# Universal Design of ICT for Emergency Management

## A Systematic Literature Review and Research Agenda

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**Abstract.** The primary objectives of this article are to give a systematic overview of the current state of the emerging research field of Universal Design of Information and Communication Technology (ICT) for Emergency Management, and to highlight high-impact research opportunities to ensure that the increasing introduction of ICT in Emergency Management can contribute to removing barriers instead of adding more barriers, in particular for the elderly and people with disabilities. A systematic review on various literature with respect to Universal Design, ICT and Emergency Management between 2008 to 2018 was employed in this study, and reviewed systematically using a predefined framework. The ultimate goal of this effort is to answer the following questions: 1) How strong is the coverage of research on Universal Design of ICT in Emergency Management in the different categories of Emergency Management ICT tools? 2) What potential next steps in research on Universal Design of ICT in Emergency Management have the highest potential impact in terms of improved Emergency Management and reduced Disaster Risk? We identify a set of gaps in the literature, indicating that there are some challenges where Universal Design is not so much taken into account in the technology development to support the different phases of the crisis management cycle. We also derive a research agenda based on areas that are missing in the literature, to serve a future research in the area of universal design and Emergency Management.

**Keywords:** Universal Design of ICT, Accessibility, Emergency Management.

## 1 Introduction

Universal Design concerns the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design. A prerequisite for Universal Design is *accessibility*. According to WAI/W3C, for the web, accessibility means that people with disabilities can perceive, understand, navigate, and interact with websites and tools, and that they can contribute equally

without barriers [1]. In other words, accessibility and usability for the broadest possible diversity of users.

Universal Design in Emergency Management has until now primarily been a research field where the focus has been on the physical environment, buildings and escape routes. However, Universal Design of ICT in Emergency Management and crisis communication can also greatly impact the ability to save people's life in a disaster situation. Practitioners as well as scientists agree that appropriate ICT technology can improve all parts of the disaster management and crisis communication cycle regarding the needs of people with disabilities [1].

However, research indicates that the focus on Universal Design in design of tools and platforms for use in Emergency Management has not been strong enough. To mention two examples: A selection of web-based tools and platforms for crowdsourcing of information for enhanced public resilience were examined. The results show that none of the tested tools were universally designed and accessible to all users [2]. A study of a set of emergency alert sign-up pages in the northeast of US showed that of 26 webpages that were evaluated, 21 had accessibility issues [3].

To get a more complete overview of the situation concerning Universal Design of ICT for Emergency Management and to highlight future directions for research in this area, the following research questions are proposed: 1) How strong is the coverage of research on Universal Design of ICT in Emergency Management in the different categories of Emergency Management ICT tools? 2) What potential next steps in research on Universal Design of ICT in Emergency Management has the highest potential impact in terms of improved Emergency Management and reduced Disaster Risk?

The rest of the article is organized as follows: Section 2 presents the framework that forms the basis of the systematic literature review. Section 3 presents the methodology used, and Section 4 provides the results and findings. Section 5 discusses the potential impact of research on different aspects of Emergency Management and proposes a research agenda for future research directions in this area, and Section 6 concludes this study.

## 2 Framework

To understand better the knowledge status and current research on Universal Design and Emergency Management, we need solid framework to analyse the literature.

The four-phase of Emergency Management i.e. preparedness, response, recovery and mitigation is the most acceptable Emergency Management life cycle [4]:

- *Mitigation* seeks to eliminate or reduce the impact of hazards. It also includes the long-term activities to reduce the consequence of the disaster.
- *Preparedness* measures seeks to improve disaster response operations and reduce disaster damage.
- *Response* include activities during a disaster such as evacuation and supplying disaster victims with emergency aids.

- *Recovery* assists the reconstruction of infrastructure and help community return to normal.

Aman, Irani and Liang [5] examined the use of ICT in Emergency Management, and have defined the following categories where ICT technologies are used:

- *Communication* - Technologies for communication among first-responders, victims and the public, and information creation, dissemination and validation.
- *Event Detection and Assessment* - Technologies used for disaster prevention, early response and damage mitigation.
- *Warning* - Technologies used to alert the public of potential dangers.
- *GIS Supported* Collaboration - Map-based technologies to help in collaboration.
- *Decision Support* - Technologies to aid in decision making.
- *Training* - Tools used in training of first responders for emergency response activities.
- *Navigation* - Technologies that assist in navigating to/from affected areas.
- *Evacuation* - Technologies used to assist in evacuating affected areas or areas under risk.

Universal Design of ICT seeks to ensure that ICT tools are usable and accessible to the widest range of people. It is most achievable through integrating closely with solid development methodologies. In general, a user-centred design approach is required to prioritise the requirements of diverse user groups. This approach, in the context of Universal Design of ICT, involves iterations of requirements, prototyping, and testing with different methods such as review/case study, automatic testing, heuristic testing, and user testing.

In the following, we will use these as the main frameworks to classify tools and technologies in the impact analysis as well as for the prioritization of the items in the research agenda.

## 3 Method

To better understand the status of art research in Universal Design of ICT for Emergency Management, we have conducted a systematic literature review in this emerging research field.

Based on the research questions, we have identified three topic groups to cover in the literature search:

- Universal Design, covering Universal Design, design for all, and accessibility
- Emergency Management covering crisis management, Emergency Management, disaster management, disaster resilience
- ICT covering Web, technology, digital, mobile, smartphone, computer, internet.

Before conducting the literature search, we defined the following inclusion and exclusion criteria:

- Papers must cover the three topic groups
- Papers must be peer-reviewed scientific journal and conference articles
- Paper must be in English
- Literature review papers are excluded
- Papers published during 2008-2018 are included

We chose semanticscholar.com as our search database. The search was conducted during 4-5 February 2018. Using search phrase ("Universal Design" OR "Design for all" OR Accessibility) AND ("Crisis Management" OR "Emergency Management" OR "Disaster Management" OR "Disaster Resilience") AND (ICT OR Web* OR Technology OR Digital OR Mobile OR Smartphone OR Computer OR Internet), the search resulted in 1623 papers for 2008-2018.

The 1623 papers were manually checked against the inclusion and exclusion criteria. In the first iteration, the title and abstract were checked first, and if the title and abstract do not give enough information for making a decision, full text was checked. After this iteration, we concluded with a preliminary selection of 33 papers. Three researchers conducted the in-depth review and information extraction of the 33 papers.

We use two frameworks to analyse the relevant papers. First, we use the most acceptable Emergency Management cycle to divide the literature, i.e. preparedness, response, recovery and mitigation [4]. Second, we look at their approach if it is about evaluating existing system, prototyping, model or design or proposal of a system, case study, or about testing such as automated, heuristic and user tests. We also categorize the work based on ICT tools category for Emergency Management as suggested by Aman, Irani and Liang [5].

# 4 Literature Review: Overview and Results

## 4.1 Overview and Further Refinement of the Selection of Papers

As mentioned earlier, we reviewed in-depth 33 papers after manual filtering through Title and Abstract checking. For illustration purpose, few papers were published in the last 10 years discussing Universal Design with respect to the technology for supporting Emergency Management, as seen in Fig.1. In 2014, 8 papers were published. In 2011 and 2018, there was only 1. However, there may still be more published in 2018.

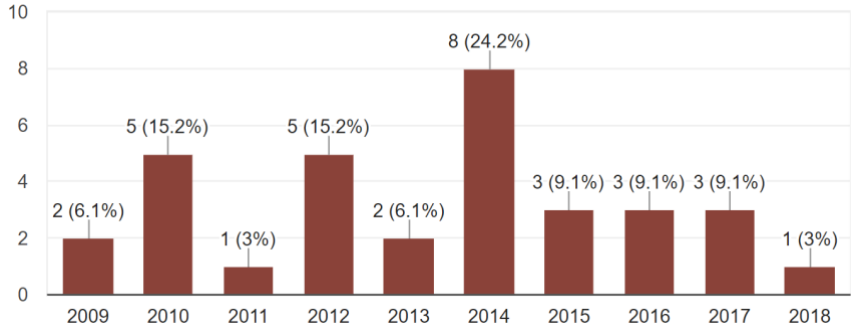


**Fig. 1 Publications per year between 2009-2018 on Universal Design and Emergency Management (preliminary selection).**

Moreover, the main topics covered by the selected publications based on the in-depth review can be classified as the list seen in the Table 1.

**Table 1. Topic Coverage in the preliminarily selected literature.**

| Topics | Reference |
|---|---|
| Online Social Network; Web 2.0; Social Media | [6-10] |
| Open Source Intelligence; Simulations, e-Service | [11-13] |
| Systematic Training, Teaching | [14, 15] |
| Technology Mediated Citizen Participation; Disaster Resilience; Community Resilience; User Engagement, Community-Centred Crisis System, Inclusion, Digital Divide, Social Vulnerability | [16-24] |
| Linguistic, Multilingualism | [24] |
| Accessible technology, Assistive Technology, Alert Technology, Communication Technology | [25-31] |
| Smartphone Technology | [20, 32-34] |
| Usability, User Interface, User Testing, Universal Design | [35, 36] |

Nevertheless, our in-depth review showed that some papers still were not really relevant or not at all fulfilled our criteria, and therefore, would not be suitable for further analysis. Some papers used the accessibility term, but in fact, it was about access to information, access to resources or access to the Internet. In other words, in some cases accessibility was to be interpreted as "availability" or "being able to reach or obtain" rather than about design of a system or a technology that could be used by all regardless their impairments. Some papers discussed accessibility and Universal Design in terms of evacuation routes and built environment. Therefore, we discarded 10 papers from being included in the results and analysis. Thus, in the following result we present the analysis of 23 papers.

### 4.2 Results

Table 2 shows the articles tagged as A1-A33 evaluated across the different criteria described in the framework in Section 2 (the gaps in the numbering of the article labels are caused by the discarded articles).
The degree of Universal Design awareness is indicated as:

- *Implicit UD* - there are indications that the awareness of accessibility and diversity of users is there, but it is not discussed),
- *Brief mention of UD* - Universal Design, accessibility or requirements of persons disabilities is mentioned in passing, but without clear signs that it has been taken into account.
- *Explicit UD discussion* - Universal Design is discussed at some length, and is taken into account.
- *UD main topic* – The article is primarily about Universal Design.

**Table 2. Articles evaluated across criteria.**

| Article | Year | Category | Phase | Method | Degree of UD |
|---|---|---|---|---|---|
| A1 [7] | 2010 | GIS, Communication | Response | Case study / review | Implicit UD |
| A5 [17] | 2012 | Other[1] | Preparedness | Proposal | Explicit UD discussion |
| A7 [14] | 2013 | Training | Preparedness | Case study / review | Explicit UD discussion |
| A8 [16] | 2016 | Communication | Preparedness | Proposal | Brief mention of UD |
| A10 [37] | 2012 | Communication | All | Prototype, user testing | Implicit UD |
| A11 [18] | 2012 | Communication | Preparedness, response | Prototype, user testing | Implicit UD |
| A12 [25] | 2009 | Communication, Warning | Preparedness | Prototype, Heuristic testing | UD main topic |
| A13 [19] | 2014 | Communication, Warning | Preparedness | Prototype, user testing | Implicit UD |
| A14 [26] | 2017 | Communication, Evacuation | Preparedness, response | Case study / review | Brief mention of UD |
| A16 [28] | 2017 | Communication | Preparedness | Case study / review | Brief mention of UD |
| A18 [15] | 2014 | Communication | Preparedness, Response | Proposal, prototype | Explicit UD discussion |
| A19 [20] | 2010 | GIS | Preparedness, Response | User testing | Brief mention of UD |
| A20 [38] | 2014 | Mostly non-EM | Mostly non-EM | Proposal | Explicit UD discussion |
| A21 [13] | 2017 | Mostly non-EM | Mostly non-EM | Proposal | Brief mention of UD |
| A22 [33] | 2014 | Communication | Preparedness | Prototype | UD main topic |
| A23 [31] | 2014 | Communication, Warning | Preparedness, Response | Proposal | UD main topic |
| A24 [21] | 2014 | Communication, Warning | All | Case study / review | UD main topic |
| A27 [9] | 2016 | Communication | Response | Case study / review, Proposal | Explicit UD discussion |
| A28 [36] | 2015 | Training | Response | Heuristic testing, | Brief mention of UD |

[1] Health information system

| Article | Year | Category | Phase | Method | Degree of UD |
|---|---|---|---|---|---|
| | | | | User testing | |
| A30 [29] | 2013 | Communication, Warning | Response | Other[2] | Implicit UD |
| A31 [34] | 2010 | Communication | Response | Prototype, User testing | Implicit UD |
| A32 [10] | 2014 | Communication, Warning | Preparedness, Response | Case study / review | Implicit UD |
| A33 [30] | 2010 | Warning | Preparedness | Proposal, Case study / review, Heuristic testing | Explicit UD discussion |

### 4.3 Identified Key Gaps

From our systematic review, and also from comparing with the papers that were *not* included as relevant in the study, we found several key gaps. For example:

- Most of the work on ICT tools and platforms for Emergency Management does not take into account Universal Design nor accessibility.
- Accessibility is used for example in a context of "accessible emergency communication systems" or web that accessible from different devices. It is also used the accessibility in terms of people that have no access to internet in the disaster, and reveal the fact the less educated people has less access to internet.
- Frequently, concerns about access to information and data in general, without a concern for the diversity of users and users with disabilities triggered false positives in the literature search.
- Research issues arise in the areas of data access, data quality, information synthesis, emerging patterns of human behaviour in emergencies, analysis and visualization of nested social networks, implementation of information systems for Emergency Management, privacy, and equity.
- There is a lack of communication support between emergency medical responders and people that are deaf.
- In use of social network in emergency situations, age gap was identified as significantly more severe than the disability gap.
- Good efforts towards accessible tools and platforms exist, but most of them are on the conceptual or at best on the prototype level.
- Awareness about people with disabilities is increasing in Emergency Management, but the concerns are still more commonly focused towards non-ICT issues.

[2] Optimization of technology solution based on performance evaluation.

- Awareness about how Universal Design can benefit all users, not only the disabled, was rarely found.
- Research on the use of assistive technology by older adults during disasters is a neglected issue.
- None of the mobile system being reviewed in the study actually considered Universal Design. This highlights the importance of a Universal Design research agenda with respect to Emergency Management systems on mobile devices.

# 5 Impact Analysis and Research Agenda

As a basis for the research agenda, we will first examine the different categories of Emergency Management ICT tools and platforms in terms of the potential impact of Universal Design. This, together with the identified gaps above, give rise to a prioritized research agenda.

## 5.1 Impact of Universal Design in Emergency Management

We prioritize the importance of Universal Design in different classes of ICT tools in Emergency Management according to the following issues:

- How many people would be affected by a lack of access?
- How severely are they affected?

From the perspective of information flow, we divide the tools into these distinct classes, with the strongest impact of Universal Design listed first:

1. Information between the public and emergency practitioners. (PEP)
2. Information crowdsourcing concerning emergency situation. (CR)
3. Information among first-responders. (FR)
4. Information among public concerning less-urgent issues such as finding friends and family. (PFF)
5. Information flow among practitioners. E.g. in control rooms and decision makers' offices. (PRR)
6. Non-essential information flow, training, etc. (NIF)

In the first two classes of tools (PEP and CR), we can expect that members of the public are actively avoiding hazards in the affected area, and in addition to any disabilities they will be affected by *situational disabilities* such as reduced ability to interact, type and read on a mobile terminal because of the situation that may involve severe weather, noise, crowds, etc. This, combined with the importance of the communication makes these cases top priority. Concerning the third class of tools (FR), the responders are affected by the same issues, but are trained to come with them and have specialized communication equipment. Additionally, we should also not neglect the importance of Universal Design and usability for communication among practitioners (PRR). Although they are in a controlled environment and trained with the communication and information equipment, the amount of information that needs to be processed makes it important that the interaction with the equipment is as smooth as possible.

Referring back to Aman et al. [39], we prioritize their categories of ICT tools as shown in Table 3:

**Table 3. Categories prioritized.**

| | 1. PEP | 2. CR | 3. FR | 4. PFF | 5. PRR | 6. NIF |
|---|---|---|---|---|---|---|
| Warning | X | | | | | |
| Communication[3] | X | X | X | X | | |
| Navigation | | | X | | | |
| Evacuation | | | X | | | |
| Event Detection and Assessment | | | | | X | |
| GIS Supported Collaboration | | | | | X | |
| Decision Support | | | | | X | |
| Training | | | | | | X |

We see from the previous section that the selected literature is primarily focused on the preparedness (16 of the 23 selected papers) and response (12 of 23) phases of Emergency Management. Most of the literature is also concerned with the categories of ICT support that we assign the highest priority to; the ones involving the public, and in particular Communication (16 of the 23). However, it is also encouraging to see that Warning category is covered within the existing research in 6 of the 23 papers.

Although these categories are important for future research, we should also not neglect to focus research efforts on the other categories and on the recovery and mitigation phases of the Emergency Management cycle.

### 5.2 Research Agenda

Based on the impact analysis, Warning systems should have the highest priority in terms of potential impact. We have seen several research efforts in this area, but there is still a way to go towards fully implemented universally designed warning systems that functions well for all users including people with hearing-related disabilities.

Information sharing and crowdsourcing tools are becoming important in disaster resilience, and it is essential that these tools are accessible and usable for as many potential users as possible [2]. This should have a high priority as these tools are affecting many users and their ability to report the situation in their area. Situational disabilities such as being unable to type messages on a mobile phone using virtual keyboard due to cold, wet and shaky hands, noisy background, only using one hand, bumpy roads, eyes are busy observing surrounding areas, can frequently occur in a disaster situation, adding to the importance of the universally designed information sharing tools.

[3] Priority 1 to 4, depending on actors and topic of the communication.

Although Universal Design of ICT for interactions with the public should be highly prioritized, there are also many other important issues such as Universal Design of communication tools, ICT equipment for control rooms, situation visualization tools, situation maps, decision support systems, logistics systems, etc. Emerging technologies such as augmented reality bring a new range of potential barriers and solutions to the table. Technologies like augmented reality can become essential, e.g. in evacuation situations; and assistive technologies facilitating communication between responders and victims can be of great value.

We expect to see the increasing use of wireless technologies to empower people with disabilities regarding individual preparedness (technology outreach), response (warning and reaction), recovery (enable location of accessible shelters) and mitigation (wireless technologies integrated into post-disaster reconstruction).

A standardized framework for accessibility testing and evaluation of tools and technologies for Emergency Management would be very beneficial, as it would simplify the identification of barriers. A selection of relevant and popular tools and platforms for each of these prioritized categories should be evaluated, in order to identify common barriers to create barrier removal strategies and facilitate Universal Design of the next generation of tools.

Awareness must be raised through targeted information to relevant stakeholders with an emphasis on relevant laws and regulations, and consequences of failing to comply with Universal Design. Clear Universal Design-related recommendations and requirements for new acquisitions should be provided. User involvement with a broad diversity of users in all stages of development of new systems, including design and testing, is essential, and must be strongly encouraged. This is where the impact of this emerging research field might be most clearly seen in the future.

## 6 Conclusions

Given the continuing number of man-made and natural disasters around the world, the development of accessible technologies is clearly very important and has a high potential impact in terms of helping those affected by these disasters. We have conducted a systematic literature review on the last 10 years of research on Universal Design and accessibility of ICT tools and technologies for Emergency Management, and identified gaps as well as trends in this emerging research area. We have highlighted and prioritized the most important research activities needed to bridge these gaps. It is our hope that in the future, Universal Design will be an obvious and obligatory feature of any Emergency Management system. Until then, this research agenda may provide some steps along the way towards that goal.

Some limitations of this study should be mentioned. Only one database (SemanticScholar.org) was searched, and we might have achieved a more complete set of research by adding additional databases such as Scopus, IEEE Xplore and Google Scholar. In addition, a more careful selection of search terms avoiding the frequently ambiguously used term “accessibility”, might have contributed to far less false positives to handle in the manual filtering. On the other hand, we might then have run the risk of

missing important research where this is the main term used for the efforts to make ICT tools for Emergency Management accessible and usable for all users.

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