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Research Paper

Improving Emergency Call Accessibility via Location Technologies in Romania

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Abstract. This study examines Romania's progress in emergency caller location technologies and accessibility between 2020 and 2024, within the broader European context. Applying a PRISMA-informed review methodology, it draws on official reports, academic sources, and EU regulatory data to evaluate the implementation of Advanced Mobile Location (AML), HTML5 geolocation, and the Apel 112 mobile application Romania was among the first EU countries to deploy AML and subsequent performance metrics indicate notable advancements in geolocation accuracy through hybrid handset- and network-based methods.However, despite these advancements, the adoption of the Apel 112 app has declined, raising concerns about user trust, public awareness, and accessibility. To assess system inclusiveness, this study applies the International Classification of Functioning, Disability and Health (ICF) framework. Findings reveal that persons with hearing, speech, and cognitive impairments continue to face substantial barriers due to the absence of real-time text (RTT), video relay services, and universally designed interfaces. These results support both hypotheses: Romania has strengthened its technical infrastructure for caller location (H1), yet persistent accessibility and interoperability limitations remain (H2). The study concludes that inclusive design, user education, and cross-platform compatibility must become priorities for emergency communication policy to ensure equitable access for all users.

Keywords: Emergency Call Systems, Location Technologies, Accessibility, Advanced Mobile Location (AML), PRISMA Systematic Review, Inclusive Public Services, Digital Interoperability

Introduction

The concept of *accessibility*, originally derived from the Latin *accessibilis*—meaning "approachable"—has evolved far beyond its linguistic roots. According to the Online Etymology Dictionary, the term first appeared in the mid-18th century to describe "the condition or quality of being accessible" [1]. In today's digital era, accessibility encompasses more than physical or technical access; it is better understood as a multidimensional model comprising the responsibility of individuals to seek tools and support, the duty of public institutions to understand and adapt to diverse needs, and a collective commitment to

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fostering inclusion. `Within this model, emergency technologies can only enhance safety when both citizens and public service providers engage in a cooperative effort toward digital inclusion.

Persons with disabilities are not passive recipients of technological interventions. When equipped with digital literacy and accessible interfaces, they become active agents in utilizing emergency systems. Public service providers, in turn, must broaden their understanding of functional impairments and proactively embed accessibility features during system design. Only by aligning both user agency and institutional readiness can we ensure that technological advancements in emergency call systems do not inadvertently exclude the very populations they aim to protect.

Accurate caller location identification is central to effective emergency call management. Alongside the need to determine the nature of the emergency, pinpointing a caller's location is among the most critical components of timely response. Advances in geolocation technologies, smartphone applications, and interoperable networks have significantly improved emergency services' ability to respond promptly and accurately, ultimately reducing fatalities and improving outcomes in acute medical and disaster scenarios.

Emergency geolocation technologies now play a vital role in reducing response times. Innovations in mobile apps and smart devices have expanded how individuals access emergency services. For instance, [2] found that geolocation-enabled applications considerably reduce emergency response times compared to traditional methods. A cornerstone of their effectiveness is system interoperability—particularly in multi-network environments. As noted by [3], the Enhanced 911 (E911) system requires seamless transfer of calls and data across various networks, ensuring accurate location delivery regardless of the caller's device or provider.

Further technological developments, including the integration of 5G protocols, have introduced additional capabilities for emergency response. According to [4], 5G facilitates device-to-device (D2D) communication, allowing devices to connect directly without relying on central infrastructure—a feature particularly useful during disasters or in areas with limited coverage. D2D communication extends emergency access to otherwise unreachable populations[5]. Complementary technologies such as automatic emergency call functionalities, embedded in smartphones and smartwatches, also play an increasingly important role. As noted by [6], such features can autonomously detect trauma or accidents and initiate calls to emergency services, thereby improving response accuracy and timeliness.

Several researchers have emphasized the potential of geolocation data in disaster response planning. [7] highlight its importance in enabling authorities to deploy resources efficiently during emergencies. Similarly, [8] show how location uncertainty models can optimize real-time logistical responses, thereby enhancing coordination and speed. At the same time, the efficiency of these systems is compromised by ongoing issues such as misuse and non-urgent calls, a concern discussed by [9] in the Romanian context. In response to these inefficiencies, [10] propose integrating AI-assisted call triage mechanisms to improve system responsiveness and reduce operator burden.

Romania has taken significant steps in improving emergency caller location accuracy over the last several years. In 2020, it became one of the first EU Member States to implement *Advanced Mobile Location (AML),* a protocol defined by the European Telecommunications Standards Institute (ETSI). AML enables smartphones to automatically activate their built-in *GNSS (Global Navigation Satellite*

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System, which includes satellite networks such as GPS in the United States and Galileo in the European Union) and *Wi-Fi positioning functions* when dialing 112, transmitting precise geographic coordinates—typically within 50–100 meters—to public safety answering points (PSAPs) [11]. This measure was complemented by the release of the free *Apel 112 mobile application* in February 2019, which transmits GPS coordinates from compatible smartphones directly to emergency services or, in the absence of internet connectivity, displays them for manual reporting to the operator [12]. These innovations build upon the traditional *Cell-ID/Sector-ID method,* which identifies the GSM antenna handling a call and provides only approximate coverage areas ranging from hundreds of meters in urban settings to several kilometers in rural regions. More recently, the *Geolocation 112 service*, based on HTML5 technology, has also been introduced: when an STS operator sends an SMS link, the caller can grant browser permission for the phone to transmit its coordinates directly to the 112 system. Together, these four methods form a complementary suite of location solutions, ensuring that caller positioning can be achieved under a wide range of technical and situational conditions (Figure 1).

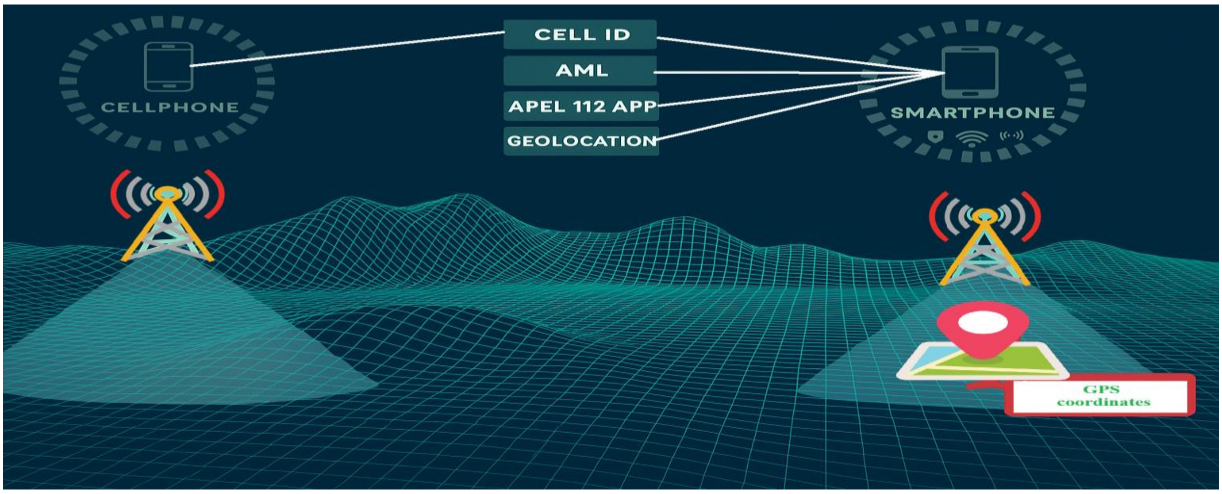

Figure 1. Caller location technologies in Romania's 112 system: Cell-ID/Sector-ID, Advanced Mobile Location (AML), Apel 112 mobile application, and HTML5 Geolocation.
Source: Authors' illustration based on STS [13].

However, Romania's emergency location systems—like those of many EU countries—continue to face significant limitations. As documented by the European Emergency Number Association (EENA) [14], several unresolved challenges persist. These include VoLTE roaming incompatibilities, anonymous emergency call handling, blocked PSAP callbacks, and device-level restrictions that undermine both reliability and inclusiveness. These obstacles call for continued system testing, enhanced cross-border coordination, and greater attention to accessibility as technologies evolve.

To assess Romania's progress in this domain within a broader European context, this study employs a systematic literature review based on the PRISMA 2020 methodology [15]. The initial literature search was conducted using the Litmaps citation discovery tool, which facilitated the identification of relevant academic sources on emergency geolocation and accessibility. The review is complemented by an analysis of three key European Commission reports (2020, 2022, and 2024), as well as a comparative assessment of emergency location systems in selected EU countries to identify trends and implementation gaps.

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This study addresses a research gap that has been insufficiently explored in academic literature—namely, the intersection between emergency caller location technologies and accessibility for persons with disabilities in Romania. By applying a PRISMA-informed methodology and analysing both national and EU-level data, the paper provides a structured evaluation of Romania's progress while drawing attention to enduring accessibility challenges.

Research question:

To what extent has Romania improved emergency caller location accuracy and accessibility between 2020 and 2024, and how does it compare to other EU Member States?

Hypotheses:

- **H1:** Romania has significantly improved the accuracy and reliability of emergency caller location systems following the implementation of Advanced Mobile Location (AML), mobile application technology, and regulatory reforms between 2020 and 2024.
- **H2:** Despite Romania's technological improvements during this period, substantial accessibility and interoperability limitations persist, particularly affecting persons with hearing, speech, and cognitive impairments.

Methodology

This study employs a systematic review approach informed by the PRISMA 2020 guidelines [15], with the objective of synthesizing scholarly and institutional evidence on emergency caller location technologies and accessibility solutions. The methodology integrates both academic research and policy-level documentation to ensure a comprehensive understanding of the Romanian context within the broader European framework.

The literature search was conducted in April 2025 using the Litmaps citation discovery platform, which enabled citation network exploration and thematic clustering. The initial query used the keyword *"location"*, generating approximately 260 articles related to geolocation technologies and emergency services.

As a first screening criterion, only publications from 2020 to 2025 were retained, yielding a reduced pool of 62 sources. Titles and abstracts were then manually reviewed to determine their relevance to four domains: (1) emergency service systems, (2) caller geolocation technologies, (3) mobile app-based emergency tools, and (4) accessibility for persons with disabilities or vulnerable groups.

Following a full-text review, 11 articles met the eligibility criteria and were included in the final analysis. These articles covered diverse topics, including the implementation of Advanced Mobile Location (AML), smartphone-based emergency alert technologies, real-time location systems (RTLS), HTML5 geolocation tools, accessibility innovations for users with disabilities, and interoperability improvements for public safety answering points (PSAPs).

In addition to academic sources, this review incorporates three key European Commission reports on the status of emergency number 112 implementation, published in 2020, 2022, and 2024 [17]–[19]. These reports provide vital insights into Romania's progress relative to EU benchmarks in terms of accuracy, technological alignment, and inclusion.

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To better understand regional positioning, a comparative analysis of emergency caller geolocation systems in selected EU Member States was also conducted. This enabled the identification of patterns, gaps, and variations in national implementation practices, particularly regarding AML availability, device compatibility, regulatory frameworks, and reported accessibility barriers.

The article selection process is illustrated through a PRISMA flow diagram[15] (Figure 2), detailing the steps of identification, screening, eligibility, and inclusion. The final synthesis integrates both qualitative assessments of accessibility challenges and quantitative data extracted from policy reports and technical annexes.

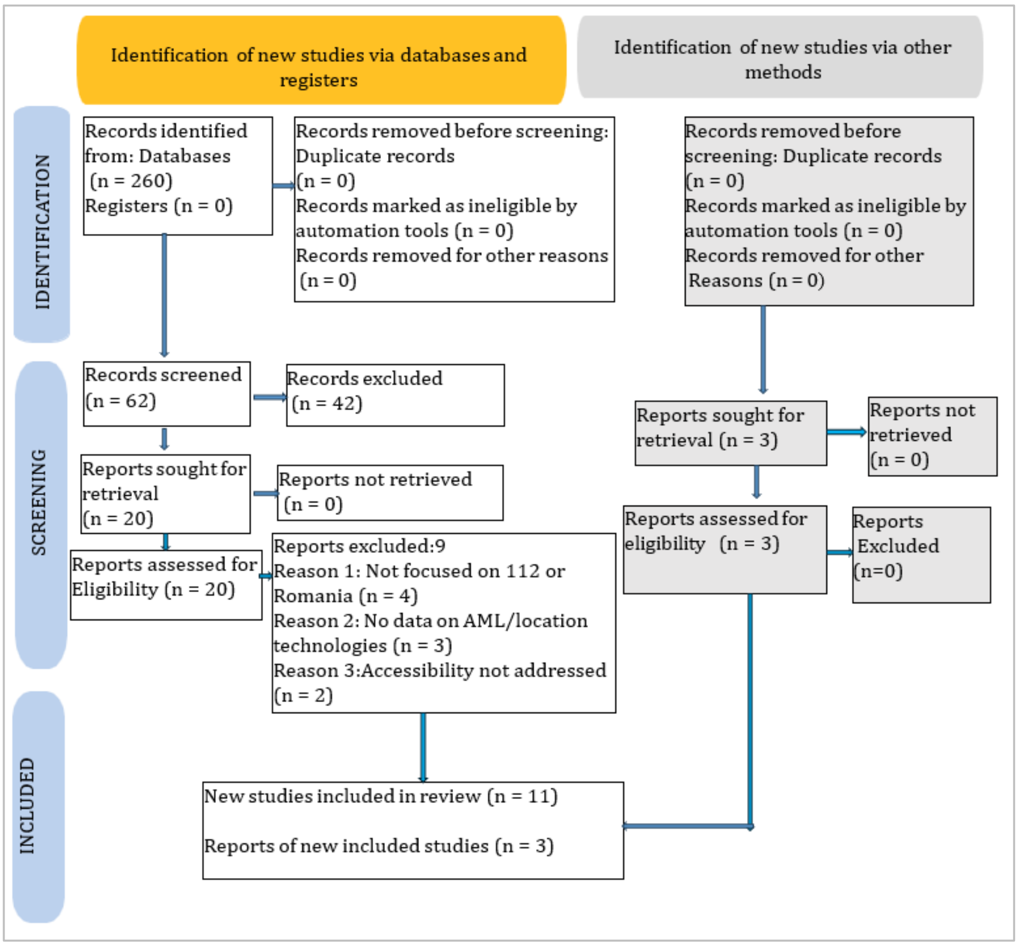

Figure 2. PRISMA 2020 Flow Diagram illustrating the study selection process.
(Source: Author's adaptation based on [15],[16])

Findings and Discussion

A total of 11 peer-reviewed articles published between 2021 and 2025 were identified through the PRISMA 2020 systematic review protocol. These studies examine recent innovations in emergency caller location technologies, system performance, and accessibility for vulnerable populations. The literature reveals key technological developments, including enhancements in Advanced Mobile Location (AML), improvements in LTE-based positioning, device-to-device (D2D) communication during network failures, automatic emergency alerts from smartphones, and inclusive digital solutions for people with disabilities. Romania's trajectory is visible through national-level research addressing

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the integration of artificial intelligence and emerging technologies into the country's 112 emergency call management system. Table 1 summarizes the core topics, methodologies, and key findings of the selected studies.

Year	Main Topic (based on keywords)	Short Citation	Key Findings
2021	Emergency geolocation based on messages	Scalia et al. (2021) [20]	Developed CIME system for extracting location from emergency messages using text mining.
2021	Fixing mobile emergency call geo-location	Al-Nuaimi et al. (2021) [21]	Proposed solutions to overcome mobile emergency call location inaccuracies.
2022	Adaptive emergency calls during network outages	Basnayake et al. (2022) [4]	Introduced D2D communications for emergency calls when networks are compromised.
2023	Automatic emergency calls from smartphones	Hongo et al. (2023) [6]	Smartphones and smartwatches can autonomously detect trauma and contact emergency services.
2023	Accessibility for deaf users (Sign-to-911)	Guo et al. (2023) [22]	Developed mobile service allowing sign language communication during emergencies.
2024	Enhanced LTE location service for emergencies	Moon et al. (2024) [23]	HELPS system improves LTE positioning accuracy for emergency services.
2024	Designing outdoor emergency rescue stations	Xiao et al. (2024) [24]	Location theory used to optimize emergency rescue station placements.
2024	App to reduce emergency medical response time	Gabella et al. (2024) [2]	Geolocation app significantly reduced EMS response times compared to conventional methods.
2024	Enhanced emergency call network reliability	Patel & Patel (2024) [3]	Improved network reliability for emergency calls (e911) through advanced call routing.
2024	EMS accessibility assessment in NYC	Su & Chow (2024) [25]	Data-driven method to identify EMS accessibility gaps based on intersection analysis.
2024	AI and technology in emergency call management (Romania)	Bokor et al. (2024)[26]	Analysed the integration of AI and advanced technologies in Romania's 112 emergency call system.

Table 1. Summary of Articles Included in the Systematic Review (2020–2025)
(Source: Author's summary of the referenced studies)

In addition to the systematic review of academic literature, this study incorporates official European Commission reports on the implementation and performance of the European emergency number 112, published in 2020, 2022, and 2024[17],[18],[19]. These documents provide essential quantitative benchmarks on network-based and handset-derived location accuracy, the rollout of Advanced Mobile Location (AML) across Member States, and the general effectiveness of emergency communication systems. This data formed the basis for a comparative assessment of Romania's progress relative to wider European trends, particularly in terms of geolocation precision, AML adoption, and the integration of mobile-based technologies within emergency response frameworks.

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A particularly important aspect of emergency call management is the accuracy and reliability of location information derived from network-based solutions, especially in the context of fixed-line communications. Over the past five years, EU countries—including Romania—have progressively improved their strategies for locating emergency callers. Until 2023, Romania relied on the installation or billing address associated with the calling party. Beginning in 2023, this practice was replaced with the use of the physical address of the network termination point, reflecting broader regulatory shifts aimed at increasing accuracy and aligning with EU standards for emergency services.

Between 2019 and 2023, the accuracy and reliability of emergency caller location within mobile networks improved significantly, propelled by advancements in telecommunications infrastructure and reinforced by evolving EU regulatory standards. Initially, most Member States relied on basic positioning methods such as Cell-ID or Sector-ID, which provided only broad approximations of caller location (ranging from 500 meters up to 40 kilometers). Gradually, more accurate techniques—including Timing Advance (TA) and Round-Trip Time (RTT)—were adopted, particularly in densely populated urban areas where higher precision is critical. Timing Advance estimates the distance between a mobile device and a base station based on the delay of the transmitted signal, while Round-Trip Time measures the delay for a signal to travel from the network to the device and back, offering accuracies of up to 50 meters in LTE networks [27].

Advanced Mobile Location (AML) is a major step forward in emergency caller geolocation, as it supplements traditional network-based methods with handset-derived information such as Global Navigation Satellite System (GNSS) and Wi-Fi positioning. When a person dials 112, AML-compatible smartphones automatically activate their internal sensors to determine precise coordinates and transmit them to the Public Safety Answering Point (PSAP). Since 2019, AML has been progressively rolled out across the European Union, with early adopters including Croatia, Denmark, France, Germany, Hungary, Portugal, and Sweden. Romania joined the second wave of adopters in 2020, ensuring full deployment of the protocol at an early stage. According to European Commission benchmarks, AML can improve caller location accuracy to within 50–100 meters under optimal conditions [19], [27].

Year/Period	Countries adopting AML	Notes
2019	HR, DK, FR, DE, HU, PT, SE	First adopters (HELP112 II project)
By Sept 2020	CZ, EL, LV, RO, LT, BE, FI, IE, EE, MT, SI, NL, IS, NO	Romania joins; 19 MS + 2 non-EU
2021	AT, BG, ES, IT, LU (and additional late 2020 confirmations)	Expansion phase
2023	SK, SE (full national coverage), others → total 25 EU Member States with AML deployed	Near-complete EU coverage

Table 2. Timeline of AML Deployment in EU Member States (2019–2023)
(Source: Author's adaptation based on [17]–[19])

Between 2019 and 2023, the implementation of Advanced Mobile Location (AML) expanded significantly across EU Member States. AML enhances traditional network-based methods (such as Cell-ID) by integrating GNSS and Wi-Fi data, enabling geolocation accuracy of up to 100 meters. Romania was among the early adopters, joining other Member States in deploying AML by 2020. As shown in Table 3, the number of EU countries using AML grew steadily, reflecting increasing alignment with EU objectives on public safety and emergency geolocation. This progress is documented in the European

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Commission's official reports on the implementation of 112 services published in 2020, 2022, and 2024 [17]–[19].

Year	AML Accuracy	AML Functionality	Countries with AML Deployment (new countries in bold)
2019	Up to 100 m	Supplements Cell-ID with GNSS/Wi-Fi	HR, DK, FR, DE, HU, PT, SE (HELP112 II project)
By Sept 2020	Up to 100 m	Supplements Cell-ID with GNSS/Wi-Fi	All above + **CZ, EL, LV, RO, LT, BE, FI, IE, EE, MT, SI, NL**, IS, NO
2021	Up to 100 m	Supplements Cell-ID with GNSS/Wi-Fi	All above + **AT, BG, ES, IT, LU**
2023	Up to 100 m	Supplements Cell-ID with GNSS/Wi-Fi	All above + **SE (full national coverage), SK**

Table 3. Advanced Mobile Location (AML) Implementation
(Source: Author's adaptation based on [17]–[19])

Table 4 summarizes Romania's progress in emergency caller location technologies between 2019 and 2023. On the network-based side, Romania transitioned from using billing or installation addresses and Cell-ID/Sector-ID—offering only approximate locations—to more precise techniques such as Timing Advance (TA) and Round-Trip Time (RTT). By 2023, the reference for fixed location was updated to the physical address of the network termination point, improving reliability to as much as 100%. On the handset-derived side, Romania officially joined the AML deployment wave in 2020, alongside the Czech Republic (CZ), Greece (EL), and Latvia (LV). By 2023, Romania was among 25 EU Member States with AML fully implemented. This has contributed to enhanced mobile caller location accuracy (within 100 meters) and increased system reliability (ranging from 55% to 80%). These developments underscore Romania's alignment with EU-wide digital emergency communication standards.

Year	Network-Based Location	Handset-Derived Location (AML)
2019	Fixed: Installation address or street/mailing/billing address. Mobile: Cell/Sector ID (accuracy: 500 m – 40 km). Timing Advance, Round Trip Time, or Sector ID used for higher accuracy (up to 50 m).	Joined AML deployment in 2020, alongside **CZ**, **EL**, **LV**. By Sept. 2020, Romania was among the 19 Member States with AML enabled: **CZ**, **EL**, **LV**, **RO**, **HR**, **DK**, **FR**, **DE**, **HU**, **PT**, **SE**, **LT**, **BE**, **FI**, **IE**, **EE**, **MT**, **SI**, **NL**
2021	Fixed: Installation address or street/mailing/billing address. Mobile: Cell/Sector ID (accuracy: 500 m – 40 km). Timing Advance, Round Trip Time, or Sector ID used for higher accuracy (up to 50 m).	Romania among the 22 Member States with AML deployed: **AT**, **BE**, **BG**, **CZ**, **DE**, **DK**, **EE**, **EL**, **ES**, **FI**, **FR**, **HR**, **HU**, **IE**, **IT**, **LT**, **LU**, **LV**, **MT**, **NL**, **PT**, **RO**
2023	Fixed: Physical address of the network termination point (reliability: 60–100%). Mobile: Accuracy up to 100 m, reliability between 55–80%.	Romania among the 25 Member States with AML deployed: **AT**, **BE**, **BG**, **CZ**, **DE**, **DK**, **EE**, **EL**, **ES**, **FI**, **FR**, **HR**, **HU**, **IE**, **IT**, **LT**, **LU**, **LV**, **MT**, **NL**, **PT**, **RO**, **SE**, **SI**, **SK**

Table 4. Romania's Caller Location Solutions (2019-2023)
(Source: Source: Author's adaptation based on [17]–[19])

Performance indicators for Romania's 112 emergency service were also drawn from official reports of the Special Telecommunications Service (STS). Table 5 summarizes key metrics, including the percentage of emergency calls with available location information (Cell-ID/Sector-ID and AML), the number of calls placed via the Apel 112 app, and the integration of HTML5-based geolocation methods. These indicators underscore Romania's sustained efforts to improve location precision and embed mobile-based innovations into its emergency response framework.

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The data show a slight but consistent decline in the percentage of calls accompanied by basic network-based location data (Cell-ID/Sector-ID), decreasing from 99.99% in 2019 to 99.65% in 2022. While marginal, this decline may indicate a shift toward handset-based location technologies such as Advanced Mobile Location (AML), which are increasingly used in parallel with or instead of traditional methods. Temporary integration issues, changes in device compatibility, or inconsistencies in reporting procedures may also explain these fluctuations.

In contrast, AML coverage has improved steadily, with the share of emergency calls transmitting AML data rising from 61.30% in 2021 to 72.90% in 2024 (Table 5). This confirms Romania's progress in expanding AML-compatible infrastructure and enhancing PSAP capabilities.

The Apel 112 mobile app, however, shows a different trend. After a relatively stable period (3,707 calls in 2019; 3,360 in 2021), usage dropped sharply to 1,989 calls in 2023, before recovering slightly to 2,025 in 2024. This trajectory suggests that the decline cannot be explained solely by the automatic transmission of AML data during voice calls. Other contributing factors likely include limited promotion, delayed introduction of multilingual support (added only in 2022), and persistent accessibility barriers for users with disabilities. The modest rebound after 2022 indicates that the app still holds untapped potential, especially if combined with targeted awareness campaigns and accessibility improvements.

Meanwhile, HTML5 geolocation cases rose steadily (from 1,841 in 2019 to 6,444 in 2024), reflecting its growing importance as a browser-based alternative that does not require app installation, thereby offering greater accessibility for certain user groups.

PERFORMANCE INDICATOR	**2019**	**2021**	**2023**	**2024**
PERCENTAGE OF CALLS RECEIVED WITH PRIMARY LOCATION INFO (CELL ID/SECTOR ID)	99.99%	99.97%	99.95%	99.65%
PERCENTAGE OF CALLS TO 112 WITH AML LOCATION INFO	N/A	44.83%	49.72%	56.16%
PERCENTAGE OF EMERGENCY CALLS TO 112 WITH AML LOCATION INFO	N/A	61.30%	67.03%	72.90%
NUMBER OF CALLS THROUGH THE 112 APP	3,707	3,360	1,989	2,025
NUMBER OF CASES WHERE HTML5 LOCATION METHOD WAS USED	1,841	4,090	6,366	6,444

Table 5. Performance indicators - 112 Romania Emergency Service
(Source: Author's adaptation of STS data [28])

To offer broader comparative insights into emergency communication systems within the European Union, this study includes a focused analysis of Romania, Hungary, and Germany. Table 6 presents key performance indicators from 2023, including the total number of emergency calls, population statistics, the volume of e-Calls (automated emergency calls from vehicles), and the number of e-Calls per 100,000 inhabitants. Romania stands out with a notably higher e-Call rate per capita than both Germany and Hungary, underscoring the country's proactive approach to integrating advanced vehicle-based emergency technologies into its public safety infrastructure. This disparity may reflect differences in vehicle fleet composition, e-Call module activation rates, national road safety dynamics, or the degree of interoperability between e-Call systems and public safety answering points (PSAPs).

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Country	Total Emergency Calls	Population	eCalls	Emergency Calls / 100.000	eCalls / 100.000
Romania	10 489 979	19,06 mil.	20 200	55 043,9	105,9
Hungary	5 806 749	9,592 mil.	5 153	60 541,5	53,7
Germany	20 169 966	84,40 mil.	76 947	23 890,4	91,2

Table 6 Comparative Analysis of Emergency Calls and e-Calls in Romania, Hungary, and Germany (2023)
(Source: Author's compilation based on [19])

Table 7 reveals persistent accessibility gaps in Romania's emergency system despite the adoption of advanced technologies such as AML and HTML5 geolocation. While location precision has improved, several groups—particularly persons with hearing, speech, cognitive, and psychosocial impairments—remain underserved. Core accessibility features are still lacking from Romania's 112 emergency communication system, including: Real-Time Text (RTT), a communication mode that allows characters to be sent instantly as they are typed, enabling real-time interaction between users and emergency responders. RTT is vital for persons who are deaf, hard of hearing, or who have speech impairments, and is recognized as a component of Next Generation 112 services [29],[30];Video Relay Services (VRS), which enable deaf or speech-impaired users to connect via a sign language interpreter using video communication. The interpreter relays the conversation in real time between the caller and the emergency operator [31];Simplified user interfaces, which are essential for persons with intellectual or neurodevelopmental disabilities, allowing easier interaction with emergency applications and reducing cognitive load during crises.

HTML5 geolocation refers to a *browser-based location method* that can determine a user's position through GPS, Wi-Fi, or mobile network signals, without requiring the installation of a dedicated mobile application. In practice, a person who opens a web page that supports HTML5 geolocation can share their location directly with emergency services by granting permission in the browser. This makes it especially valuable for users who are unable or unwilling to download an app, or for those using shared or low-capacity devices. Unlike AML, which automatically activates on compatible smartphones during a 112 call, HTML5 geolocation requires the user to click a web link or interact with a browser-based form. The method therefore complements AML by covering situations where app installation is impractical or where the caller initiates contact through digital channels rather than a standard voice call. These features make HTML5 geolocation a promising tool for improving accessibility—particularly for persons with disabilities or individuals with limited digital literacy [32]. These findings partially support Hypothesis 2 (H2): despite technical advancements in geolocation, the absence of inclusive communication features continues to limit accessibility for persons with disabilities.

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ICF Disability Category	Accessibility Needs	Technology in Romania	Status	Comment / Gap
Mobility Impairments	App-based access, hands-free features	112 App, AML (mobile-based location)	Partially met	App useful, but mobility in reaching device still a barrier
Hearing Impairments	Visual/text-based communication, RTT, VRS	SMS-113, 112 App, no national RTT or video relay	Limited support	No RTT or VRS in 112; SMS slow and limited
Visual Impairments	Voice control, screen readers, clear app UI	112 App, AML (automatic)	Partial	App interface not evaluated for screen reader compatibility
Speech Impairments	Text-based communication	SMS-113 only	Limited support	No real-time text; no dedicated speech-neutral pathways
Cognitive Impairments	Simplified UI, confirmation prompts	112 App, unclear accessibility features	Not addressed	Cognitive load not assessed
Psychosocial Impairments	Clarity, stress-reducing interfaces	No personalization or adaptive UI	Not addressed	No known accommodations
Neurological Impairments	Emergency contact automation, fall detection	HTML5 location, smart device AML	Emerging	Supported if device configured properly
Autism Spectrum Disorders	Predictable, sensory-friendly interfaces	Not addressed in 112 App	Not addressed	No known autism-friendly design
Chronic Illness-Related	Passive detection, emergency shortcuts	e-Call, AML, smart devices	Met	Strong for physical emergencies (vehicles, smartwatches)
Multiple Disabilities	Integrated, multi-modal communication	No integrated accessible system yet	Fragmented	Users must switch between SMS, app, voice — not inclusive

Table 7: ICF Disability & Emergency Technology Alignment in Romania
(Source: Adapted by the authors from [19], [34])

Technical Limitations of LTE and IMS Emergency Communications in Romania and Beyond

Despite recent advancements in emergency caller location technologies, several technical limitations persist within LTE (Long-Term Evolution) and IMS (IP Multimedia Subsystem)-based emergency communications—both in Romania and across the European Union. These issues undermine the reliability, interoperability, and inclusiveness of 112 services.

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One major challenge is VoLTE roaming incompatibility, which prevents some travellers from accessing emergency services while abroad due to inconsistent support across mobile networks [35]. Additionally, callback failures occur when public safety answering points (PSAPs) are unable to reconnect with a caller because the system fails to recognize or retain the caller's number in internet-based transmissions [36].

Another limitation concerns caller ID presentation. Emergency operators often attempt to call back using "112" as the displayed number, but certain devices and networks block this as an invalid or incomplete number, based on SIP protocol constraints[37],[38] This issue disproportionately affects users of older or low-end mobile phones, particularly in lower-income communities.

The removal of essential technical identifiers—such as Uniform Resource Names (URNs)—during IP-based call routing presents further complications. These URNs signal whether a call concerns police, fire, or medical emergencies; when omitted, incorrect routing can delay response times or misallocate resources[38] . Furthermore, emergency SMS messages may not reach 112 centers when sent over LTE networks, posing a critical barrier for people who cannot make voice calls [34].

These persistent shortcomings, while technical in nature, have direct human consequences—especially for vulnerable populations. They highlight the urgent need to complement technological modernization with inclusive, interoperable, and accessible communication protocols across all EU Member States.

Conclusion

This study confirms that Romania has made substantial progress in improving the accuracy and reliability of emergency caller location services. As one of the first EU Member States to implement *Advanced Mobile Location (AML)* in 2020, and through the integration of *HTML5 geolocation and handset-based technologies,* Romania has demonstrated a strategic commitment to innovation in the interest of public safety.

The findings show that Romania's emergency call management system is now largely aligned with *European performance benchmarks*, particularly in terms of location precision derived from both network-based and handset-based methods. However, the observed decline in the number of calls made via the *Apel 112 mobile application* (Table 5) suggests a persistent gap between technical deployment and user adoption. Possible factors include limited public awareness, accessibility shortcomings, and redundancy with native AML capabilities. Thus, while the technological framework is in place, greater efforts *in user education, inclusive design, and trust-building* are necessary to ensure meaningful adoption.

Equally important, the path toward a fully inclusive emergency communication system remains incomplete. As demonstrated in Table 7 and analysed through the *ICF framework*, persons with hearing, speech, and cognitive impairments still face significant accessibility barriers due to the lack of features such as *real-time text (RTT), video relay services, and universally designed interfaces.*

These findings support both initial hypotheses: *H1 is confirmed*—Romania has significantly improved its emergency caller location capabilities between 2020 and 2024; *H2 is partially confirmed*—despite

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technological advances, accessibility and interoperability barriers persist, especially for persons with functional limitations.

Beyond the case of Romania, this study makes an original contribution by combining technical evaluations of caller location systems with an analysis of accessibility gaps, a perspective that remains underdeveloped in the literature. By integrating insights from official standards, EU benchmarks, and disability frameworks, it demonstrates that *emergency call technologies cannot be assessed solely on technical accuracy but must also be evaluated through the lens of inclusion.*

Ultimately, emergency services are not only about technological advancement but also about people—and about reaching them in their most vulnerable moments. Romania's progress illustrates how improved geolocation, and mobile tools can directly contribute to saving lives. Yet, only when these tools are inclusive, reliable, and widely adopted can their full potential be realized. Continued investment, public outreach, and cross-sector collaboration are therefore essential for building an emergency response system that truly leaves no one behind.

Looking ahead, future research and policy initiatives in Romania and across the EU should focus on enhancing vertical location accuracy—especially in dense urban environments with multi-story buildings. This involves integrating barometric sensors, smartphone motion data, and advanced capabilities provided by 5G and future 6G networks. Many of these technologies are already embedded in modern smartphones, making it both feasible and urgent to improve indoor emergency detection. Strengthening vertical accuracy can significantly reduce response times when callers are unable to verbally communicate their exact location or floor level, thus saving additional lives.

Conflicts of Interest

The authors declare no conflicts of interest

Glossary

Acronym / Term	Definition
112	The European Union emergency number, available free of charge across all EU Member States.
Apel 112	Romania's official emergency mobile application, launched in 2019 to transmit GPS coordinates and additional caller data.
AML (Advanced Mobile Location)	A handset-based technology that automatically transmits a caller's precise location (via GNSS, Wi-Fi, or mobile networks) to the PSAP during a 112 call.
HTML5 Geolocation	A browser-based method that determines user location via GPS, Wi-Fi, or cell towers without requiring a dedicated app.
eCall	An automated in-vehicle emergency call system that transmits crash data and location to 112 centers.
RTLS (Real-Time Location Systems)	Systems that continuously track and provide the location of assets or people in real time.

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GNSS (Global Navigation Satellite System)	A general term for satellite navigation systems, including GPS (United States), Galileo (EU), and GLONASS (Russia).
GPS (Global Positioning System)	A U.S. GNSS constellation widely used for positioning and navigation.
Wi-Fi Positioning	Location determination method using nearby wireless access points when GNSS is unavailable.
Cell-ID / Sector-ID	Network-based methods identifying caller location by the cell tower or sector handling the call.
TA (Timing Advance)	A positioning method estimating distance between a mobile device and a cell tower using signal delay.
RTT (Round-Trip Time)	A network-based metric measuring the time for a signal to travel from the network to the device and back, used for caller geolocation.
NG112 (Next Generation 112)	A European initiative to modernize emergency services with IP-based technologies, enabling advanced features such as RTT and VRS.
PSAP (Public Safety Answering Point)	An emergency call center where 112 calls are received, located, and dispatched to response agencies.
SMS-113	Romania's dedicated text-to-112 service for persons with hearing or speech impairments.
EMS (Emergency Medical Services)	Pre-hospital medical response services that provide urgent treatment and transport.
LTE (Long-Term Evolution)	A fourth generation (4G) mobile data standard supporting high-speed wireless communication.
5G / 6G	Fifth and sixth-generation mobile network standards offering higher speeds, lower latency, and advanced emergency communication capabilities.
IMS (IP Multimedia Subsystem)	A network architecture supporting IP-based voice, video, and messaging services, including emergency VoLTE calls.
VoLTE (Voice over LTE)	A technology enabling voice calls over 4G LTE networks, critical for IP-based emergency calling.
SIP (Session Initiation Protocol)	A signaling protocol used to initiate and manage multimedia communication sessions, including emergency calls.
URN (Uniform Resource Name)	A persistent identifier used in emergency call routing to indicate service type (police, fire, ambulance).
ETSI (European Telecommunications Standards Institute)	European standards organization that defines protocols such as AML and IMS for emergency services.
3GPP (3rd Generation Partnership Project)	International collaboration developing mobile network standards, including LTE and 5G emergency call protocols.
EENA (European Emergency Number Association)	A Brussels-based NGO supporting 112 implementation, research, and best practices.
E911 (Enhanced 911)	The U.S. emergency calling system requiring automatic caller location delivery to PSAPs.

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RTT (Real-Time Text)	An accessibility feature allowing text characters to be transmitted instantly as typed, enabling real-time interaction for deaf or speech-impaired users.
VRS (Video Relay Service)	A service allowing deaf or speech-impaired users to communicate with emergency services via a sign language interpreter over video.
ICF (International Classification of Functioning, Disability and Health)	A World Health Organization framework used to analyze disability, health, and accessibility barriers.
STS (Special Telecommunications Service)	Romania's government agency responsible for administering the 112-emergency system.
PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)	A methodological framework and reporting guideline for systematic literature reviews.
MS (Member States)	Refers to the countries belonging to the European Union (EU).
D2D (Device-to-Device Communication)	Direct communication between mobile devices without using central infrastructure, useful in disasters or network outages.

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