto an indoor map, it becomes possible to understand not just where a caller is located in abstract terms, but where a caller is within a building in a way that is meaningful for response.

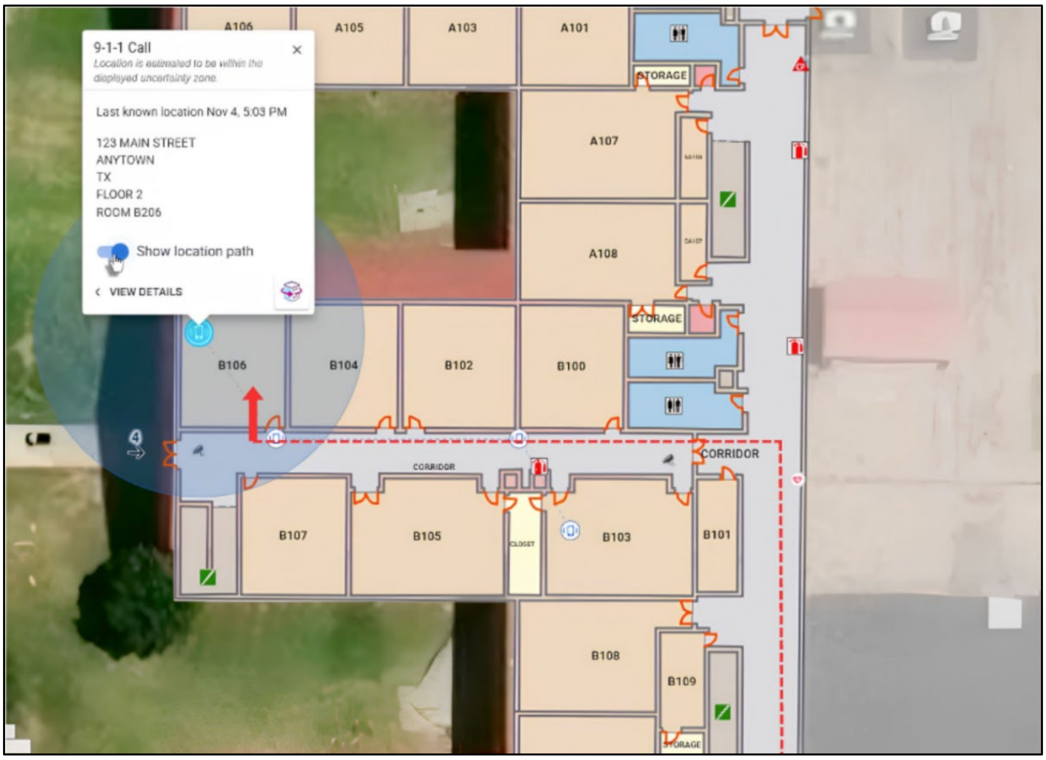

Figure 1. The location of an emergency call overlaid onto an indoor map. The blue dot represents the caller's estimated location, with the location's uncertainty represented by the transparent blue circle. The dashed red line indicates the optimal route that responders should follow to reach the caller's location. Image courtesy of GeoComm.

Instead of seeing a set of coordinates, a call-taker can see that a caller is in a specific room on a particular floor. A dispatcher can identify the nearest entrance and determine the best route through the building. And, a first responder can navigate directly to the location, rather than searching for the caller. These capabilities are especially important in large or complex facilities such as hospitals, airports, shopping centers, office complexes, and high-rise residential structures. In these environments, even finding the correct entrance can be challenging, let alone navigating to a specific room. In one case, fortunately not during an emergency, a mother was re-admitted to a hospital shortly after returning home after giving birth. She was transported by ambulance from one building at the hospital to another, and her husband and newborn baby were not allowed to accompany her while she was being moved. Because hospital staff lacked access to an accurate indoor map, they unknowingly gave her husband incorrect navigation directions to the woman's new location, forcing him and their 3-day-old child to walk outside at 2:00am on a bitterly cold January night to find the building his wife was in. In an emergency, an error such as that could have significant and grave consequences. When equipped with detailed, up-to-date, and accurate indoor maps, responders can identify the best access points, determine the fastest routes through and between buildings, and reach a caller's location more quickly.

Indoor maps also contribute to responder safety by helping responders avoid hazards, identify safe routes, and understand the location of critical infrastructure. If a responder becomes disoriented or loses communication, their last known location can be visualized on an indoor map, supporting rescue efforts.

And, if built and stored within a geographic information system (GIS), indoor maps can do much more. Any indoor map can contain visual elements like rooms, floor levels, points of interest, and critical infrastructure such as fire alarm control panels, standpipes, utility shut-offs, hazardous materials, and medical equipment like AEDs. But, vector GIS-based indoor maps, described further in section 6, can contain *attributes* of each of those features. These attributes can contain valuable extended information, such as the names of room occupants, the kinds of hazardous materials that might be stored in a room, whether a door is always locked in one or both directions, whether a window can be opened or not, and even links to real-time data sources such as video feeds or IoT sensors. Vector GIS-based indoor maps help emergency personnel move beyond simply locating a caller towards understanding the broader context of an incident.

Making actionable intelligence a reality requires that indoor maps be integrated into systems routinely used by PSAPs and first responders, and that indoor maps are maintained as accurate, up-to-date, and interoperable GIS data. Indoor maps are not just a visual aid - they become a foundational component of emergency communications and emergency response.

6. Types of Indoor Maps

Indoor maps can take many different forms, and understanding these differences is important when considering how they can be used in emergency response. While all types of indoor maps provide some level of value, indoor maps can vary significantly in their capabilities, ease of use, and ability to support advanced workflows. At a high level, indoor maps can be grouped into three categories: file-based maps, geo-referenced raster maps, and vector GIS-based maps.

File-based indoor maps are the most common. These typically include formats such as PDFs or image files that contain floor plans. They are widely used because they can be easy to create, share, and view without specialized software. In many cases, they can be opened on standard-issue devices like mobile phones, tablets, and computers, and can be printed for use in the field. While file-based maps can provide useful visual references, they are static and non-interactive. Users cannot easily search for specific locations, learn additional information about rooms or infrastructure beyond what is visually represented on the map, or dynamically obtain navigation routes through a building. File-based indoor maps also typically lack geographic context, making it difficult to understand how a building relates to its surroundings. That lack of geographic context can, for example, make it difficult to determine the fastest way to navigate to a specific building entrance or to learn what nearby natural features or infrastructure may impede or impact expeditious response.

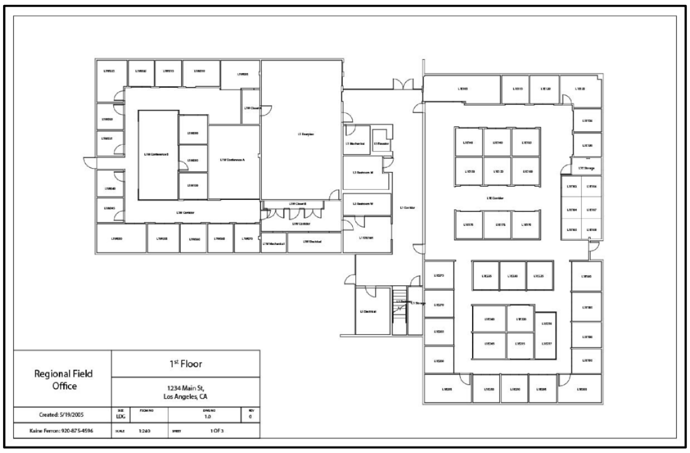

Figure 2. A file-based indoor map, representing a single floor of a building. Image courtesy of Esri.

Geo-referenced raster indoor maps build on file-based maps by placing them within a geographic context. These maps are typically overlaid onto a basemap within a mapping application, allowing users to view indoor layouts alongside outdoor features such as roads, buildings, landmarks, bodies of water, and topography. The kinds of mapping applications that can display geo-referenced raster indoor maps often allow users to display specific floors within a building using a floor picker or floor filter, making it easy to view different floors within multi-story buildings. While geo-referenced indoor maps improve situational awareness by providing context, the underlying indoor maps themselves share the same drawbacks as filed-based maps as they remain static and are not inherently interactive.

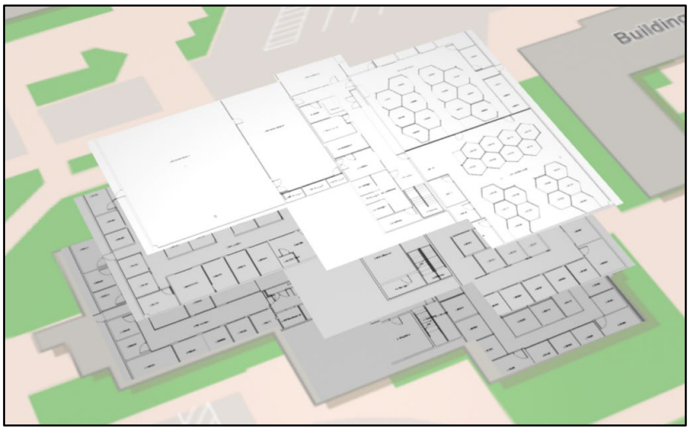

Figure 3. Three altitude-aware geo-referenced indoor maps, each representing a floor within a building, displayed in 3D. Image courtesy of Esri.

Vector GIS-based indoor maps are the most advanced and flexible type of indoor maps. These maps are built using points, lines, and polygons that represent indoor spaces and features, and they are stored within a GIS. Each feature can be associated with attributes, such as room names, identifiers, occupancy information, or links to external data sources. Because vector GIS-based maps are fully interactive, they can support searching, dynamic viewing, querying, routing, and analysis. They also support integration with call handling systems, CAD systems, and mobile applications used by first responders, and can be updated rapidly, ensuring changes are reflected across systems.

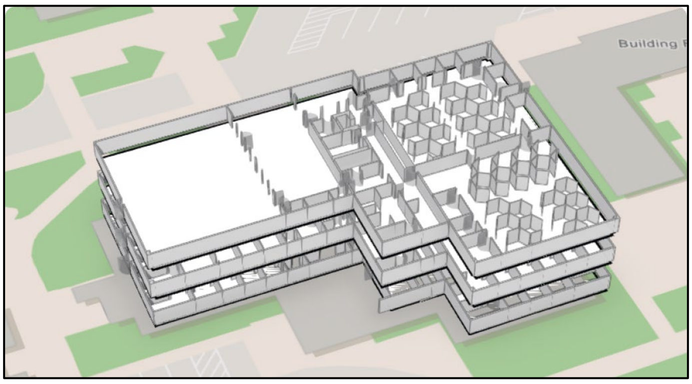

Figure 4. Three floor-aware and altitude-aware 2D vector GIS indoor maps, each representing a floor within a building. The maps are displayed in 3D with interior and exterior walls extruded by their height. Image courtesy of Esri.

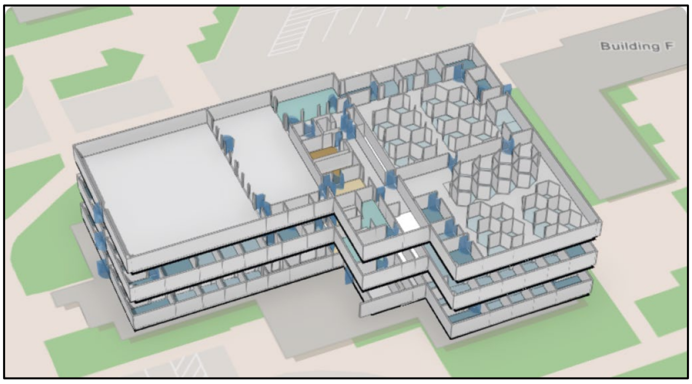

Figure 5. Three floor-aware and altitude-aware 2D vector GIS indoor maps, each representing a floor within a building. The maps are displayed in 3D with features such as walls and doorways extruded by their height. Doorways, rooms, and other interior features are classified by use type, which is an attribute of each feature. Image courtesy of Esri.

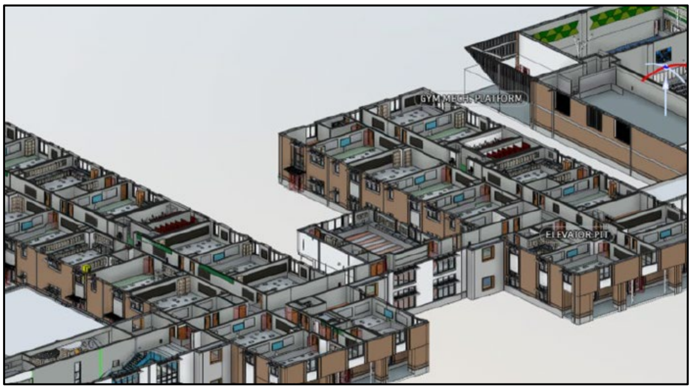

Figure 6. A floor-aware and altitude-aware 3D vector GIS indoor maps, representing a floor within a building. The map shows elements such as doors, windows, and architectural elements in 3D, along with room names. Image courtesy of Map I.T.

Figure 7. A floor-aware, vector GIS-based indoor map representing the first floor of a building. The map is shown in 2D, and maps of other floors can be displayed by selecting a floor on the upper right-hand side of the screen. Interior spaces are classified by use type and rooms are labeled with room numbers. The map also shows the location of fire hydrants, exits, and AEDs. Image courtesy of Map I.T.

Vector GIS-based indoor maps provide the greatest value for emergency response. They enable the full integration of indoor location data, support advanced workflows, and facilitate interoperability across agencies and systems. In practice, many organizations begin with simpler forms of indoor maps if they already exist and evolve toward more advanced indoor maps, like vector GIS-based indoor maps, over time. This incremental approach can allow agencies to realize value quickly while building toward the creation and use of more advanced indoor maps.

7. Indoor Mapping Across the Emergency Response Lifecycle

The value of indoor maps is not limited to the moment an emergency call is received. Indoor maps support the entire lifecycle of emergency response, from preparedness and planning to real-time response and post-incident analysis. By integrating indoor maps into each stage of this lifecycle, agencies can improve outcomes and maximize the value of their investments in creating and maintaining indoor maps.

Preparedness and planning are critical components of effective emergency response. Before an incident occurs, agencies can use indoor maps to better understand the environments they serve. Virtual walkthroughs of buildings allow responders to familiarize themselves with layouts, identify potential hazards, and plan entry and exit routes. Agencies can use indoor maps to conduct scenario-based planning, simulating incidents and developing response strategies tailored to specific facilities.

Indoor maps also support inspections and risk assessments. Fire services can use them to plan inspections and identify the locations of critical infrastructure, such as standpipes, fire alarm control panels, and utility shut-offs. Law enforcement agencies can use them to plan for large events and assess security vulnerabilities. Emergency managers can use them to evaluate evacuation routes and identify potential bottlenecks. These activities help ensure that responders are not entering unfamiliar environments during an emergency and that risks and vulnerabilities can be identified and mitigated well before incidents ever occur.

During an emergency, indoor maps provide a shared operational picture that supports coordination and decision-making. When a 112 call is received, call-takers can use indoor maps to verify the caller's location and understand the environment in which the incident is occurring. Dispatchers can identify the best routes for responders and provide guidance based on the building's layout. And first responders can navigate directly to a 112 caller's location, using the map to identify entrances, corridors, stairwells, and rooms.

Indoor maps also support coordination between multiple agencies in situations where incidents require response from more than one agency. When all stakeholders = call-takers, dispatchers, and first responders - have access to the same indoor map, including real-time locations of 112 callers, first responders, and real-time data such as video feeds and IoT telemetry, they can benefit from shared understanding of the situation. For example, indoor maps can help first responders from any responding agency avoid hazards, identify safe routes, and understand the location of critical infrastructure. If a first responder becomes disoriented or requires assistance, their location can be visualized on the map, supporting rapid intervention from any responding agency = not just their own.

After an incident, indoor maps support recovery and analysis. Agencies can use them to review how an incident unfolded, analyze response times and movements, and identify opportunities for improvement. They can also use indoor maps to assess damage, plan repairs, reallocate resources and adjust the locations of critical infrastructure, and update response plans based on lessons learned.

Indoor maps can also support everyday operations, including inspections, facility management, and security. By integrating indoor maps into routine workflows, agencies can ensure that the data remains current, that personnel are familiar with building layouts before an emergency occurs, and that they know how to quickly access indoor maps during an emergency.

Indoor maps are not simply digital representations of floor plans. They are a foundational data asset that supports situational awareness, coordination, and decision-making across the entire emergency response lifecycle.

8. Operational Use Cases

Indoor maps provide value across a wide range of environments and use cases. While initial investments in indoor mapping for public safety are often driven by specific needs - such as fire incident pre-planning, occupant safety and security, or in preparation for large-scale events - the benefits extend far beyond any single type of use case or type of facility. By expanding the use of indoor maps across different uses and environments, agencies can maximize their impact and improve safety for a broader population.

In educational facilities, indoor maps have been widely adopted to support school safety initiatives. Detailed floor plans can be shared with emergency responders, allowing them to quickly locate classrooms, offices, and other areas within a school. During an incident, responders can use indoor maps to identify the fastest routes to a specific location, coordinate their movements, and access additional information such as camera feeds or access control systems. And school staff can plan and execute evacuation and family reunification plans.

In healthcare facilities, indoor maps can support both emergency response and day-to-day operations. Hospitals are often complex environments with multiple floors, departments, and restricted areas. Indoor maps can help responders navigate quickly to a patient in need, identify critical infrastructure, and coordinate with hospital staff. They can also support patient transport and evacuation planning.

In large public venues, such as stadiums, shopping centers, and transportation hubs, indoor maps can help manage large crowds and respond to incidents efficiently. These environments often have complex layouts and high volumes of people, making it difficult to locate individuals during an emergency. Indoor maps provide a way to visualize the environment and coordinate response efforts across large areas.

In residential buildings, particularly high-rise structures, indoor maps can significantly improve response times. These buildings often have multiple entrances, stairwells, and lift systems, and finding the correct unit can be challenging, especially when only certain stairwells or lifts can be used to access certain floors. Indoor maps can help responders identify the best entry points, navigate directly to the correct floor and unit, and quickly locate important infrastructure like utility shut-off valves. They can even help determine the apparatus needed for response, such as the length of ladders and hoses required by firefighters.

In government and commercial buildings, indoor maps support a wide range of functions, from emergency response to security and facility management. They can be used to identify hazards, plan evacuations, and coordinate response efforts during incidents. They can also support routine operations, such as inspections and maintenance.

Real-world implementations demonstrate the value of indoor maps in these environments. In one example, a city in the state of Texas, in the United States, deployed indoor maps across hundreds of facilities, integrating them into both call-taking and field applications. During a severe winter weather event in 2021 that caused widespread infrastructure failures, responders used indoor maps to respond to alarms and quickly locate critical fire suppression systems within unfamiliar buildings and mitigate risks when the systems were rendered inoperable. In another case, indoor maps integrated with real-time video feeds allowed responders to identify the exact location of a fire within a school building and direct resources to the most appropriate entry point. And, in 2024, a student in a school in southern Minnesota, in the United States, experienced an overdose. Because officials had access to an indoor map, first responders were able to navigate directly to the entrance closest to the student. Lacking an indoor map, they would have instead gone to the school's front office, which saved precious time. In yet another example, a city's administrative department used indoor maps to collect the locations of AEDs within each city-owned building to assess cardiac arrest risk levels.

As a last example, taking it a step further, the power of indoor maps can significantly extend the goal of simply mapping AEDs for purposes of visual reference. Indoor maps can be utilized to calculate the optimal placement of AEDs within buildings based upon occupancy patterns and shortest-path distances from the places where people normally spend their time indoors to clearly visible areas within buildings where AEDs can be installed. According to the American Heart Association, for every minute that passes after a person experiences cardiac arrest without the administration of CPR or the use of an AED, the person's chances of survival diminish by 10%. In the United States alone, according to the United States Federal Communications Commission, 10,120 lives could be saved annually by decreasing the average response time by just one minute. Every second is of critical importance, and indoor maps can help save lives well before responders arrive on scene.

These examples highlight a key point: indoor maps are not limited to a single use case. They provide a flexible platform that can support a wide range of operational needs, both during emergencies and in everyday activities. The more broadly indoor maps are used, the greater their value becomes.

9. The Role of GIS in NG112 and Modern Emergency Communications

GIS plays a foundational role in modern emergency communications. It enables the integration of multiple geospatial datasets into a single, coherent operational picture, including address points, road networks, administrative boundaries, emergency service zones, and increasingly, indoor maps. GIS supports a common operational picture where all stakeholders, =in the PSAP as well as in the field, can access and share the same information, including real-time geo-referenced information such as the location of first responder vehicles, first responders themselves via locatable devices such as radios and wearables, the locations of alarms, live streaming video feeds, and telemetry from IoT devices like flood gauges. Indoor maps bring these GIS capabilities into buildings using the exact same mechanisms that have been used outdoors for many years.

In NG112, GIS plays a fundamental role by supporting geospatial call routing. Unlike legacy 112 calls, NG112 calls routed to the most appropriate PSAP based on the geographic location of the caller in relation to PSAP jurisdictional boundaries. This kind of call routing can significantly reduce misrouted 112 calls from mobile phones and requires authoritative GIS data that accurately defines jurisdictional boundaries to ensure that calls are directed to the appropriate PSAP, as well as complete, accurate address datasets to support geospatially routing 112 calls with locations represented as street addresses instead of X/Y/Z coordinates. GIS is also used when transferring 112 calls from one PSAP to another, or from a PSAP to a first response agency, by enabling geospatial call transfers. In this context, GIS is not just a visualization and coordination tool; it is a mission-critical component of real-time NG112 call routing infrastructure.

GIS also supports analytics and data-driven decision-making. By capturing and analyzing location-based data, agencies can identify patterns, evaluate response times, and optimize resource allocation. Indoor maps add another dimension to this analysis, enabling agencies to better understand how incidents unfold within buildings and how response strategies can be improved.

10. Standards and Interoperability

Interoperability is essential for effective emergency response. Incidents often involve multiple agencies, jurisdictions, and systems, all of which must work together seamlessly. Without a common framework for sharing information, coordination becomes more difficult, and the risk of delays or errors increases significantly. Standards provide this common framework.

In the context of NG112, ETSI standards define how emergency communications systems interwork together and how data is formatted and conveyed between systems. Standardized data formats like PIDF-LO support the conveyance of geodetic coordinates, civic addresses, uncertainty and confidence information, and, where available, vertical location data. By using standardized formats, systems can exchange location data without ambiguity, ensuring that the information received is consistent and reliable.

Indoor maps also benefit from standardization. There is a growing need for common data models and formats that allow indoor maps to be shared and used across different systems. Interoperability is particularly important in scenarios where multiple agencies respond to the same incident, or where calls are handled by backup PSAPs in different locations. In these situations, all parties must have access to the same information, including indoor maps and location data, supported by both technical compatibility and governance frameworks that define how data is shared and accessed.

By adopting and adhering to common standards that support interoperability, security, and data rights management, agencies can ensure that indoor location and indoor maps can be shared and used effectively across systems and organizations. This creates a foundation for coordinated, efficient, and scalable emergency response.

11. Operationalization Within PSAPs

Improving indoor location accuracy is an important step forward, but it is only part of the solution. For indoor location to have a meaningful impact on emergency response, PSAPs must be able to receive, interpret, and utilize that information within their systems and workflows.

First, systems must be able to ingest and display location data from sources such as AML or PIDF-LO in a timely and reliable manner. This includes not only horizontal coordinates, but also uncertainty information and, where available, vertical (Z-axis) data. Location information should be presented in a way that is easy for call-takers to interpret, allowing them to quickly assess the accuracy of the location and verify it with the caller if possible.

Second, systems must be able to accept vertical location information and present it to call-takers and dispatchers in a meaningful way. Altitude values are often expressed as height above ellipsoid, measuring how far a location is from a mathematical approximation of the Earth's surface.

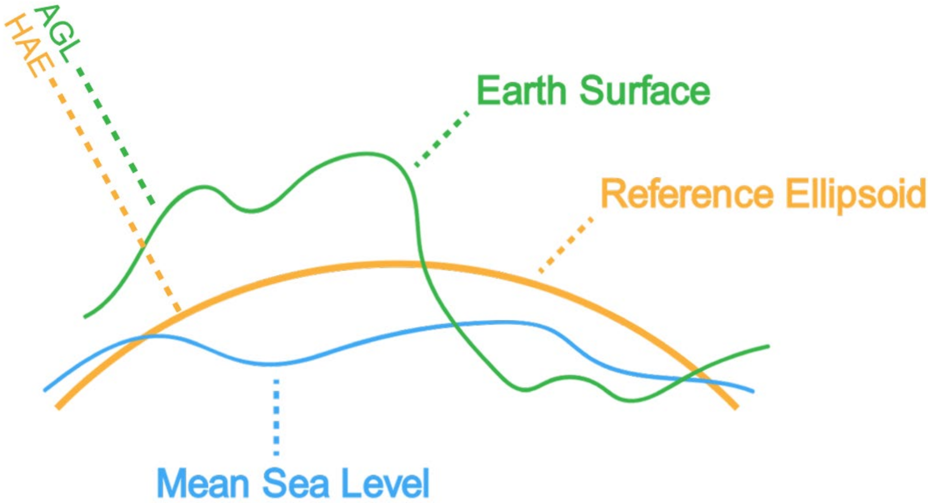

Figure 8. The relationship between the Earth's surface, a reference ellipsoid, mean sea level, above ground level (AGL) height, and height above ellipsoid (HAE). For more information, see [NENA-REQ-003.1-2022] section 2.3. Image used with permission from NENA: The 9-1-1 Association.

Measurements based on the ellipsoid are not intuitive for operational use. Humans generally think of height as a measurement expressed from a common reference surface, such as the ground. People tend to not use abstract frames of reference, such as an ellipsoid that approximates the Earth's surface. Those can be two very different reference frames, sometimes hundreds of meters apart. That can cause a great deal of confusion when call-takers observe a 112 caller's vertical location and believe it is dozens of meters below ground when really the caller's location is dozens of meters below the ellipsoid. Converting vertical location information into a more meaningful representation, like height above terrain or an estimated floor level, is essential for making vertical location actionable. This may require additional data, such as digital elevation models and floor- and altitude-aware indoor maps, as well as software capabilities to perform the necessary calculations.

Third, systems must support the integration of indoor maps, including floor-aware maps, automatic floor selection where appropriate, and the ability for users to navigate between floors. Indoor maps should be integrated into the same applications routinely used for call handling and dispatch, so that users do not need to switch between systems to access critical information.

Fourth, systems must enable interaction with indoor data. Call-takers and dispatchers should be able to search for rooms or features, view additional information about specific locations, and identify key infrastructure within a building. They should also be able to access integrated real-time data such as video feeds and IoT telemetry, if available.

Fifth, systems should support sharing information between agencies so indoor location and maps are available to first responders in the field and can be accessed by multiple agencies during incidents that require more than one agency to respond. Standards are critical to ensuring seamless data sharing, and systems must implement these standards.

Finally, systems must be designed with usability in mind. During an emergency, call-takers and dispatchers work under significant pressure, and every second matters. Information must be presented clearly and intuitively, without requiring extensive training or complex interactions to obtain. The goal is to reduce cognitive load and enable users to focus on the task at hand.

12.Implementation Roadmap

The adoption of indoor location and indoor maps does not need to happen all at once. Agencies can take a phased approach to implementing them, starting with simple, high-impact steps and building toward more advanced capabilities over time. This approach allows organizations to begin realizing value quickly while managing resources and complexity. Indoor location and indoor maps can each provide value independently, and in many cases, they can be implemented in parallel.

Indoor maps can be introduced first as visual references. Agencies may begin by collecting and storing floor plans as PDF documents linked to building locations if those files already exist. These maps can be accessed by call-takers and responders within 112 call-handling and computer aided dispatch systems to provide basic visual context during an incident. These file-based indoor maps should then be converted into vector GIS-based maps to maximize their value. An interim step, if needed, can involve converting file-based indoor maps to geo-referenced raster indoor maps and integrating them into GIS-based mapping applications, where they can be overlaid onto existing basemaps for easier access and display.

If indoor maps do not exist for a particular facility, agencies should strive to create vector GIS-based indoor maps from the start, instead of creating file-based or geo-referenced raster indoor maps as a first step, due to the additional cost and effort required to produce multiple kinds of maps. Vector GIS-based indoor maps can be integrated directly into modern call handling and dispatch systems and enable advanced workflows, such as automatically displaying the caller’s location on the appropriate floor of a building, estimating a caller’s indoor dispatchable location (e.g., the building, wing, floor, and room they are within) and automatically generating turn-by-turn indoor navigation guidance for first responders.

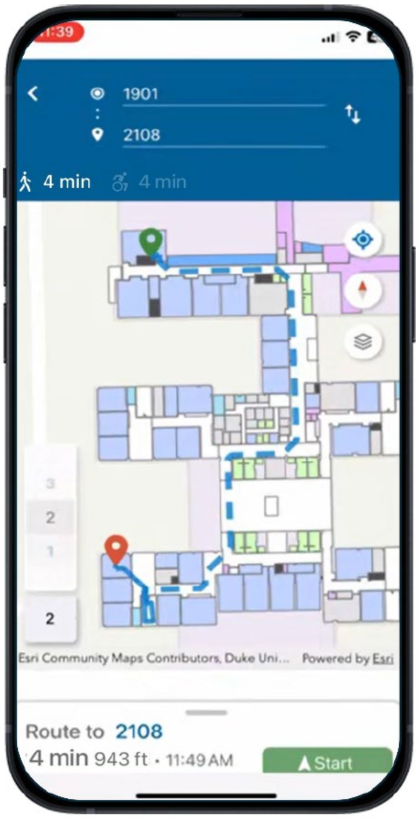

Figure 10. An indoor map used to calculate and display a navigable route inside a building. Image courtesy of Map. I.T.

In parallel, agencies can work to improve their ability to use indoor location data over time, ensuring their systems follow and implement the recommendations outlined in section 11. As indoor location methods continue to evolve, it is likely that the devices used by the public (e.g., cellphones) and devices used by first responders (e.g., wearables) may not natively support the latest, most innovative location estimation technologies within their hardware or operating systems. Novel location determination methods might only be supported within mobile apps or other software that can directly interface with the providers of such determination methods. It may be advantageous to explore augmenting popular mobile apps, such as national 112 apps, to take advantage of new technology that can augment indoor location to provide better 3D location estimates than what a particular device may be able to provide on its own.

As both indoor location and indoor mapping capabilities mature, they can be combined to deliver greater value. The key is to start with achievable steps and build incrementally.

13.Governance Considerations

The adoption of indoor location and indoor maps introduces important considerations related to privacy, security, accessibility, and data sharing. Addressing these factors is essential to ensure that these capabilities are implemented in a way that is responsible, compliant, and trusted by the public and stakeholders.

Location data, particularly when associated with individuals, is considered personal data under GDPR. Emergency services have a clear and legitimate purpose for processing location data, but this does not remove the need for safeguards. Data minimization, purpose limitation, and appropriate retention policies should be applied to ensure that location data is used only for its intended purpose and is not retained longer than necessary.

Security is equally important. Both location data and indoor maps must be protected from unauthorized access, modification, or misuse. This includes securing data in transit and at rest, implementing authentication and authorization mechanisms, and monitoring access to sensitive information. Indoor maps can also contain sensitive information. Detailed floor plans may reveal building layouts that a bad actor could use to inflict damage or harm, as well as the location of security systems that could be compromised. Additional data accessible via vector GIS-based maps, such as the location of hazardous chemicals or critical infrastructure, could also be compromised by bad actors. Agencies should consider role-based access controls, so users only have access to the level of detail required for their role. In certain cases, maps may need to be redacted to remove sensitive details before being shared more broadly.

Accessibility is another important consideration. Indoor maps can support accessibility by providing information about accessible routes, entrances, and facilities, such as lifts, ramps, and accessible exits. Systems used by emergency personnel should be designed to accommodate users with varying needs and should ensure that critical information can be accessed and understood by all operators.

Data sharing presents both opportunities and challenges. Effective emergency response often requires coordination across multiple agencies and jurisdictions. Agencies must establish clear policies that define what data can be shared, with whom, and under what circumstances. Regional or national repositories of indoor maps can support data sharing, but they must be designed with appropriate governance and access controls. Ultimately, governance frameworks must balance the need for access to information with the need to protect sensitive data.

14. Maximizing Value and Return on Investment

The key to maximizing the return on investment made in indoor location technologies and indoor maps is to ensure they are frequently used in as many ways as possible.
Investments in indoor location and indoor mapping can deliver significant value but realizing that value requires a strategic approach. While these capabilities are often justified based on their impact on emergency response, such as within specific contexts like safety and security in the face of criminal or terrorist threats or fire safety, their benefits extend far beyond the nature of one class of incidents and the associated uses cases alone.

Indoor maps are most valuable when they are used regularly. When maps are integrated into everyday workflows - such as inspections, planning, training, and facility management - they become a living dataset that is continuously updated and validated. This ongoing use helps ensure that the data remains accurate and that personnel are familiar with it before an emergency occurs. By embedding indoor maps into routine operations, agencies can distribute the effort required to maintain them. Instead of relying on a single team to update maps, multiple stakeholders can contribute, ensuring that changes are captured as they occur. This improves data quality and increases return on investment by extending the use of the maps beyond emergency response.

Indoor location capabilities also benefit from integration into broader systems. When location data is used for analytics, resource planning, and performance measurement, it provides additional value. And, as described in section 7, indoor maps provide maximum value when they are used to support as many use cases as possible before, during, and after emergency response. For example, indoor maps add another layer of insight when analyzing indoor location data, allowing agencies to understand how incidents unfold within buildings and how response strategies can be improved.

15.Recommendations

For PSAPs

PSAPs play a central role in operationalizing indoor location and indoor maps. To fully leverage these capabilities, they should follow the guidance outlined in section 11; integrate indoor maps into everyday operational workflows; promote training and familiarity; and collaborate with local stakeholders to acquire and maintain indoor mapping data for as many buildings as the PSAP would find beneficial.

For Governments and Policymakers

Governments and policymakers have a critical role in creating an environment that supports adoption. They should support the implementation of NG112 and standardised caller location transmission as AML and PIDF-LO, encourage or mandate the availability of indoor mapping data for critical infrastructure and public buildings, provide funding and incentives, establish governance frameworks that address privacy, security, and data sharing, promote standards to ensure interoperability, and facilitate collaboration between public safety agencies, local governments, and private sector stakeholders. Governments and policymakers should also engage with building owners to educate them on the benefits of indoor maps, not just for public safety purposes, but for their own use, to incentivize indoor map creation and maintenance.

For the European Union and International Bodies

At the European and international level, coordination is essential to ensure consistency and interoperability. Relevant bodies should continue to promote the adoption and advancement of NG112 standards, including support for vertical location and indoor environments; promote harmonization of data models and formats for indoor mapping; encourage cross-border interoperability; support research and innovation in indoor positioning technologies and their integration into emergency services; issue recommendations for uniform location accuracy standards, and provide guidance and best practices to help Member States implement indoor location and mapping capabilities.

For Industry and Solution Providers

Technology providers play a key role in enabling these capabilities. They should ensure that systems support the latest caller location transmission and NG112 standards, and follow the guidelines outlined in section 11.

16.Conclusion

Indoor location and indoor maps each provide meaningful benefits for emergency response. However, their true value is realized when they are combined and integrated into the systems and workflows that support public safety.

As the means by which people seek help during emergencies changes and evolves, the ability to accurately locate callers and understand their environment will become increasingly important. While significant progress has been made in improving location accuracy and its transmission, particularly through standards such as AML and PIDF-LO, challenges remain in translating that location into actionable information - especially indoors.

Indoor maps provide the context needed to bridge this gap. By enabling location data to be visualized and understood within the environment in which an incident is occurring, indoor maps transform location into actionable intelligence. This supports faster response times, improved coordination, and enhanced safety for both the public and responders.

Realizing this potential requires more than technology alone. It requires investment in systems, data, and processes that enable indoor location and mapping to be used effectively, adherence to standards that ensure interoperability, governance frameworks that address privacy and security, and collaboration across agencies, jurisdictions, and sectors. The opportunity to improve outcomes is significant and the need is well understood. The next step is to move from awareness to action.

Appendix A: Methods of Estimating Indoor Location

This appendix is intended for readers who would like to better understand how indoor location is estimated and how indoor positioning systems work. While the main body of this document focuses on operational value and governance considerations, this section provides additional technical detail.

It is important to note that no single technology can reliably determine location in all indoor environments. Buildings vary widely in their construction, layout, and radio frequency characteristics, which can significantly impact the performance of different positioning methods. As a result, most modern indoor positioning systems rely on a combination of techniques, often referred to as sensor fusion, to improve accuracy, reliability, and availability.

Research and development in this field is ongoing. New approaches and improvements to existing technologies continue to emerge, with the goal of enhancing not only horizontal (X/Y) accuracy, but also vertical (Z-axis) positioning, which is critical in multi-story buildings.

Satellite-Based Positioning (GNSS and Assisted GNSS)

GNSS (e.g., GPS, Galileo, GLONASS, BeiDou) is widely used for outdoor positioning and relies on time-of-flight measurements from satellites. Indoors, GNSS performance is often degraded due to signal attenuation, reflection, and multipath effects caused by building materials such as concrete, steel, and glass. As a result, GNSS signals may be weak, unavailable, or unreliable in indoor environments.

Assisted GNSS (A-GNSS) improves performance by providing additional information from the network, such as satellite positions and timing data, allowing devices to acquire a position fix more quickly and with lower signal strength. While A-GNSS can help near windows or in lightly obstructed environments, it is generally insufficient on its own for accurate indoor positioning.

Cellular Network-Based Positioning

Cellular positioning uses signals from mobile network base stations to estimate the location of a device. Techniques include Observed Time Difference of Arrival (OTDOA), which measures differences in signal arrival time from multiple base stations to estimate position through multilateration; angle-based methods (Angle of Arrival/Departure) that leverage antenna arrays for directional information; and simpler approaches such as Cell ID and signal strength-based estimates.

With 5G, positioning can be improved through better timing, denser deployments, and dedicated positioning reference signals. While cellular positioning can provide useful information indoors, accuracy is often limited by signal propagation conditions, network geometry, and non-line-of-sight effects.

Wi-Fi-Based Positioning

Wi-Fi is widely available indoors and supports several positioning methods. Received Signal Strength Indicator (RSSI) fingerprinting compares current Wi-Fi signal measurements to a pre-recorded database of signal patterns collected at known locations. Fingerprinting can achieve strong performance but often requires site surveys and ongoing maintenance, as renovations, furniture changes, and access point modifications can impact signal characteristics.

Wi-Fi Round-Trip Time (RTT) / Fine Time Measurement (FTM) estimates distance by measuring time-of-flight between a device and access points, enabling trilateration when multiple RTT-capable access points are available. This method can achieve meter-level accuracy in favorable deployments but requires compatible infrastructure.

Bluetooth Low Energy (BLE) Positioning

BLE beacons transmit signals at regular intervals and can be used for proximity-based positioning, RSSI-based trilateration, or fingerprinting. BLE systems are popular due to low cost and ease of deployment. However, accuracy can be affected by environmental variability, beacon placement, and RF interference.

Ultra-Wideband (UWB) Positioning

UWB uses short pulses over a wide spectrum, enabling highly precise time-of-flight measurements and strong resilience to multipath. UWB deployments typically include anchors installed in the environment and tags (or UWB-capable devices) that measure distances to those anchors. Multilateration can yield sub-meter accuracy in many environments, though UWB requires dedicated infrastructure and compatible endpoints.

Inertial Measurement Units (IMU) and Dead Reckoning

Modern devices include accelerometers, gyroscopes, and magnetometers that can estimate motion through dead reckoning. Starting from a known reference point, the device's position is updated based on detected steps, direction, and motion changes. Dead reckoning can provide continuous positioning when radio signals are weak, but it accumulates drift over time and typically requires periodic correction from other sources.

Barometric Sensors and Vertical Positioning (Z-Axis)

Barometric sensors estimate changes in elevation by measuring air pressure differences. These measurements can support floor estimation when combined with building context, but they are influenced by weather, HVAC pressure zones, and calibration methods. Vertical positioning is critical in multi-story buildings. While horizontal accuracy has improved significantly, reliable floor determination remains an active area of research, development, and operational integration.

Visual Positioning Systems (VPS)

Visual positioning uses camera imagery and computer vision to match observed features (e.g., corridors, signage, structural edges) to a reference database. When the environment is well-mapped and conditions are favorable, VPS can provide high accuracy and can also estimate device orientation. It requires a maintained visual reference dataset and can be impacted by lighting changes and environmental modifications.

LiDAR and 3D SLAM

LiDAR-based systems can create detailed 3D representations of environments and support simultaneous localization and mapping (SLAM). SLAM estimates a device's position while building or updating a map. These methods are widely used in robotics and surveying and are increasingly relevant for indoor positioning as sensing capabilities expand.

Magnetic Field Mapping

Indoor environments often have unique magnetic signatures due to structural steel and electrical systems. Magnetometers can measure local magnetic field patterns and compare them to a reference map. Magnetic positioning can work without added RF infrastructure, but it often requires initial mapping and may be affected by changes in building infrastructure.

RFID and NFC Markers

RFID and NFC can provide highly precise location at specific points by detecting tags placed at known locations. These technologies are often used for access control and asset identification and can be used to anchor positioning systems (e.g., known waypoints) rather than provide continuous tracking.

Infrastructure-Based Indoor Positioning Systems

Some indoor positioning solutions deploy dedicated infrastructure - such as synchronized radios, anchors, gateways, or sensor networks - to provide high reliability and precision for specific environments (e.g., industrial facilities, campuses, or critical infrastructure). These systems may leverage combinations of radio ranging, inertial sensing, and environmental constraints to optimize performance.

Sensor Fusion and Hybrid Positioning

Given the limitations of individual technologies, most modern indoor positioning systems rely on sensor fusion. Sensor fusion combines multiple inputs - such as GNSS (when available), cellular, Wi-Fi, BLE/UWB, IMU, barometer, and map constraints - to produce a more accurate and robust estimate of position and uncertainty.

Fusion engines often use techniques such as Kalman filtering, particle filtering, and machine learning models to estimate position and adapt to changing conditions. The output typically includes both X/Y/Z and uncertainty bounds that help downstream systems interpret how much confidence to place in the estimate.

Map Matching and Contextual Positioning

Indoor maps can improve positioning through map matching. Map matching constrains estimated positions to valid indoor spaces - such as corridors, rooms, and accessible areas - rejecting impossible positions (e.g., inside walls) and improving usability for responders.

When combined with indoor routing networks, map matching can also support wayfinding and path computation from an entry point to an estimated incident location, helping translate a location estimate into an operational plan.

Summary

Indoor positioning is a complex problem that cannot be solved by a single technology. Different methods offer different strengths and limitations, and performance varies by building, device, and deployment. Effective solutions increasingly combine multiple technologies and data sources, improving accuracy, reliability, latency, and coverage.