School Map Requirements for Multi-Agency School Emergency Response

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ABSTRACT

School emergencies routinely involve EMS, fire, and law enforcement responding under distinct objectives and uncertainties, yet these agencies often rely on the same non-standardized school maps, which vary widely in quality and availability. This paper reports findings from a qualitative interview study (n = 10) examining the spatial decision-making and spatial information needs of EMS, fire, and law enforcement responders during school emergency response. Using a Goal-Directed Task Analysis exercise, participants worked through dispatch scenarios using (1) satellite imagery of a school exterior and (2) the same imagery augmented with an indoor school map. Findings identify spatial information needs shared across agencies that support rapid orientation and spatial inference, as well as agency-specific needs tied to distinct operational goals. Results inform requirements for standardized, minimalist school maps that support wayfinding and flexible inference alongside complementary, agency-specific GIS.

Keywords

Public safety, first responders, spatial decision-making, situational awareness, building maps, GIS, multi-agency coordination.

INTRODUCTION

School emergencies routinely involve EMS, fire, and law enforcement (LE) responding individually or simultaneously, yet U.S. agencies are often provided with the same non-standardized building maps of schools—or none at all—despite having different goals, responsibilities, and decision pressures (McWhorter et al., 2025). As a result, maps intended to support both individual responders and multi-agency coordination can fail to align with how responders reason about space under time-critical conditions (Sørensen et al., 2025). This misalignment is especially consequential in school settings, which are recognized as critical infrastructure for public safety planning, given their high-occupancy, vulnerable populations, and multi-agency response complexity.

Researchers examine the use of maps as external representations that support first responders' spatial decision-making (Johansson et al., 2010; McWhorter et al., 2025; Rezaeifam et al., 2023; Ruiz-Cartiel et al., 2021). Spatial decision-making includes spatial assessment, in which responders make inferences about the locations and spatial relationships of people, objects, and events to construct and update internal spatial knowledge or situational awareness (e.g., determining which room an injured person is located within a school building). Spatial assessment informs wayfinding, which involves spatial decision-making about route selection (e.g., which entrance to use) as well as route execution, through which responders carry out movement while continuously monitoring the environment for information that may prompt reassessment and/or rerouting (McWhorter et al., 2025). Spatial decision-making for both spatial assessment and wayfinding unfold through the integration of overlapping forms of spatial knowledge (Siegel & White, 1975; Montello, 1998):

- **Landmark knowledge** of distinct features in an environment (e.g., the main entrance)
- **Route knowledge** of action sequences that connect landmarks (e.g., enter the main entrance and turn left to reach the library)

- **Survey knowledge** of spatial layouts, including the relative positions and distances between landmarks that support inferences about unseen locations (e.g., a central corridor divides the school into east and west sections).

These forms of spatial knowledge are acquired and utilized together as responders orient themselves, move, and act in complex environments. Maps are a primary external source of survey knowledge, which users consult opportunistically in coordination with landmark, route, and internally constructed survey knowledge, when memory and real-time environmental perception are insufficient (Montello, 1998; 2005; 2018).

However, existing research has not clearly identified the spatial information needs shared across EMS, fire, and LE during school emergencies, nor articulated how different forms of spatial information support different spatial decision-making by EMS, fire, and LE. Prior work often conflates spatial information requirements for spatial assessment (e.g., inferring the location of an injured person) and wayfinding (e.g., selecting a route and moving toward the injured person). Without this distinction, efforts to design interoperable school maps risk privileging exhaustive detail intended to satisfy every agency's requirements over shared spatial information that supports common activities such as wayfinding while affording flexible inference to support unique agency needs. The result is often dense maps that are less useful to responders, who rely on maps to supplement memory, perception, and other external sources of spatial information in time-sensitive, dynamic environments.

This paper reports findings from a qualitative study (n = 10) examining how EMS, fire, and LE responders make spatial decisions to identify spatial information needs shared across these agencies during school emergencies. Using a Goal-Directed Task Analysis (GDTA) exercise, participants worked through realistic dispatch scenarios with satellite imagery of a school exterior and the same imagery augmented with an indoor map. The study identifies shared and agency-specific spatial information needs grounded in responders' operational goals and decision-making, clarifying which spatial features are commonly required across agencies and how they support different forms of spatial reasoning. Findings show that static maps are most valuable for wayfinding, which requires rapid orientation and spatial inference at specific moments (e.g., pre-entry), and function as supplements to spatial knowledge gained from environmental perception and responder communication rather than exhaustive spatial representations. These findings inform requirements for standardized, minimalist school maps that responders can use effectively alongside GIS that support agency-specific, real-time information needs.

BACKGROUND

First responders—including firefighters, LE, and EMS—depend on timely, accurate spatial information to establish situational awareness and make effective decisions during emergencies. *Spatial information refers to the locations, movements, and relationships of people, objects, hazards, and events, enabling responders to determine who is where, what is happening where, and how conditions are changing*, using both static representations (e.g., physical maps) and dynamic representations (e.g., real-time GIS displays). Below, we review prior fire, LE, and EMS studies to show that, despite this extensive work, shared spatial information needs in school emergency response remain underexamined, motivating the present study.

First Responder Spatial Information Needs

Firefighting research has developed the most explicit and structured accounts of spatial information needs, yet these needs are largely defined within fire-specific contexts and scenarios. Studies consistently show that firefighters rely on both pre-existing spatial knowledge and real-time incident data to navigate, assess risk, and coordinate actions, particularly in indoor fire and search-and-rescue operations (Nunavath et al., 2016). Across this literature (Guyo et al., 2023; Nunavath et al., 2016; Rezaeifam et al., 2023; Ruiz-Cartiel et al., 2021), firefighter spatial information needs commonly include:

- **Building information**, such as structure type, internal layout, number of floors, exits, stairwells, elevators, and fire doors.
- **Hazard information**, including the locations of hazardous materials, utilities, standpipes, and suppression resources.
- **Occupant information**, such as the number, location, and characteristics of people inside the structure
- **Fire dynamics**, including the location, extent, and progression of fire and smoke.
- **Resource and unit locations**, including the positions of crews and equipment.

These needs vary by incident type, role, and scale. Specialized scenarios such as chemical tank fires introduce additional spatial requirements related to hazard and evacuation zones (Wang & Zhu, 2025), while interior crews require room-level detail and incident commanders benefit from aggregated overview maps that support coordination and projection (Rezaeifam et al., 2023). Despite the recognized importance of spatial information, firefighters frequently contend with outdated or incomplete pre-incident plans and compensate by using personal smartphones and commercial navigation tools, like Google Maps (McWhorter et al., 2025; Choong et al., 2022). Prior work shows that summarizing pre-planned building information into concise static maps and interactive 360° walkthroughs can support firefighters' pre-incident orientation, reinforcing the value of minimal over exhaustive representations (Ruiz-Cartiel et al., 2021). However, other studies show that, compared to static maps, GIS with real-time locations of responders and hazards can improve response effectiveness and command and control (Johansson et al., 2010).

Prior research demonstrates that LE spatial information needs are critical, showing that police rely on spatial information about the locations of suspects, officers, civilians, and environmental features, and that experienced officers develop mental models of distance, time-to-contact, and relative positioning to support tactical decision-making in dynamic incidents (Huhta et al., 2023), paralleling findings in fire response (McWhorter et al., 2025). These needs vary by context, with routine patrol emphasizing navigation and area familiarity, and critical incidents—such as active shooter events—requiring rapid reasoning about movement, convergence, containment, and the communication of hot, warm, and cold zones during multi-agency response (Norri-Sederholm et al., 2016). Despite increasing access to digital maps, officers frequently encounter missing or inaccurate spatial information, undermining use of agency-issued mapping/navigation systems and motivating the widespread use of personal smartphones and commercial navigation apps (Choong et al., 2022; Dawkins et al., 2020, p. 42).

Existing research shows that EMS responders rely heavily on spatial information, yet their needs are examined less systematically than those of firefighters and LE. Prior work emphasizes that EMS's core mission—to locate, treat, and transport patients—depends on understanding spatial relationships among patients, access routes, ambulances, and medical facilities, with maps playing a central role in navigation and patient access. A survey of U.S. first responders indicated that EMS personnel use mapping/navigation applications more frequently than fire and LE responders, underscoring the importance of wayfinding in their work (Dawkins et al., 2020, p. 43-44). Research on EMS command and dispatch further highlights the need to maintain an up-to-date spatial picture of unit locations, incident distribution, and evolving response plans, as well as EMS's reliance on spatial information generated by fire and LE during coordinated response (Norri-Sederholm et al., 2016).

Studies of School Emergency Response

Despite the prevalence of school active shooter planning, surprisingly little research has examined first responders' situational awareness needs in school emergency contexts. Few studies identify responders' spatial information needs or specify the critical tasks, performance measures, and benchmarks required to evaluate whether maps and GIS systems support situational awareness or reduce response times during school-based active shooter incidents. Beyond research comparing school lockdown policies (Jonson et al., 2020), studies have rarely evaluated how first responders or school safety officials use physical maps or GIS systems during live exercises that simulate realistic active shooter responses.

Instead, prior research has focused primarily on students' and school personnel's responses to active shooter emergencies, particularly through studies of evacuation and lockdown drills in K–12 schools and higher education institutions (Howard, 2022). These studies typically assess drill design and participants' perceptions of preparedness and safety, finding that drills increase perceived preparedness while decreasing perceived safety (Scott et al., 2021). Related experimental and simulation studies have, for example, examined how building design features and awareness of shooter location influence student and teacher response times and decision-making (e.g.,, run, hide, fight) (Zhu et al., 2022). However, this body of work primarily addresses occupant protection and evacuation, rather than how spatial information systems support first responders' goal-driven decision-making and response activities.

Gap: Shared Spatial Information Needs in School Emergencies

Prior research across fire, LE, and EMS has produced detailed, agency-specific accounts of spatial information needs—typically grounded in situational awareness theory, elicited through GDTA, and formalized in domain-specific ontologies—showing that responders rely on both static and dynamic spatial information and use maps and GIS to support situated spatial reasoning. However, this work largely examines spatial needs in isolation by agency and incident type, leaving limited empirical understanding of the spatial decisions responders make across agencies, the goals that drive those decisions, and how different spatial representations—including the presence or absence of indoor maps, or reliance on commercial apps such as satellite imagery from Google Maps—shape spatial reasoning in practice (Choong et al., 2022; Dawkins et al., 2020; McWhorter et al., 2025). This gap is especially consequential for school emergencies, which involve complex indoor environments, vulnerable populations, and tightly coordinated multi-agency response, and where it remains unclear which spatial information needs are shared versus role- or scenario-specific, and how common map features support spatial reasoning as conditions evolve. To address this gap, our study addresses the following research questions:

1. How do fire, LE, and EMS responders make spatial decisions with and without indoor school maps?
2. What shared and agency-specific spatial information do first responders require during school emergencies?

METHODS

We conducted a qualitative interview study to examine first responders' spatial information needs during school emergencies and to evaluate how indoor maps support spatial and situational awareness. The study combined semi-structured interviews with a map-evaluation task using satellite imagery and an indoor map of a U.S. high school (Figure 1).

Figure 1. Representations shown to participants during the GDTA exercise: Outdoor satellite image of school building (left) and indoor school map (right)

Participant Recruitment

Participants included 10 first responders: EMS (n=2), LE (n=3), and firefighters (n=5). Using purposive sampling through professional networks, we recruited current or recently retired responders from municipal jurisdictions in Texas to capture variation in agency, role, and instructor experience. The sample included field training officers and state- or national-level instructors in active shooter response. The study received Institutional Review Board approval; all participants provided informed consent, received compensation, and are reported in anonymized form. The study received Institutional Review Board approval. All participants provided informed consent and received compensation. Identifying details were removed from transcripts, and results are reported in anonymized form.

Data Collection and Analysis

Methods such as GDTA link responders' goals and decisions to the spatial information required for situational awareness (Jones & Endsley, 2005; Rezaeifam et al., 2023; Sørensen et al., 2025). For each of the 10 participants, we conducted a 60-minute session via Microsoft Teams, beginning with a semi-structured interview on their experiences responding to school emergencies, with a focus on goals, decisions, and spatial information needs. Participants then worked through a realistic dispatch scenario (see Findings) tailored to their role (EMS, fire, or LE), but referencing the same location—the upper floor of D-block in a fictional Central High School.

As part of a GDTA exercise, participants were shown two spatial representations: (1) satellite imagery of the school exterior and grounds, such as responders might access via Google Maps (Choong et al., 2022; Dawkins et al., 2020; McWhorter et al., 2025), and (2) the same imagery augmented with an indoor school map showing entrances, room and block labels, and key interior features. Significantly, many U.S. municipalities may not maintain or widely distribute indoor building maps of schools among EMS, fire, and LE agencies. In a 2020 national survey of U.S. responders, for example, indoor mapping was considered a "futuristic technology" that few EMS (22%), FF (35%), and LE (19%) respondents indicated they would use (Dawkins et al., 2020, p. 55-57). For each representation, identified their response goals, reasoned through goal-relevant spatial decisions (e.g., where to enter the school), and discussed the extent to which the satellite image and indoor map met their spatial information needs (Jones & Endsley, 2005). Each session was audio-recorded and screen-captured.

Data were analyzed using a hybrid inductive–deductive coding approach (Fereday & Muir-Cochrane, 2006). Deductive codes captured goals, decisions, spatial information needs, representation requirements, and types of spatial knowledge (Siegel & White, 1975; Montello, 1998), while inductive analysis identified and compared emergent subthemes to identify shared and agency-specific spatial information needs and requirements for static maps and GIS in school emergency response.

RESULTS

This section first reports how fire, law enforcement, and EMS responders make spatial decisions with and without indoor school maps (RQ2), and then identifies shared and agency-specific spatial information needs (RQ2).

EMS: Efficient Entry and Exit

EMS participants began the GDTA exercise with the following dispatch scenario: "A teacher has collapsed in a classroom on the upper floor of D-block of Central High School. The caller suspects a heart attack, but the teacher is unconscious and unresponsive. The teacher is large and uses a motorized scooter." In this scenario, EMS participants' primary goal was to provide *immediate life-saving care and efficient hospital transport,* with spatial decision-making focused on *quickly reaching the patient and efficient egress from the school*. To do so, EMS participants (P4, P6) focused on the following three spatial decisions when using the satellite image and indoor map.

Where should we park the ambulance for quick access and exit? Ambulance staging prioritized exterior access and egress, with indoor maps playing little role. EMS responders defaulted to the main circle drive shown in satellite imagery because it allowed quick entry and exit—"are we going to be able to pull straight out, or are we going to have to back up?" (P4)—and was reinforced as "where everybody goes" upon arrival. The indoor map did not alter parking decisions—"That really doesn't change where I'm going to park" (P4)—with responders instead relying on windshield surveys and cross-checking dispatch information to support coordination.

Who will guide us to the right place when we arrive? Initial wayfinding depended on human guides, with indoor maps serving as a reliable fallback. EMS responders typically followed flaggers or school staff—"almost 100% of the time, there's a flagger… or a security person" (P4)—while indoor maps provided a "static" reference that helped responders "get it as right as possible if we don't have enough information" when guidance was incomplete or conflicting (P6).

Which entrance best supports stretcher access to the patient? When reasoning with satellite imagery alone, both EMS participants (P4, P6) oriented to what they identified as the main entrance along the North Circle Drive, which they associated with efficient ingress and egress and proximity to the main office where they expected to find a flagger. They relied on visual cues such as "bus entrance" or "main entrance" to infer where to approach (P6). At the same time, participants noted that the satellite image failed to provide critical access details needed for confident decision-making. P4 looked for safety bollards that might prevent the ambulance from getting close to the door, while both P4 and P6 searched unsuccessfully for indications of ramps versus stairs. P4 also emphasized the importance of door type, explaining that automatic doors are far preferable for stretcher movement, whereas manual doors create difficulty because "rolling a cot with a bunch of stuff on it… somebody's got to go backwards and reach out and hold [it]" (P4).noted that the satellite image did not provide the information needed to assess stretcher accessibility at specific entrances, such as the presence of ramps, automatic doors, or elevators. As a result, while the outdoor view helped them decide where to arrive on campus (e.g., the north-side circle drive), it did not support decisions about which door would best accommodate stretcher movement. As P4 explained, these decisions hinge on basic physical access: "Is there a ramp that I can roll this stretcher up or am I going to have to carry it up the stairs?" (P4).

For EMS participants, the indoor map lacked key accessibility details—such as barriers, ramps, door types, and elevators—but still influenced entrance and access decisions in distinct ways. For P4, the map primarily served as confirmation of an initial judgment: although it revealed that D-block was located in the "dead center" of the building rather than in a wing, P4 concluded that entering via the North Circle Drive remained optimal because it aligned directly with the main North–South hallways—"I'm right in line with one of the two main hallways running North and South, so even if I've chosen poorly, I'm easily gonna rectify that situation by moving through the main hallway" (P4). In this sense, the indoor map increased confidence and effectiveness by enabling precise navigation to the room without relying on a human flagger. By contrast, the possible indication of an elevator on the indoor map prompted P6 to reconsider entrance and parking decisions based on vertical access to the second floor of D-block. P6 explained that if an elevator were shown near a side entrance, she would pivot staging accordingly: "If there was an elevator… right when we walked in that door by 6, then we would park on that end of the parking lot… because it's quick, it's a shorter distance between the truck and then how we need to get to them and then also with getting back out" (P6). For P6, the indoor map thus functioned as a decisive factor that could alter both entrance choice and parking strategy to minimize distance and support efficient patient access and egress.

EMS Recommendations for Static and Dynamic Map Design

Suggestions for static maps:

- Functional room labeling: Replace or supplement room numbers with plain-text labels (e.g., gym, cafeteria, main office), since staff and students rarely use room numbers in practice. (P4)
- Vertical access points: Clearly mark elevators and stairwells, as elevator locations can directly affect entrance and routing decisions for upper-floor patients. (P6)
- Key resource offices: Identify the SRO office, nurse/first aid station, and main office, where the most current situational and spatial information is likely held. (P6)
- Access and entry details: Show access/egress points, fire hydrants, door types (automatic vs. manual), and bathrooms, which are common locations for medical calls. (P4)
- Professional standardization: Use professionally drawn, standardized maps rather than hand-drawn versions that are difficult to interpret under stress. (P6)

Suggestions for dynamic maps/GIS:

- Responder tracking: Display responder location on indoor maps with high spatial precision. (P4)
- Dynamic pathfinding: Provide automated navigation paths from the responder's current location to the patient once inside the building. (P4)

Fire: Protect Life, Control the Hazard

Firefighter participants began the GDTA exercise with the following dispatch scenario: "Multiple callers report smoke on the upper floor of D-block of Central High School. Staff are trying to evacuate students, but visibility is limited." Firefighters articulated two interrelated objectives: *protecting life and controlling the hazard.* While firefighters discussed multiple spatial decisions with respect to this objective, including the locations of evacuating people and where to position vehicles/apparatuses to access hydrants, participants focused on the following decisions when using the satellite image and indoor map during the exercise:

What is the shared building orientation? Firefighters impose a shared spatial frame by assigning "alpha" to the chosen reference side of the building (not necessarily north) and labeling the remaining sides "bravo," "charlie," and "delta" in clockwise order—such that, for a square building, "charlie" designates the rear. This convention enables consistent orientation and communication across incoming units. "I want to geographically divide the scene up as quickly as possible" (P8)

What hazards are present and what risks do they pose? The satellite image supported the identification of limited ingress/egress, apparatus access constraints, and standoff distance from potential hot zones. The indoor map failed to convey room function, materials, or infrastructure critical for assessing interior hazards. As P10 noted, it "doesn't say what that class is… if it's a chemistry class, then we have to be more concerned with the hazmat" (P10).

How should we access the incident location? With only the satellite image, firefighters defaulted to the front office, identifying it as the north circle drive (P2, P5, P9, P10). P10 and P3 noted that the "first stop would be at the front office" to find a "responsible party" (like a principal or custodian) with keys and institutional knowledge (P10). Only P8 indicated he would enter from the north and move to the west side of the building "where those 3 red roofs are" and designate an Alpha side before entering.

With the indoor map, however, participants made more targeted and flexible tactical entry decisions grounded in the building's internal layout, even though initial access would still often begin at the main entrance. P3 maintained the default choice to enter via the main entrance (north circle drive) but emphasized that this decision could change mid-response if the incident location made that entrance inefficient, with the indoor map supporting pivots by revealing alternative hallway alignments and access routes to D-block. Similarly, P10 thought "the decision on where to enter the building would change" based on indicated "access points… closest to get to that spot." However, P5, P8, and P9 shifted to a closer entry point to D-block, such as Door 6. P5 reasoned that Door 6 avoided passing through the primary hazard zone to access central stairs more safely. P8 shifted to using Door 6 or 7 near "F-200" on the Charlie side—opposite the initial Alpha entry from the north circle drive—to shorten the route to D-block. P9 also adjusted to Door 6, using the indicated corridors for subsequent wayfinding: " if it's in D-block, let's say D 217… I'm gonna pass the corridor on the left, another corridor, and then it's gonna be on my right-hand side" (P9). Taken together, these shifts show that the indoor map transformed entry from a general, uncertainty-driven choice into a deliberate, tactical judgment that could be coordinated among units and adjusted as new information emerged.

Firefighter Recommendations for Static and Dynamic Map Design

Suggestions for static maps:

- Standard exterior reference points that make it easy to declare and share an Alpha side (and therefore Bravo/Charlie/Delta) using recognizable anchors on or near campus (e.g., "Alpha is the main office across from the football field") (P9).
- Functional room labeling (not just numbers) that identify what rooms are (chemistry lab, shop, natatorium, cafeteria) so crews can anticipate materials, fuel loads, and hazmat risk.
- Clearly marked door numbers/locations and access points for ingress/egress and the circulation elements that matter under smoke or low visibility (primary corridors, compartment boundaries/fire doors if known, and stairs/elevators for upper-floor access). (P3, P5, P8, P9, P10)
- Fire protection and water supply features such as hydrants, fire department connections (FDCs), and sprinkler connections so apparatus placement and water supply decisions can happen fast. (P3, P5, P8, P10)
- Building systems that enable control, such as alarm panels, key access points, and utility shutoffs (gas/electric/HVAC controls when known) since these drive hazard control and operational choices. (P7, P8, P10)

Suggestions for dynamic maps/GIS:

- A shared view of where crews are (and where they've been) to support accountability, assignments, and rapid intervention decisions.
- The ability to mark and share where smoke/fire is showing (even as rough zones), plus updates as conditions change. (P3, P9)
- Live status from building systems, such as alarm activations, sprinkler flow, door status/access control, and power loss.
- Toggleable map layers to manage cognitive load rather than forcing one dense "everything map."
- 360°/street-view style exterior context for size-up to support windshield survey and pre-entry planning when approaching an unfamiliar campus.

Law Enforcement: Stop the Threat

LE participants began the GDTA exercise with the following dispatch scenario: "There's a report of a student with a gun in the main building of Central High School. A caller reports that the student was last seen on the upper floor of D-block. The dispatcher heard what sounded like gunshots and screaming before the caller hung up." LE participants' primary objective was to *stop the threat as quickly as possible.* For an active shooter response, LE's spatial decision-making prioritizes speed rather than completeness and certainty. During the exercise, LE participants (P1, P2, P7) primarily reasoned about the following spatial decisions when using the satellite image and indoor map:

Where is the threat? LE participants emphasized that credible threat locations are established through verification, radio communication, and environmental perception rather than maps. Determining whether a threat is real and ongoing depends on confirming reports—"the first is verifying the information… finding out if there's multiple reports" (P7)—with neither the satellite image nor the indoor map materially informing this initial assessment. Participants focused on descriptions, last known locations, and movement—"Do we have a description of the person? The last location they were at? Are they still moving?" (P1)—while treating dispatched locations as potentially outdated, since "the likelihood of that still being relevant information by the time you get there is pretty low" (P2). Responders instead oriented to immediate environmental "driving forces," such as gunfire or people fleeing, turning to maps only when such cues were absent and there was time to "look at the map… [and] study it a little bit better" (P2).

How do I coordinate with other responders on scene? Coordination relied on radio and standard operating procedures, with indoor maps supporting command-level planning, rather than the immediate response to stop the threat. The satellite image did not aid movement coordination or crossfire avoidance—"that's the last thing you want is that crossfire" (P1)—whereas the indoor map provided a shared reference that could support incident commanders in coordinating deliberate entry and convergence planning to reduce "blue on blue" risk (P7).

How can I move toward the threat inside the building? Movement toward the threat relied on real-time cues, with indoor maps supporting pre-entry orientation. Once inside, responders acted on environmental cues and radio traffic—"much more stimulus and lizard-brain level of response" (P2)—using the indoor map only to form a pre-entry "mental snapshot" that was "100% better" than exterior imagery for initial orientation (P1). However, participants emphasized that maps supporting such a mental snapshot must be extremely simple "cartoon maps," as detailed or technical maps quickly become unusable under extreme demands of an active shooter response: "I don't know if you've seen a technical map of a building, but once you take a picture of it… you're toast within 50 steps inside the building… you're not going to remember what you saw" (P2).

Where should I enter the school to approach the threat? When deciding where to enter the school, participants described the satellite image as useful only for high-level orientation—identifying the building footprint and parking areas—but not for selecting an optimal entrance or aligning entry with the threat's location. As a result, access decisions were framed as provisional and driven by speed and tactical positioning rather than precision. P2 cautioned against over-analysis, stating, "Try not to let perfection be the enemy of good enough… your primary focus is to enter the school at any point that's immediately accessible" (P2). P1 attempted to infer the reported location by matching "D-block" to exterior features—"D-Block's going to be probably this. We'll say it's the most south red roof" (P1)—but acknowledged that this guess lacked confidence without labels or familiarity. P2 and P7 were skeptical that the dispatched location would still be valid on arrival: "The likelihood of that [D-block] still being relevant information by the time you get there is pretty low… I don't see anything in the photo that says D block" (P2). In this context, real-time environmental cues dominated: "you're really being driven by gunfire or students running" (P2). P7 added that knowing only that the suspect was on the second floor framed entry tactically, as an elevated position confers a "greater field of vision," leading him to prioritize gaining a foothold from a blind spot rather than converging on a specific door (P7).

The indoor map enabled more intentional entry reasoning, but participants emphasized that it functioned primarily as an initial orientation aid rather than a precise wayfinding tool. P1 described the indoor map as "100% better" because it clearly centralized D-block and labeled rooms, prompting him to revise his entry plan to North Doors 1 or 18, which offered the most direct routes to the threat. P2 noted that while the indoor map "made it easy with saying 'D-block,'" it did not fundamentally change his access decision, since the block was "essentially equidistant no matter where you park," reinforcing his view that "starting to gather on-the-ground intelligence is sometimes better than trying to find the perfect spot" (P2). For P7, the indoor map supported higher-level tactical reasoning by revealing that Door 6 was the closest point of ingress and that Doors 12 and 18 provided long hallway sightlines, enabling visibility and "360-degree security" during movement toward the objective.

Law Enforcement Recommendations for Static and Dynamic Map Design

Suggestions for static maps:

- Simplified "cartoon maps" layouts that prioritize bold labels for major landmarks (e.g., gyms or cafeterias) over complex detail to better support "gross movements" during high-stress responses. (P1, P2)
- Actionable architectural details, including door swing directions (inward vs. outward), lock mechanisms (badge vs. physical key), and material composition (glass vs. metal) to help officers select the appropriate breaching tools before arrival (P1, P7).

Suggestions for dynamic maps/GIS:

- Precise origin of 911 calls or panic alarms (P1)

- Current lockdown status of specific rooms and doors (P1)
- GPS locations of fellow responders to prevent "blue on blue" incidents (P1, P7)
- Ability for responders to digitally mark rooms as "cleared" on a shared common operating picture (P7)
- Color-coding “Guardian” classrooms to identify armed staff (P1)

SHARED AND AGENCY-SPECIFIC SPATIAL INFORMATION NEEDS

This subsection summarizes first responders’ spatial information needs during school emergency response. Overall, participants consistently articulated spatial information needs across three analytically distinct but operationally intertwined categories:

1. **Locations of people** (mostly dynamic and agency specific)
2. **Locations of objects** (mostly static with some across agencies)
3. **Locations of events/hazards** (mostly dynamic and agency specific)

This categorization aligns with prior work framing spatial awareness as understanding who is where, what is where, and what is happening where, while preserving cross-agency comparison. In the tables below, agency columns (LE, Fire, EMS) indicate which participant groups emphasized specific needs in each category during the GDTA exercise. Blank cells do not imply irrelevance, but rather lower salience in interview accounts. Needs are reported independent of whether they can be represented in static maps.

Locations of People (Dynamic)

Table 1 summarizes participants’ spatial information needs concerning the locations of persons whose positions were consequential during the GDTA exercises (e.g., responders, school personnel, suspects, students, and victims).

Table 1. Spatial information needs related to the locations of people.

Spatial Information Need: Locations of People (Dynamic)	LE	Fire	EMS
Responding Units: Location of fellow officers, fire units, or EMS teams. (P1, P3, P7, P9)	■	■	
School Personnel/Flaggers: Location of the principal, SROs (School Resource Officers), maintenance staff, or flaggers. (P1, P2, P3, P4, P6, P8, P9)	■	■	■
Suspect/Threat: Last known location, whether they are still moving, or if they are hiding in a specific room. (P1, P2, P7)	■	■	
Students/Vulnerable Populations: Location relative to lockdown status, evacuation routes, and rally points. (P1, P3, P5,)	■	■	
Injured/Victims: Locations where medical assistance is needed or where casualties are being collected. (P1, P3, P9,)	■	■	■
Staging Areas and Command Posts: Locations for staging areas, incident command posts, and evacuation rally points (P1, P3, P5, P7, P8, P9)	■	■	

Locations of Objects (Static)

Table 2 summarizes spatial information needs related to static physical features of the school environment, including access points, building systems, and hazards. Although these objects are fixed, their relevance is situational and varies by agency role and response context.

Table 2. Spatial information needs related to the locations of objects (static).

Spatial Information Need: Locations of Objects (Static)	LE	Fire	EMS
Entrances and Door Identification: Locations of exterior doors and windows—especially primary entry points—and the numbering of all exterior and interior doors. (P1, P2, P3, P4, P6, P7, P8, P9)	■	■	■

Exterior Ingress/Egress & Parking: Locations for parking specific apparatus (ambulances/engines), defining fastest/safest entry/exit routes. (P1, P2, P3, P4, P5, P6, P7, P8, P9)	■	■	■
Exterior Landmarks for Orientation: Recognizable exterior reference points (e.g., roads, track/stadium, off-campus buildings) used to establish building sides Alpha, Bravo, Charlie, and Delta for consistent communication during emergency operations. (P1, P2, P4, P5, P6, P7, P9)	■	■	■
Elevators and Stairwells: Location of functioning elevators and stairwells, particularly for moving equipment or stretchers to upper floors. (P3, P4, P5, P6, P7, P8,)	■	■	■
Control Rooms: Location of alarm panels, security boxes, building information (e.g., maps) and keys, internal/CCTV camera feeds, utility shutoffs, electrical panels, and ventilation system controls. (P1, P2, P3, P4, P7, P8, P9, P10)	■	■	■
Obstacles & Accessibility: Locations of ramps, manual/automatic doors, safety bollards, interior furniture, or narrow areas that might impede movement, especially when transporting patients or equipment. (P4, P5, P6)		■	■
Functional Room/Area Designations: Identifying what function a room/area serves (e.g., cafeteria, science room, main office, security operations center, evacuation assembly point) instead of just a room number or color. (P2, P4, P5, P6, P9, P10)	■	■	■
Hazards/Chemicals: Location of stored chemicals, flammable materials, welding gases, or hazmat (e.g., in science labs, shops, or natatoriums). (P3, P5, P10,)		■	

Locations of Events (Dynamic)

Table 3 summarizes spatial information needs associated with dynamic events (e.g., alarm sources, fire or smoke location, door status, evolving access routes) that emerge and change during the incident. These needs are often uncertain, inferred, and time-time-critical.

Table 3. Spatial information needs related to the locations of events (dynamic).

Spatial Information Need: Locations of Events (Dynamic)	LE	Fire	EMS
Call/Alarm Source: Exact location in the building where an emergency call originated or an alarm was triggered. (P1, P2)	■		
Fire/Smoke Location: Specific room or section where fire or smoke is located (often simplified as a colored blotch on a map). (P3, P9,)	■	■	
Locked Status: Location and status (locked/unlocked) of specific doors. (P1, P2)	■		
Alternative Ingress/Egress & Parking: Alternative ingress/egress/parking based on threats/hazards (Fire), resource movement (Fire), or issues such as traffic congestion (EMS) (P4, P5, P6, P7, P8, P9)	■	■	■

DISCUSSION

Our findings outline EMS, fire, and LE spatial information needs, but more importantly, they clarify how these needs are activated through goal-directed spatial reasoning rather than satisfied by static representation alone. In doing so, this study extends formal models of first responders' situational awareness information needs developed in prior studies (Ruiz-Cartiel et al., 2021; Guyo et al., 2023; Wang & Zhu, 2025). Furthermore, by providing insight into the goal-directed spatial decision-making of different responders, we add to emerging studies that explain how first responders navigate to and within complex environments (e.g., McWhorter et al., 2025) by describing similarities and differences in spatial reasoning across EMS, fire, and LE responders during school emergencies. In this section, we interpret our findings to examine what they reveal about the role and usability of maps in mutli-agency school emergency response.

Wayfinding and Spatial Inference in School Emergency Response

Findings from the GDTA underscore the primacy of wayfinding across EMS, fire, and LE during different school emergencies. EMS prioritizes efficient access to patients and egress routes; firefighters emphasize pathways relevant to hazard control and rescue; LE prioritizes rapid movement toward threats. Despite these differences, responders share the same wayfinding-related spatial information needs. These include:

- Exterior landmarks for orientation
- Entrances/exists and door identification
- Hallways and Paths
- Elevators and stairwells
- Functional room/area designations

As wayfinding involves both the use and acquisition of spatial information, the better first responders can move to and through a school building, the more landmark, route, and survey knowledge they can obtain (Siegel & White, 1975; Montello, 1998), including from external representations such as building maps and CCTV camera feeds found in administrative offices and other control centers. This spatial knowledge helps responders infer the dynamic locations of people and events that are not shown on maps.

By prioritizing wayfinding, relatively simple, "cartoon" maps that depict core wayfinding features can thus effectively support multi-agency response. Such maps allow EMS, fire, and LE to infer the locations, movements, and relationships among people, objects, hazards, and events in ways that align with their distinct operational roles and objectives. For example, clearly represented hallways and entry/exit points enable EMS to evaluate stretcher-accessible routes, allow fire crews to anticipate smoke, heat, and evacuation pathways, and support LE in evaluating and selecting corridors based on potential fields of fire. Rather than attempting to present a shared, exhaustive operational picture, maps that foreground common wayfinding features provide flexible external representations which different agencies can reason about movement, access, and hazards in service of their own tactical goals.

Furthermore, our findings show that responders do not treat school maps as comprehensive or authoritative representations of the environment, but as one source of spatial knowledge and situational awareness that also includes environmental perception, radio, and in-person communication. Wayfinding is driven primarily by these sources, with maps serving a supplemental role by supporting spatial assessment and decision-making when memory and real-time environmental perception are insufficient (McWhorter et al., 2025; Montello, 2005; 2018). Consequently, while prior studies highlight the importance of universal design when developing GIS that aim to provide multi-agency responders with a common operational picture (Sørensen, 2025), our findings complement this goal by showing that, in the case of static maps, what must be common across agencies is not exhaustive spatial information, but a common basis for orientation, wayfinding, and flexible spatial inference. In this respect, the specific findings of our study, together with prior research (Ruiz-Cartiel et al., 2021; Guyo et al., 2023; McWhorter et al., 2025; Wang & Zhu, 2025), support analytic generalization to an emerging theory of how first responders use maps and the resulting map requirements (Firestone, 1993). Our unique insight is that, because maps are often shared across agencies, wayfinding—understood as an activity of spatial information gathering and flexible inference—constitutes a shared activity through which shared map requirements can be elicited across EMS, fire, and law enforcement responders in the context of multi-agency school response.

Design Implications: Minimalist Maps for Wayfinding and Spatial Inference

Implication 1: Prioritize static features that support wayfinding and flexible inference: As explained above, maps should foreground spatial features that can be represented in static form that support wayfinding and allow EMS, fire, and LE to flexibly reason about unrepresented and dynamic spatial information to determine who is where, what is happening where, and how conditions are changing relevant to their distinct operational objectives.

Implication 2: Design maps as complementary spatial resources: Our findings show that responders expect to use maps in support of environmental perception, radio communication, and in-person communication when these other sources prove insufficient. Participants also described dynamic spatial information needs that cannot be represented on static maps, including real-time threat and hazard locations, locked-door status, room clearance, and the evolving locations of responders, students, and victims. These needs are time-sensitive and role-dependent, and are primarily addressed through radio communication, environmental cues, and GIS-based systems. Together, these findings clarify the role of static maps—both physical and digital—as complementary spatial information resources that enhance the use of dynamic GIS and operational practices, while remaining useful when those systems are unavailable or break down (Johansson et al., 2010).

Implication 3: Design maps for memorability over exhaustivity: Responders varied widely in their tolerance for information density and symbol interpretation, and many cautioned that excessive detail could contribute to cognitive overload under stress. Across EMS, fire, and law enforcement, maps were most valuable for forming pre-entry mental snapshots that could be carried forward when perception, radio communication, or circumstances precluded map use (e.g., during active shooter response). These observations suggest that the value of standardized school maps lies not in completeness, but in their ability to support fast, memorable spatial reasoning that different agencies can adapt to their own operational objectives.

CONCLUSION

School emergencies require EMS, fire, and law enforcement to act under distinct objectives and uncertainties, yet responders often rely on the same non-standardized school maps of uneven quality. Drawing on a qualitative interview study (n = 10) using a GDTA exercise with satellite imagery and an indoor school map, we show that responders share core spatial information needs that support rapid orientation and spatial inference, while diverging in how they use this information to meet role-specific goals. These findings suggest that standardization should focus not on exhaustive detail, but on the core functions maps support—particularly wayfinding, orientation, and spatial inference—through "simple" maps that enable flexible spatial reasoning.

Future work will extend this research through a focus group and tabletop exercise in which EMS, fire, and law enforcement jointly respond to a shared multi-agency school emergency scenario with common prompts and injects. This addresses limitations of responder-specific prompts and the lack of insight into interagency coordination. By examining how responders collectively interpret and act on spatial information, this work will further refine requirements for interoperable school maps that support both individual decision-making and coordinated action across agencies.

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