

Why Simple is Best: Lessons from Designing an Emergency System for Public Displays

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ABSTRACT

Public displays play an important role in information dissemination – market reports highlight the increasing number of displays deployed. Due to the often prominent placement of public displays in the physical environment, displays can play an important role in the dissemination of trusted content, particularly during emergency situations. In order to leverage displays in emergency situations however, appropriate content creation and dissemination technology is key to allow display and space owners to efficiently distribute important information and target affected user groups. In this paper, we present our lessons learned from designing and developing an emergency messaging system in the context of a large public display testbed. We provide insights into two design probes and feedback captured through focus groups with stakeholders of the display network. Based on the feedback, we provide insights into requirements captured and provide a discussion on lessons and design considerations.

KEYWORDS

public displays, emergency alerts, user interface design

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1 INTRODUCTION

Digital signs and public displays play an important role in information dissemination: market reports suggest a significant increase in the number of digital signs and displays deployed across public spaces to 81 million by 2021 [5, 12]. Typically displays are deployed in settings such as train stations, airports, shopping malls and in smaller-scaled buildings such as offices. Due to the embedded nature of displays in the physical environment, digital signs and public displays can play an important role in the dissemination of *trusted* information relevant to the context of the display. For example, information displayed on digital signs in train stations and airports may be considered inherently more trustworthy than the same information displayed on a mobile phone. This same sense of trustworthiness can also be leveraged when displaying information in emergency situations. For example, during emergencies such as

fire, flooding or other incidents that may require an evacuation, guidance of individuals into specific areas or the distribution of warning notices, public displays can be used as a channel that is capable of reaching large numbers of people simultaneously – without requiring viewers to actively search for important information through their mobile phones or other media. Given the importance and potential of using public displays in emergency settings, appropriate content creation and dissemination technology is required to allow display and space owners to appropriately target individuals or groups with relevant information.

In this paper, we present our lessons learned from designing and developing an emergency messaging system in the context of a large public display test-bed in a University campus setting. Our work is particularly motivated by a significant increase in the number of public displays across the University campus – within four years, the number has grown from less than 20 displays to close to 100 with displays located both indoors (e.g. departmental buildings, offices, colleges) and outdoors (e.g. transport hub, main pathways). With the rapid increase of displays, the use of such displays to distribute content in the course of emergencies (e.g. to inform staff, visitors or students on campus over issues such as power cuts or flooding) becomes increasingly important.

Our lessons are informed by the creation of two distinct designs for an emergency messages system for public displays: the first focussed on the design of an emergency messages system based on existing approaches to disaster management in the literature [7] and was the subject of a focus group evaluation by potential users. The second design was developed as a direct response to this feedback and focussed on separating out display communications from other aspects of disaster management. This second design was also evaluated by our stakeholders. Drawing on our designs and the feedback gained during the focus groups we have derived a set of *lessons learned* for the design, development and integration of emergency messages systems for pervasive displays. In particular, we make the following contributions:

- (1) we identify design considerations and requirements for the development of emergency message systems for public displays,
- (2) we present an example design and integration architecture of an emergency message system based on the identified design considerations, and,
- (3) we discuss a set of *lessons learned* for the design and development of an emergency message system in the context of a University campus.

2 RESEARCH CONTEXT

The work described was carried out in the context of the campusX display network, the world's largest digital signage test-bed located at University X [6]. University X is a collegiate campus university

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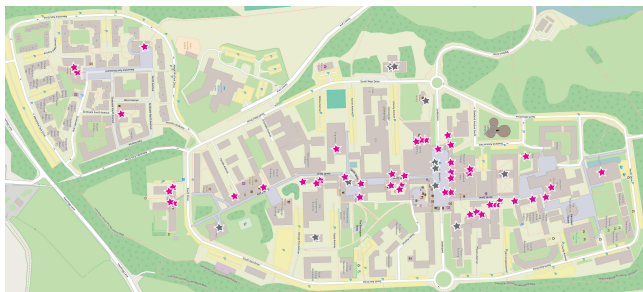


Figure 1: Map of University X campus and its display deployment.

in the North-West England with departmental and office buildings mixed in with student accommodation (fig. 1). The University currently accommodates 13, 115 undergraduate and postgraduate, 4, 515 members of staff and a large number of visitors each day.

In recent years the University has experienced a number of incidents that required prompt dissemination of messages to staff, students and visitors present on the university campus. For example, in 2015 Storm Desmond caused a significant and long-lasting (multiple days) power cut in the region that led to an evacuation of student accommodation and office buildings due to the lack of functioning fire protection systems. Support was provided in a small number of buildings that were connected to generators. The communications team was required to provide information on the buildings that were used as temporary refuge spaces and provide constant updates of the current state of the incident. Other recent incidents include temporary road closures due to accidents that impact on the travel to and from the University and for which alternative routes and advice needs to be communicated immediately.

The Internal Communications team at the University has access to a number of communication channels including e-mail (mailing lists exist for individual user groups such as academic staff and undergraduate students), social media accounts (Twitter, Facebook and Instagram) and the campusX display network (fig. 1). The campusX display network consists of almost 100 displays situated in key locations including the University's main pathway, student accommodation, departmental and office buildings and the transportation hub. The displays typically show a mix of different content including videos and static images that are supplied by colleges, departments, student union and the communications team of the university.

A number of systems underpin the campusX testbed. Display owners and content creators can manage both displays and content through the Web-based e-Channels system [6]. In order to distribute content, users can create content 'channels', i.e. folders or groups that can hold a number of content items such as images and videos. In order to make the content visible on displays they can be subscribed to one or multiple existing channels. In addition, the e-Channels system also includes an *Emergency Alerts* feature that enables responsible parties to distribute messages to all displays part of the network. The system supports two operational modes: users can either (1) choose to add a message (in the form of a static slide) into the existing content schedule of displays – in this

case, the content is interleaved with other content, or (2) prioritise the emergency content so that displays only show the emergency message. The current system is limited to only supporting only a single emergency message at a time, and only allows the selection of individual displays that are part of the network. Despite having been operational for a number of years the Emergency Alerts system has never been used.

The display nodes in campusX run Yarely, an open source digital signage player that is platform independent [2, 13]. Yarely receives its content schedule from e-Channels through the XML-based "Content Descriptor Set" [2] (CDS) consisting of descriptions of content including file locations, scheduling constraints (such as date and times), priority levels and other metadata. In order to determine which content to show from the given set of available content items, Yarely uses a Lottery Scheduler that considers the constraints and requirements provided by the CDS [13].

3 DESIGN 1: MULTI-PHASE MANAGEMENT

3.1 Motivation

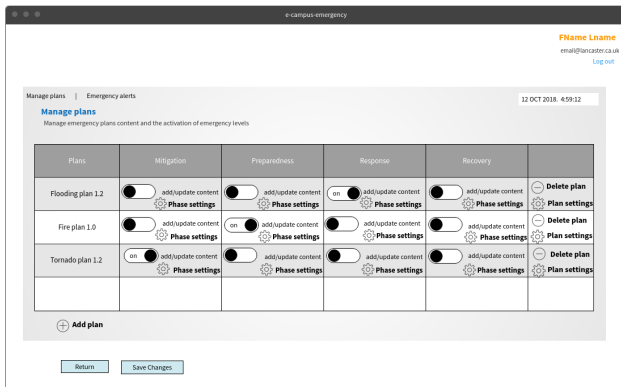
The management of emergencies involves taking a systematic approach towards the development of plans and actions in order to prepare for, prevent or minimise adverse outcomes of emergency situations. Our first design was motivated by the disaster management cycle described in [3, 7]. The disaster management cycle is comprised of four phases:

Prevention and Mitigation The prevention and mitigation phase is aimed at reducing adverse effects of an emergency, and preventing emergencies for the future. This phase focusses on applying long-term solutions and could include, for example, a disaster vulnerability analysis [3, 7]. In the context of content to be shown on displays, prevention and mitigation phases could include awareness messages to an audience informing them about the importance of hygiene to prevent the spread of diseases.

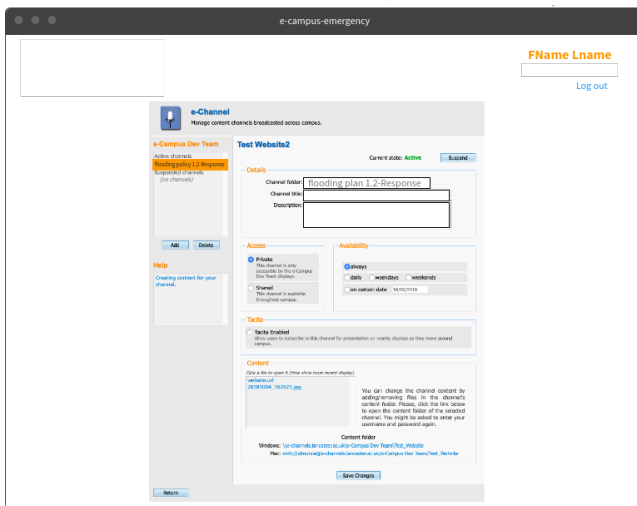
Preparation The preparation phase focusses on applying appropriate preparations for a disaster taking place. These may include updating evacuation or content dissemination plans or training [3, 7]. In the context of public displays, this may include the preparation of content that informs about plausible evacuation routes or appropriate behaviour during certain emergencies such as earthquakes.

Response The response phase defines actions and plans that are activated immediately following an emergency [3, 7]. For displays, such plans may include the dissemination of warning messages, instructions at what to do and generally keeping the audience informed about the events taking place.

Recovery The recovery phase focusses on the recovery from negative effects after an emergency, e.g. actions immediately after the emergency or long-term plans [7]. In the context of displays, the recovery phase may be dominated by content that informs about, for example, the accessibility of certain parts of a building after a fire or alternative accommodation arrangements.



(a) View of active and inactive emergency plans and phases.



(b) Adding content to a plan and phase.

Figure 2: Design 1: Proposed User Interface Design.

3.2 Design

In our first design probe, we employed the four-cycle model of emergency management as a template for process organisation and data segmentation. The user interface design (shown in fig. 2) consists of the following key features: creation and management of ‘plans’, the specification of ‘phases’ (mapping to the cycle model described above) for each plan and the ability to add prepared content to each phase of a plan. We specifically consider a potential emergency or disaster as a ‘plan’, allowing end-users of the system to prepare for a number of potential emergencies or disasters. For each phase, users can specify the level of ‘content priority’ and choose between ‘normal’ and ‘high’. Content with normal priority will be mixed into the existing content schedule of a display whilst high priority phases take over the display and show content of the activated plan/phase exclusively. Through a dedicated second interface (fig. 2a) users can then activate a plan (e.g. users activate the ‘building fire plan’ upon detection of a fire) and select the appropriate phase. Displays will then automatically show the content associated with the activated plan and phase – end-users will not be

required to add content during the emergency and can potentially save time to use on other communication channels.

3.3 Stakeholder Feedback

In order to understand whether the user interface design described above is appropriate, we conducted a focus group structured around two core themes: gaining feedback and extracting potential design considerations and requirements. The participants are four staff members from the communication team with direct involvement in emergency procedures. The interviews and focus groups lasted approximately 60 minutes. All of the feedback sessions described in this paper received ethical approval from our University.

We began our focus group by asking members of the Internal Communications team about existing disaster and emergency management strategies. Whilst comprehensive plans and strategies exist, such plans are typically focussed around the allocation of responsibility/roles during disasters (e.g. identifying people that are required to respond to emergencies on-site). The Internal Communications team *does not keep content prepared for specific types of emergencies but creates these when appropriate*, commenting that emergencies are “often not the same” (P1). Instead, the potential audience for content communicated during an emergency is segmented clearly by taking into consideration who is present on campus. Generally, public displays are seen as one of many communication channels that include text messaging, social media, targeted emails and student portals. In extreme emergencies, local radio stations may be used to communicate messages where “media response is one part of the communication plan” (P1).

As a direct response to our multi-phased management system, participants noted the relatively high complexity of the system and the requirement to prepare potential plans and content. It was considered difficult to predict possible scenarios and prepare content beforehand when, in reality, emergency situations are perceived to vary and require flexibility regarding communication strategies. For the Internal Communications team the main priority during emergencies lies in “getting the information internally and making sure that it is valid and correct” (P3) and “reducing the amount of steps technically” (P3) that are required in order to quickly push appropriate content out. Participants further mentioned the potential cost implications of complex systems (referring to multi-phased management) regarding the training of staff and ensuring that the Internal Communications team staff present on campus during an emergency are able to navigate through the system and configure appropriate plans and phases.

The focus group did identify a number of potential scenarios when the use of a multi-phased management system for the preparation and dissemination of content may be appropriate – mainly involving a small set of reoccurring events. Participants explicitly mentioned severe weather, traffic accidents or power cuts as examples but noted that such events (with the exception of weather) cannot be predicted. However, traffic incidents that impact on the journey home of staff and students happen on a regular basis and can include the distribution of identical content multiple times. Such an incident may include different content for mitigation, preparation and response phases mainly focussing on informing staff about the estimated level of impact.

Participants also saw significant potential for campusX for the distribution of awareness messages (mainly falling into the preparation and mitigation phases). For example, participants mentioned specific “look after your mate” (P1) campaigns in which students were asked to keep an eye on each other, or the distribution of messages regarding the importance of hygiene to prevent the spread of diseases (e.g. “meningitis”) (P1).

When specifically asked about the potential features of an emergency management system for public displays, participants mentioned that most importantly the content needs to be visible on the displays “straight away” (P4) and that “it is the right message at the right time” (P4) emphasising the importance of timely communication. Furthermore, “simplicity of the system adds to the amount of time that we have, if we know that publishing messages is a button click away then we can focus on the message itself and focus on the timing itself” (P3). Furthermore, participants mentioned the requirement to be able to control the scope of the distribution of emergency messages to avoid “blanking it out [...] with emergency messages unnecessarily” (P1).

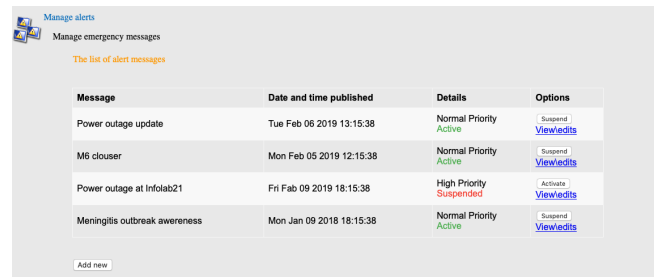
4 DESIGN 2: FOCUS ON SIMPLICITY

4.1 Motivation

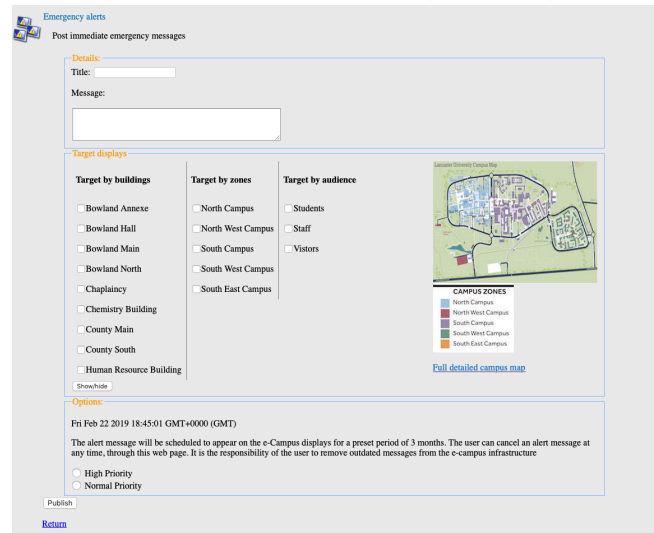
As a result of the feedback to our first design we created a new design that focussed on simplicity. During the focus group for our first design it became clear that participants favoured a separation between the processes of internal planning and external messaging – believing that this would allow them to quickly and easily control the flow of public information across a number of communication channels. Participants explained that the overhead of internal communication and deciding exactly what to communicate to people is in itself a complex process and simplicity was noted as an important feature for any future system. Time and place of an emergency with the severity of the event are all variables that the participants believed make it almost impossible to prepare content beforehand. This motivated us to revise our initial approach and to take a step back to design a system that would simply push alert messages to the displays. The Internal Communications team at the University requested flexibility in controlling content, its priority and asked to target messages based on geographical locations and audiences. Hence, instead of providing capabilities for multi-phased plans, our second design supports just two core tasks: the creation and management of emergency messages and the targeting of emergency messages to specific geographic locations or audiences.

4.2 Design

Our second design probe is comprised of two user interface screens (fig. 3). The first screen (fig. 3a) consists of an overview of current and previous emergency messages and allows users to create new messages. The second screen (fig. 3b) allows users to add content (either in the form of a text message or by uploading customised content in the form of images and videos) and to define the geographic scope or target demographic. In particular, users can scope messages based by selecting individual buildings (over 45 across the University campus), or target geographical zones of the campus. The system then maps the selected zone or set of buildings to the list of physical displays. Alternatively the system allows users to target



(a) View of active and inactive emergency messages.



(b) Adding and configuring an emergency message.

Figure 3: Design Probe 2: Proposed User Interface Design.

content to specific audiences (e.g. students, staff and visitors) where, for example, display personalisation systems such as Tacita [4] may be employed in order to identify the target group in front of displays. Targeting groups on campus can be used, for example, to distribute awareness messages and limit the reach of messages to the relevant user groups without unnecessarily occupying displays.

Users can also select the priority of the emergency message where ‘normal priority’ indicates that the content will be mixed in with the regular schedule of displays while ‘high priority’ overwrites any content that displays may be showing. The design of our revised system therefore does support reusing previously created content (by reactivating previous emergency messages) but this is not the main focus of the system.

4.3 Feedback

We presented the Internal Communications team with the revised design during a second focus group that aimed to record the participants’ attitudes towards the new system design. The participants are the same four staff members from the first focus group interview, and they are the communication team members with direct involvement in emergency procedures. The interviews and focus groups lasted approximately 25 minutes.

The participants initial reaction was focussed on the simplicity of the new design: “From what you showed last time to this, the development is really strong and that looked really simple. I am personally quite impressed”. Our participants confirmed the importance of supporting flexibility in the distribution of content regarding geographical regions (“I really liked that you [...] filter it geographically. I think that would be really useful”) and the flexibility in supporting different content. In particular, targeting various areas of the University campus with specific emergency messages at the same time appeared to be a particularly valued feature of the system. Additionally, supporting various priority levels that can be adjusted throughout the course of an emergency appeared to be highly useful in order to react to the severity of emergencies “You can take it all over and change down the priority and you could do it the other way I suppose. If we are getting an issue that was just intimate, just advice on what might be happening then okay it is really affecting everybody”. One participant expressed concerns regarding the potential ambiguity in targeting specific audience demographics and groups on campus: “There was an option to select messages for staff, students, and visitors, so what would that do? How would that target those audiences?”, whilst other participants noted that such a feature would be useful in cases of severe disasters to, for example, distribute content in native languages of the currently present audience in front of a display.

5 DISCUSSION

In this section, we compare our design probes, discuss the feedback gained through our focus groups, and present a set of design considerations and lessons learned.

5.1 Limited Reuse of Content

Our first design probe was motivated by existing disaster management concepts and emergency content was heavily segmented into individual plans and phases – allowing responsible entities to prepare content in advance for potential future emergency situations and reuse such content various times. However, participants noted that the preparation and reusability of content is only useful to a degree – only in a very limited number of cases stakeholders foresaw that content may be reused (e.g. reoccurring issues regarding traffic or raising awareness). Instead, participants emphasised that disasters or emergencies are always different and cannot be predicted – questioning the plausibility of preparing content in advance. Participants also noted over-segmentation can lead to loss of flexibility in managing content and could complicate data entry – making it more challenging to efficiently react to the nature of disasters. We note therefore *reuse of content across disasters is only useful in very limited cases – systems should instead allow for flexible and simple emergency content scheduling.*

5.2 Immediate Content Scheduling

Emergencies need timely responses, especially if the event is escalating. For both designs the Internal Communications team requested that content should become visible on displays immediately, only “a button click away” (P3). A complex design may add to the time needed to publish messages with participants noting that “in practise it is usually very very busy” (P1) during emergencies. In

addition, the use of a complex system will likely require specially trained staff to be able to control it and to have knowledge of finding the appropriate plan and phase. In contrast, participants noted that simple systems can be used by any members of staff without or only little training and provide sufficient flexibility in order to distribute important messages created in direct response to the specific emergency in a timely manner. Overall, we can derive two fundamental requirements: (1) *During emergencies, the response of the system is required to be timely and the system should allow for simple data entry and fast scheduling;* and (2) *A simple user interface design is key to support staff during emergencies.*

5.3 Targeting of Geographical Areas

Participants noted that emergencies in the context of the University campus often consist of a spatial element (as one of many variables during an emergency). Instead of targeting all displays on campus simultaneously, both for the multi-phased management and simple design the support for targeting specific geographical areas on the University campus was considered an important feature. Participants explicitly mentioned the ability to support a mix of targeting options including buildings, zones of campus and even specific viewers. Targeting displays and therefore portions of the audience further provides the advantage of not misleading or de-sensitising viewers not affected and appeared to be of higher value than, for example, multi-phased support and content reuse. As a result of the feedback we obtained our second design to feature geographical targeting both in terms of campus zones and the selection of specific buildings. Overall, *emergency message systems are required to support the targeting of content to affected areas and audiences only to support a high level of sensitivity.*

5.4 Targeting of Individuals

Participants highlighted the usefulness of targeting messages to individual user groups on campus (e.g. staff or students). With typically high numbers of international students, participants noted the potential in distributing messages to individuals in their native languages during emergencies to reduce the potential for confusion. Display personalisation technology (e.g. [4]) can be utilised to target specific audience groups during emergencies and, for example, distribute messages in the native language of individuals.

5.5 Reliance on Electricity

An obvious challenge in both emergency message systems is the reliance of the display network on the availability of electric power. In the absence of power, the distribution of messages may be focussed on a small number of displays connected to power generators. Furthermore, the Internal Communications team noted that in such cases other communication channels are preferred such as staff and student portals and social media. In any case, both the emergency message system and displays are *required to be robust and resilient against potential power cuts, and Internal Communications teams should be made aware of the availability of displays that can and cannot be used to distribute messages.*

5.6 Displays as Part of a Communication Ecosystem

During both focus groups it became clear that the campusX display network serves as one communication channel in a wider ecosystem. Internal Communications use a wide range of platforms including email, social media, staff and student portals. Using a multi-phase management platform therefore appeared to be overly complex and suggested that the management of emergencies would be conducted through this system. The recognition, however, that the Internal Communications team determine appropriate communication channels in response to a particular emergency and the challenge to predict the nature of emergencies leads to the overall rejection of such a complex system. Instead, *emergency systems for public displays should focus on their core functionalities: timely distribution of content and targeting relevant audiences.*

5.7 Technical Validity and Integration

While our designs were primarily focused on UI issues we have also considered the implementation of these systems as part of a campus network. For example, our second design can be integrated as a replacement of the existing 'Emergency Alerts' feature of the Channel System (described in sec. 2). Emergency messages created within the system can be modelled as individual 'Channels' to which any types of content (such as images or videos) can be added. Geographical targeting can be supporting by providing a mapping of buildings and campus zones to individual displays, and providing a modified Content Descriptor Set (CDS) to displays associated with the target zone selected. The CDS can then also specify the priority level of the emergency messages content (i.e. 'normal' or 'high'). In the current implementation of campusX, display nodes periodically pull an updated CDS from the scheduling API of the Channel System. In the case of an emergency, however, messages need to be distributed in a timely fashion and waiting for a periodic an update may not be appropriate. Instead, additional software sensors can be implemented on display nodes used to trigger a forced update – similar to sensors used to support display personalisation [4]. In addition to altering the CDS, the emergency management system would also send an immediate content update request to targeted display nodes in order to ensure that the messages appear immediately.

6 RELATED WORK

There has been significant prior work on developing emergency alert systems using radio and television [1]. Our general approach can be compared with that taken in the public displays context: broadcasts typically follow their regular schedule (e.g. television program) and can be interrupted in the case of an emergency in which important messages have to be distributed to the general public [1]. However, such systems do not provide the type of management interface that has been the subject of our work. The use of public displays to coordinate first responders, medical teams and volunteers was explored in Reddy et al. [15] which identified “inadequacies of current communication tools” as a key challenge in challenge that prevents an effective collaboration between emergency departments and medical services on-site. Other work has also focussed on designing public displays to improve collaborative

work in emergency departments and to help with interpersonal communication between caregivers [16]. Using public displays as a communication medium to coordinate volunteers has also been previously explored by Ludwig et al. [11]. The authors conducted a set of interviews with different groups including “volunteers, public administrators as well as the emergency services” and identified major challenges faced by volunteers who arrive at the scene – for example, it appears to be difficult for volunteers to familiarise themselves with the area, identify affected zones and find emergency contact points. The authors suggested the use of public display systems in order to allow volunteers to retrieve relevant information and initiate contacts with locals. The system requires the use of mobile client to communicate with the display through QR- code to create offers and demands or to share content. Other research such as [14] investigated the use of interactive public pin-boards to provide access to information during disasters – additionally allowing volunteers and responders to create profiles and find other responders for collaboration based on their skill sets.

Public displays are also used to support the evacuation of buildings. Langner and Kray [10] examined the role of displays in large scale evacuations with the development of an agent based model and the simulation of peoples' movement when exiting a local football stadium. Displays were used to automatically guide people to exits nearby. The authors concluded that “dynamic signage can speed up evacuation and reduces fatalities in the vast majority of simulated cases” [10]. Additional work integrated displays with wireless sensor networks and RFID to appropriate alert messages [9]. Related work considered the use of augmented reality and digital signage to guide evacuations and appropriate messages to smart phones, showing direction of movement during emergencies [8].

7 CONCLUSIONS

We presented two distinct designs for future emergency message systems for public display networks. We evaluated our designs in the context of campusX, the largest public display testbed and identified a set of design considerations: *limited reuse of content* (every emergency is different, therefore creating content ahead is of limited use only), the importance of *immediate content scheduling*, the *targeting of geographical areas* (e.g. individual buildings and zones on campus) simultaneously, and the consideration of *power cuts* in which messages are focussed on a small number of displays or alternative communication channels such as social media and portals are preferred. Overall, public displays are only a *part of a communication ecosystem* employed when appropriate.

Future work may explore alternative trigger mechanisms in order to reduce the workload on staff and to accelerate the distribution of crucial emergency information. For example, connecting the display network to existing sensor infrastructures such as intrusion, panic or fire alarm systems would allow triggering of alerts without any human involvement and thereby significantly decrease the content delivery time. The rich data provided by interconnected systems (e.g. knowledge of the location of a fire, the location of the display and floor plans) can allow the system to dynamically create content in order to target spacial areas or individuals. Such a system could address the need for very fast response times and the concerns regarding the unique nature of emergencies.

REFERENCES

- [1] S. J. Choi. 2007. Analysis of Emergency Alert Services and Systems. In *2007 International Conference on Convergence Information Technology (ICCIT 2007)*. 657–662. <https://doi.org/10.1109/ICCIT.2007.362>
- [2] Sarah Clinch, Nigel Davies, Adrian Friday, and Graham Clinch. 2013. Yarely: A Software Player for Open Pervasive Display Networks. In *Proceedings of the 2Nd ACM International Symposium on Pervasive Displays (PerDis '13)*. ACM, New York, NY, USA, 25–30. <https://doi.org/10.1145/2491568.2491575>
- [3] Kimberly A. Cyganik. 2003. Disaster preparedness in Virginia Hospital Center-Arlington after Sept 11, 2001. *Disaster Management & Response* 1, 3 (2003), 80 – 86. [https://doi.org/10.1016/S1540-2487\(03\)00048-8](https://doi.org/10.1016/S1540-2487(03)00048-8)
- [4] Nigel Davies, Marc Langheinrich, Sarah Clinch, Ivan Elhart, Adrian Friday, Thomas Kubitz, and Bholanathsingh Surajbali. 2014. Personalisation and Privacy in Future Pervasive Display Networks. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 2357–2366. <https://doi.org/10.1145/2556288.2557287>
- [5] DigitalSignageToday. 2017. Global shipments of digital signage displays to reach 22.9 million by 2021. <https://www.digitalsignagetoday.com/news/global-shipments-of-digital-signage-displays-to-reach-229-million-by-2021/>
- [6] Adrian Friday, Nigel Davies, and Christos Efstratiou. 2012. Reflections on Long-Term Experiments with Public Displays. *Computer* 45, 5 (May 2012), 34–41. <https://doi.org/10.1109/MC.2012.155>
- [7] George D Haddow. 2011. *Introduction to emergency management* (4th ed. ed.). Butterworth Heinemann, Burlington, MA.
- [8] Kazuyoshi Hikita and Hiroyoshi Miwa. 2017. Evacuation Guidance Method by Using Augmented Reality and Digital Signage. In *International Conference on Intelligent Networking and Collaborative Systems*. Springer, 355–366.
- [9] Huan Po Hsu, Kun Ming Yu, Shao Ting Chine, Shao Tsai Cheng, Ming Yuan Lei, and Nancy Tsai. 2014. Emergency evacuation base on intelligent digital signage systems. In *2014 7th International Conference on Ubi-Media Computing and Workshops*. IEEE, 243–247.
- [10] Norman Langner and Christian Kray. 2014. Assessing the impact of dynamic public signage on mass evacuation. In *Proceedings of The International Symposium on Pervasive Displays*. ACM, 136.
- [11] Thomas Ludwig, Christoph Kotthaus, Christian Reuter, Sören van Dongen, and Volkmar Pipek. 2017. Situated crowdsourcing during disasters: Managing the tasks of spontaneous volunteers through public displays. *International Journal of Human-Computer Studies* "102" (2017), "103 – 121". <https://doi.org/10.1016/j.ijhcs.2016.09.008> Special Issue on Mobile and Situated Crowdsourcing.
- [12] Chuck Martin. 2017. 38 Million Connected Digital Signs In Use, Heading To 87 Million. <https://www.mediapost.com/publications/article/297163/38-million-connected-digital-signs-in-use-heading.html>
- [13] Mateusz Mikusz, Sarah Clinch, and Nigel Davies. 2015. Are You Feeling Lucky?: Lottery-based Scheduling for Public Displays. In *Proceedings of the 4th International Symposium on Pervasive Displays (PerDis '15)*. ACM, New York, NY, USA, 123–129. <https://doi.org/10.1145/2757710.2757721>
- [14] Peter-Scott Olech, Daniel Cernea, Helge Meyer, Sebastian Schoeffel, and Achim Ebert. 2012. Digital interactive public pinboards for disaster and crisis management-concept and prototype design. In *Proceedings of the International Conference on Information and Knowledge Engineering (IKE)*. The Steering Committee of The World Congress in Computer Science, Computer . . . , 1.
- [15] Madhu C. Reddy, Sharoda A. Paul, Joanna Abraham, Michael D. McNeese, Christopher DeFlitch, and John Yen. 2009. Challenges to effective crisis management: Using information and communication technologies to coordinate emergency medical services and emergency department teams. *International journal of medical informatics* 78 4 (2009), 259–69.
- [16] M. Sunm, A. M. Bisantz, and R. J. T. Fairbanks. 2005. Interpersonal communication and public display tools in the emergency department. In *2005 IEEE Design Symposium, Systems and Information Engineering*. 249–252. <https://doi.org/10.1109/SIEDS.2005.193265>