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Development and Validation of The Instrument for Accessibility Model Framework with Integration of Internet-of-Things for Fire Emergency Preparedness

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ABSTRACT

Fire emergencies present significant risks when building safety systems do not adequately address accessibility, preparedness, and inclusive evacuation needs. The increasing use of Internet-of-Things (IoT) technologies provides opportunities to strengthen fire emergency preparedness through real-time alerts, emergency exit guidance, automated lighting, smart fire extinguisher indicators, and voice-assisted evacuation support. This study develops and validates an instrument for assessing an Accessibility Model Framework with IoT integration for fire emergency preparedness. The instrument is structured around two main dimensions: technology acceptance and accessibility-based fire emergency support. The technology acceptance dimension includes performance expectancy, effort expectancy, social influence, facilitating conditions, perceived usefulness, perceived ease of use, attitude, subjective norms, and perceived behavioural control. The accessibility-based fire emergency support dimension includes IoT-based emergency exit guidance, real-time fire alerts on mobile applications, automated emergency lighting, smart fire extinguisher location indicators, and voice-assisted evacuation support. Six experts from fire safety management, facilities management, IoT technology, and emergency response evaluated the instrument using the Content Validity Index method. The results showed strong content validity, with most items achieving acceptable Item-Level Content Validity Index values and the overall Scale-Level Content Validity Index falling within the recommended range. The findings indicate that the instrument has acceptable conceptual coverage and expert-agreed relevance for evaluating accessibility and preparedness in IoT-enabled fire emergency contexts. However, the findings should be interpreted as evidence of content validity only, rather than evidence of field effectiveness or actual user performance. The validated instrument provides a foundation for future pilot testing, empirical implementation, and refinement in real-world IoT-enabled buildings. It may support researchers, building managers, emergency planners, and policymakers

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in identifying key accessibility and IoT readiness dimensions, although further testing with users and operational building systems is required before broader policy or practice recommendations can be made.

1. Introduction

The integration of Internet of Things (IoT) technologies into fire emergency preparedness frameworks represents a significant advancement in enhancing safety and response efficiency. Developing and validating an instrument for an accessibility model framework that incorporates IoT for fire emergency preparedness is a critical step toward modernizing contemporary fire safety protocols. This effort aims to generate a reliable and comprehensive system capable of assessing and predicting individuals' readiness to adopt IoT-based fire safety solutions. By drawing on the Technology Readiness Index (TRI) and the Technology Acceptance Model (TAM), researchers have created a validated survey instrument to measure users' acceptance and willingness to use IoT technology in residential fire detection and preparedness contexts. The instrument underwent rigorous expert validation, ensuring strong content relevance and reliability for assessing IoT integration readiness [1].

Beyond readiness assessment, IoT demonstrates transformative potential when integrated with machine learning (ML) and other advanced computational systems. Real-time IoT sensor data, when processed through ML-based predictive models, can enhance emergency response mechanisms by prioritizing actions based on impact severity, urgency, and resource availability. Such capabilities support both immediate operational responses and long-term strategic planning, offering data-driven insights into potential fire hazards and emergency scenarios [2]. Furthermore, the fusion of IoT with Building Information Modeling (BIM) provides an innovative pathway for improving fire prevention and emergency management. This integration enhances situational awareness, supports decision-making, and strengthens the infrastructural foundation required for smart city development [3].

IoT-enabled fire safety systems also address practical, context-specific challenges in residential and public settings. For example, IoT-based fire alarm systems embedded in everyday public objects such as dustbins can detect fire hazards caused by improperly discarded cigarette waste, triggering multi-level alerts to improve public safety [4]. Additionally, IoT monitoring frameworks designed for public buildings can relay real-time environmental and human-occupancy data, enabling rescuers to optimize search, evacuation, and suppression strategies during fire emergencies [5]. Collectively, these technological innovations underscore the transformative potential of IoT in developing responsive, efficient, and safer fire emergency preparedness systems, contributing significantly to broader smart city aspirations and public safety enhancements.

Although IoT-enabled fire emergency preparedness offers clear potential, several real-world implementation challenges must be considered. First, technological variability may affect the applicability of the instrument across different buildings. IoT-enabled buildings may use different types of sensors, communication networks, mobile applications, emergency lighting systems, alarm devices, and building management platforms. This variation can make it difficult to apply a single assessment instrument uniformly without contextual adaptation. Second, cost may become a major barrier, especially for older buildings, small facilities, public buildings with limited budgets, or buildings that require retrofitting. The installation and maintenance of IoT sensors, smart emergency lighting, real-time alert systems, mobile applications, backup power systems, and integrated monitoring platforms may require substantial financial investment. Therefore, the instrument should be used not only to assess ideal preparedness conditions, but also to identify practical priorities for phased implementation.

Third, system interoperability is a critical concern. IoT-based fire safety systems may involve multiple vendors, software platforms, communication protocols, and data formats. If emergency alerts, sensors, building information systems, and mobile applications cannot communicate effectively, the overall emergency response system may become fragmented. This can reduce the reliability of real-time guidance and weaken the effectiveness of emergency preparedness. Fourth, reliability and maintenance issues must be considered. IoT-enabled fire safety systems depend on stable internet connectivity, sensor accuracy, software updates, battery performance, cybersecurity protection, and continuous system monitoring. Any failure in these components may affect the delivery of emergency alerts or evacuation guidance during critical situations. Therefore, future implementation of the instrument should include technical performance indicators and maintenance-related criteria.

Lastly, user readiness and accessibility remain important challenges. Building occupants, including persons with disabilities, older adults, and users with limited digital literacy, may respond differently to mobile alerts, voice-assisted guidance, or digital evacuation instructions. For this reason, the instrument should be tested with real users to ensure that IoT-enabled preparedness systems are not only technically available, but also accessible, understandable, and usable during emergencies.

2. Literature Review

The development and validation of an instrument for an accessibility model framework integrating Internet of Things (IoT) for fire emergency preparedness involves several key components. The primary focus is on creating a reliable and valid survey instrument to assess users' readiness to accept and use IoT technology in home fire safety systems. This process utilizes the Technology Readiness Index (TRI) and the Technology Acceptance Model (TAM) to develop instrument items, followed by content validation with expert panels. The final instrument, consisting of 38 items, demonstrates high content validity and reliability, making it a valuable tool for researchers, policymakers, and industry professionals to predict IoT technology readiness in residential fire detection systems [1].

Integrating IoT with emergency response systems can significantly enhance fire emergency preparedness. IoT-driven frameworks, such as the one proposed for fire prevention and emergency management, leverage real-time data from sensors and predictive analytics to optimize incident response and improve situational awareness. These systems utilize various technologies, including Building Information Modeling (BIM), machine learning, and cloud computing, to dynamically assess risks, predict hazards, and provide actionable insights. For instance, the integration of IoT with BIM tools offers exceptional opportunities for creating innovative fire safety systems in buildings, enhancing both immediate response capabilities and strategic planning [3][6]. Additionally, IoT-based smart emergency response systems incorporating sensors and communication technologies can provide comprehensive solutions for real-time data monitoring and emergency management across vehicles, homes, and healthcare settings, thereby improving overall safety and efficiency [2].

The validation of IoT integration frameworks for fire emergency preparedness also involves evaluating accessibility and response efficiency. Studies have shown that effective resource deployment during emergencies can be revolutionized by integrating IoT and machine learning, enabling rapid and informed responses based on real-time data analysis and predictive modeling [7]. Furthermore, accessibility models, such as the Rational Agent Accessibility Model (RAAM) and gravity models, assess the spatial distribution and accessibility of emergency services, highlighting the need for strategic infrastructure planning to optimize evacuation routes and reduce response times. These models provide localized and regional insights into spatial disparities, guiding emergency planners in enhancing disaster preparedness and response strategies.

Table 1
Summary of Key Components in IoT-Integrated Fire Emergency Preparedness Frameworks

Component	Detailed Description	Supporting Sources
IoT Readiness Instrument Development	Development of a 38-item validated survey instrument grounded in TRI and TAM theories to assess user readiness and acceptance of IoT technologies for residential fire safety. Includes expert content validation, demonstrating strong reliability and construct relevance.	[1]
IoT–BIM Integration for Fire Management	Integration of IoT sensor data with BIM enhances fire detection, situational awareness, and emergency response planning. Supports smart building infrastructure and real-time visualization of fire-related data for decision-making.	[3], [6]
Smart Emergency Response Systems (SERS)	IoT-driven systems for monitoring vehicles, homes, and healthcare conditions. These systems utilize sensor networks, communication modules, and cloud processing to support early detection, automated alerts, and holistic emergency response functions.	[2]
Predictive Analytics and Machine Learning	ML algorithms improve incident prioritization and enhance emergency response by analyzing real-time IoT sensor data. Predictive models enable proactive hazard identification, resource deployment, and optimized response strategies.	[2]
Accessibility and Spatial Modeling for Emergency Services	RAAM and gravity-based models analyze spatial accessibility to shelters and emergency services. These models highlight disparities in service distribution, identify risk zones, and guide planners in optimizing evacuation routes and emergency infrastructure.	[8]

In conclusion, the integration of IoT technology into fire emergency preparedness frameworks offers significant advancements in early detection, response optimization, and strategic planning. The validated survey instrument provides a reliable tool for assessing IoT readiness, while IoT-driven frameworks and accessibility models enhance emergency response efficiency and situational awareness. These innovations contribute to creating smarter and safer environments, ultimately improving fire safety and emergency preparedness at both community and organizational levels.

3. Methodology

Recent studies from the last five years, as shown in Table 2, indicate that CVI evaluation methods have become more organized, multi-layered, and iterative. To make instruments more reliable, researchers are combining more than one indicator. Abbady et al. [9] used a multi-level CVI method with strict cut-off rules and 22 experts to decide which items should be kept, modified, or removed. Md Nasir et al. [10] used a five-step validation process that included I-CVI, S-CVI/Ave, CVR, and kappa to account for chance agreement. The 2023 study by Dalawi et al. [11] employed a combination of I-CVI, S-CVI/Ave, S-CVI/UA, CVR, and FVI to ensure that Version 2.0 of their instrument achieved both expert consensus and satisfactory face validity. These methodological advancements have also benefited organizational research. For example, Karthik and Devi [12] used CVI with modified kappa on 52 items, demonstrating the importance of kappa-adjusted dependability for large item pools. Huang et al. [13] utilized the Delphi method to demonstrate that multiple rounds of expert review can raise CVI values from moderate to excellent levels, with I-CVI rising to 1.00 and S-CVI improving from 0.84 to 0.96. Collectively, these studies indicate a clear trend toward employing multiple CVI indices, chance-corrected statistics, and iterative expert review processes to enhance the accuracy, reliability, and overall methodological robustness of research instruments.

Table 2
Recent Applications of CVI

Study (Year)	Expert Panel & Rating Scale	CVI Indices Used	Criteria Applied	Features of CVI Method
[9]	22 experts, relevance and clarity ratings (4-point scale)	I-CVI, E-CVI (per expert), S-CVI	I-CVI > 0.79 retained; 0.70–0.79 revised; <0.70 deleted	Demonstrates multi-level CVI (item, expert, scale) and explicit decision rules for revising/deleting items.
[10]	7 experts, likert-type relevance scale	I-CVI, S-CVI/Ave, kappa, CVR	I-CVI ≥ ~0.80, S-CVI/Ave ≈ 0.96; kappa > 0.74	Five-step content validation process; combines CVI with kappa and CVR to address chance agreement and essentiality of items.
[14]	8 experts, rated relevance and clarity	I-CVI, S-CVI (for relevance & clarity), CVR, modified kappa	CVR ≥ 0.75 and I-CVI ≥ 0.78 for retention; S-CVI (relevance) = 0.91, (clarity) = 0.83	Uses separate CVI for relevance and clarity; integrates CVR and modified kappa; multiple items revised/deleted based on CVI outcomes.
[11]	6 experts, excel-based analysis	I-CVI, S-CVI/Ave, S-CVI/UA, CVR, FVI	S-CVI/Ave > 0.90 across domains; CVR > 0.70 for most items	Combines CVI, CVR and face validity; reports S-CVI/Ave and S-CVI/UA; items with low CVR/I-CVI revised or removed in Version 2.0.
[12]	6 experts, structured feedback on 52 items	I-CVI, S-CVI, modified kappa (K*)	I-CVI ≥ 0.78 deemed acceptable; S-CVI ≈ 0.94; K* > 0.74 for most items	Illustrates CVI use in organisational/management context; emphasises kappa-adjusted interpretation for larger item pools.
[13]	Delphi with expert panels (2 rounds); Likert-type relevance ratings	I-CVI, S-CVI, CV (coefficient of variation)	Target I-CVI ≥ 0.78 and S-CVI ≥ 0.90; I-CVI improved to 0.80–1.00; S-CVI from 0.84 → 0.96	Uses iterative Delphi rounds to progressively raise CVI values and consensus; combines CVI with opinion concentration and authority coefficients.

4. Results and Discussion

Six experts evaluated the instrument's content validity and utilized both item-level and scale-level indices to determine the adequacy of the measurement items. Overall, the data indicate that the instrument possesses strong content validity. Of the 42 items reviewed, 36 achieved an Item-Level Content Validity Index (I-CVI) score of 0.83 or higher, which exceeds the minimum acceptable threshold recommended by six expert reviewers. This indicates that most items were consistently rated as relevant, clear, and representative of the constructs being measured. A small number of items, primarily those related to Social Influence and certain IoT-based fire emergency features, received ratings below the threshold and require improvement. Nevertheless, these few low-scoring items do not significantly affect the overall strength of the instrument.

The Universal Agreement (UA) was also examined to determine how many items received unanimous approval from all experts. A total of 35 items met the criteria for full agreement, yielding an S-CVI/UA score of 0.833. A universal agreement score above 0.80 is widely regarded as strong and indicative of good expert consensus. This further supports the conclusion that the majority of questionnaire items demonstrate sound conceptual fit and relevance among experts in the field.

The Scale-Level Content Validity Index (S-CVI/Ave) was also calculated using the average method to complement these findings. The resulting value of 0.869 indicates that the scale as a whole possesses a high level of content validity. Values above 0.80 are considered good by established standards, while values approaching or exceeding 0.90 are regarded as excellent. Although the S-CVI/Ave does not quite meet the criteria for excellence, it is evident that the instrument is conceptually sound and requires only minor refinements, particularly to the items identified as weak.

The relevance ratings provided by each expert further aid in assessing the strength of agreement. The experts' relevance scores ranged between 0.69 and 0.95, with an average of 0.869. This indicates that most experts considered the items to be highly relevant. There is some variation in ratings across experts, which is expected given differences in professional perspectives, but the overall average remains well within acceptable validity standards. This further demonstrates that the instrument is well-constructed and aligned with the conceptual domains it is intended to measure.

Collectively, these results indicate that the instrument demonstrates strong overall content validity. The high I-CVI values for most items, strong universal agreement, and an S-CVI/Ave value of 0.869 confirm that the measurement tool is reliable and suitable for pilot testing, followed by large-scale deployment. A small number of items related to IoT and social influence may benefit from further refinement to enhance clarity and alignment. Notwithstanding these minor adjustments, the instrument's structure and content are robust, comprehensive, and consistent with the study's core conceptual framework, ensuring that it accurately measures the intended constructs.

Based on the results of the Item-Level Content Validity Index (I-CVI), Universal Agreement (UA), and Scale-Level Content Validity Index (S-CVI) tests, Table 3 presents the expert validation results for all 42 items in the instrument. Items that received at least five out of six expert ratings as relevant (I-CVI ≥ 0.83) were deemed acceptable. Items that did not meet this threshold were marked for revision. Thirty-six items achieved satisfactory I-CVI scores, while thirty-five items received full Universal Agreement. An S-CVI/Ave of 0.869 and an S-CVI/UA of 0.833 indicate that the scale as a whole demonstrated high content validity. Based on these results, the instrument appears to be conceptually sound, well-aligned with its intended constructs, and requires only minor refinements to a few items prior to pilot testing.

Table 3
Content Validity Index (CVI) Results for Instrument Items Evaluated by Six Experts

ITEM		Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Agreement	I-CVI	Category	UA
Performance Expectancy (PE)	PE1	1	1	1	1	1	1	6	1.000	✓	1
	PE2	1	1	1	1	1	1	6	1.000	✓	1
	PE3	1	1	1	0	1	1	5	0.833	✓	1
Effort Expectancy (EE)	EE1	1	1	1	1	0	1	5	0.833	✓	1
	EE2	1	1	1	0	1	1	5	0.833	✓	1
	EE3	1	1	1	0	1	1	5	0.833	✓	1
Social Influence (SI)	SI1	1	1	0	1	1	1	5	0.833	✓	1
	SI2	1	1	0	0	0	1	3	0.500	X	0
	SI3	1	1	1	1	1	1	6	1.000	✓	1
Facilitating Conditions (FC)	FC1	1	1	1	1	1	1	6	1.000	✓	1
	FC2	1	1	1	1	0	1	5	0.833	✓	1
	FC3	1	1	1	1	0	1	5	0.833	✓	1
Perceived Usefulness (PU)	PU1	1	1	1	0	1	1	5	0.833	✓	1
	PU2	1	1	1	1	1	1	6	1.000	✓	1
	PU3	1	1	1	0	1	1	5	0.833	✓	1
Perceived Ease of Use (PEOU)	PEOU1	1	0	1	1	1	1	5	0.833	✓	1
	PEOU2	1	1	1	1	1	1	6	1.000	✓	1
	PEOU3	1	1	1	1	1	1	6	1.000	✓	1
Attitude (ATT)	ATT1	1	1	1	0	1	1	5	0.833	✓	1
	ATT2	1	1	1	1	1	1	6	1.000	✓	1
	ATT3	0	1	1	1	1	1	5	0.833	✓	1
Subjective Norms (SN)	SN1	1	0	1	1	1	1	5	0.833	✓	1
	SN2	0	1	1	1	1	1	5	0.833	✓	1
	SN3	1	0	1	1	1	1	5	0.833	✓	1
Perceived Behavioral Control (PBC)	PBC1	0	1	1	1	1	1	5	0.833	✓	1
	PBC2	1	0	1	1	1	1	5	0.833	✓	1
	PBC3	1	1	1	1	1	1	6	1.000	✓	1
IoT-based Emergency Exit Guidance	A_EE1	1	1	1	0	0	0	3	0.500	X	0
	A_EE2	1	0	1	1	1	1	5	0.833	✓	1
	A_EE3	1	1	1	0	1	1	5	0.833	✓	1
Real-time Fire Alerts on Mobile Apps	A_FA1	1	1	1	1	1	1	6	1.000	✓	1
	A_FA2	1	1	1	0	1	0	4	0.667	X	1
	A_FA3	1	1	1	1	1	1	6	1.000	✓	1
Automated Emergency Lighting	A_AEL1	1	1	1	1	1	1	6	1.000	✓	1
	A_AEL2	1	1	1	1	1	1	6	1.000	✓	1
	A_AEL3	1	0	1	1	1	1	5	0.833	✓	0
Smart Fire Extinguisher Location Indicators	A_SFE1	1	1	1	0	1	1	5	0.833	✓	0
	A_SFE2	1	1	1	1	1	1	6	1.000	✓	1
	A_SFE3	1	1	1	1	1	1	6	1.000	✓	1
Voice-Assisted	A_VAE1	1	0	1	1	1	1	5	0.833	✓	0

Evacuation Support	A_VAE 2	1	1	1	0	1	1	5	0.833	✓	0
	A_VAE 3	1	0	1	0	1	1	4	0.667	✗	0
Relevance Ratio		0.93	0.81	0.95	0.69	0.88	0.95				
Average items for 6 experts				0.869							
								Total I-CVI	36.50		
								S-CVI/Ave: (Total I-CVI/Total Item)	0.869		
								Category	✓		
								Total UA	35		
								S-CVI/UA: (Total UA/Total Item)	0.833		
								Category	✓		
Notes: ✓= Acceptable, ✗ = unacceptable											

4. Study Limitation

This study has several limitations that should be acknowledged. First, the validation process relied on expert judgment using the Content Validity Index method. Although expert validation is an important step in instrument development, it does not provide evidence of how the instrument performs in actual building environments or emergency situations. The results therefore confirm content relevance and expert agreement, but they do not confirm predictive validity, usability, reliability over time, or actual effectiveness during fire emergency preparedness assessment. Second, the instrument has not yet been tested with building occupants, persons with disabilities, emergency responders, facilities managers, or end users of IoT-enabled fire safety systems. As a result, the current study does not capture user experience, behavioural response, perceived accessibility barriers, or practical difficulties encountered during real evacuation or preparedness scenarios. Future studies should involve user-based evaluation to determine whether the instrument is understandable, usable, and meaningful to different stakeholder groups. Third, this study does not include field implementation in real IoT-enabled buildings. The instrument was validated conceptually, but it has not been applied to assess actual building systems, evacuation routes, IoT sensors, mobile alert systems, emergency lighting, or voice-assisted evacuation devices. Therefore, the findings should not be interpreted as evidence that the instrument can immediately improve emergency outcomes without further pilot testing and operational validation. Finally, the expert panel consisted of six experts. While this number is acceptable for content validity assessment, a larger and more diverse panel may provide broader perspectives across different building types, regulatory environments, disability needs, IoT infrastructures, and emergency management practices. Future research should expand the expert pool and include multi-site validation to strengthen the generalisability of the instrument.

5. Policy and Practice Implications

The instrument offers preliminary practical value as a structured checklist or assessment tool for examining the readiness of IoT-integrated fire emergency preparedness systems. Its main contribution at this stage is not to prove that IoT improves evacuation outcomes, but to identify the key dimensions that should be considered when evaluating accessibility, preparedness, and technology acceptance in fire safety contexts. For practitioners, the instrument can assist facilities managers, building surveyors, fire safety officers, and emergency planners in reviewing whether important IoT-based support features are considered, such as emergency exit guidance, mobile fire alerts, automated emergency lighting, smart extinguisher indicators, and voice-assisted evacuation support. This can help stakeholders identify potential gaps before conducting more detailed technical audits or field evaluations. For policymakers, the validated instrument may serve as an early reference for developing more inclusive assessment criteria for smart and accessible fire emergency preparedness. However, policy recommendations should remain cautious because the present study is limited to content validity evidence. Before the instrument is adopted into formal regulatory guidelines or building assessment procedures, further empirical testing is required across different building categories, user groups, and IoT system configurations. For researchers, the instrument provides a foundation for future quantitative validation, including pilot testing, reliability analysis, exploratory factor analysis, confirmatory factor analysis, and user-based evaluation. These next stages are necessary to determine whether the instrument is statistically reliable, practically usable, and capable of measuring accessibility and preparedness consistently in real-world fire safety environments.

6. Conclusion

This study set out to develop and validate a specialised instrument designed to assess accessibility and preparedness in fire emergency contexts where Internet of Things (IoT) technologies are integrated into safety systems. Guided by the growing need for responsive, data-driven, and inclusive fire safety solutions, the instrument was rigorously evaluated by six domain experts representing fire safety management, facilities operations, IoT technology, and emergency response practice. Using the Content Validity Index (CVI), both item-level and scale-level agreement surpassed established thresholds, with all items achieving I-CVI values above 0.78 and the overall S-CVI falling within the recommended range. These outcomes demonstrate that the instrument is not only conceptually sound and contextually relevant, but also methodologically robust in capturing the dimensions of accessibility and preparedness within IoT-enabled environments.

The strong expert consensus confirms that the instrument reliably represents the constructs necessary for evaluating how IoT components enhance fire emergency preparedness, particularly in terms of real-time monitoring, automated alerts, and interconnected safety mechanisms. Beyond its immediate validation, the instrument offers practical value for researchers, policymakers, and practitioners seeking to benchmark, audit, or improve building readiness for fire emergencies in an increasingly digital ecosystem. By providing a structured and validated measurement tool, this study contributes to strengthening evidence-based decision-making, informing regulatory considerations, and fostering safer, more inclusive built environments. The instrument thus serves as a foundational resource for advancing future research and guiding the implementation of IoT-integrated accessibility frameworks in fire emergency preparedness.

The main contribution of this study is the development of a conceptually validated instrument that can guide future assessment of accessibility and IoT readiness in fire emergency preparedness. However, the findings should be interpreted within the scope of content validation. The study does not yet provide empirical evidence from field implementation, user testing, or operational evaluation in actual IoT-enabled buildings. Therefore, claims about policy and practice contributions should be viewed as preliminary and developmental rather than conclusive.

Future research should proceed with pilot testing involving building occupants, persons with disabilities, facilities managers, fire safety practitioners, and emergency responders. Further statistical validation, including reliability testing and factor analysis, is also needed to confirm the instrument's measurement structure. In addition, future studies should examine real-world implementation challenges, including technological variability, cost, system interoperability, maintenance requirements, cybersecurity risks, and user readiness. Addressing these issues will strengthen the practical value of the instrument and support its eventual use in improving inclusive, IoT-enabled fire emergency preparedness.

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