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

Asma Almutairi
Lancaster University
a.almutairi@lancaster.ac.uk

Mateusz Mikusz
Lancaster University
m.mikusz@lancaster.ac.uk

Hassam Niaz
Lancaster University
h.niaz@lancaster.ac.uk

Ludwig Trotter
Lancaster University
l.k.trotter@lancaster.ac.uk

Nigel Davies
Lancaster University
n.a.davies@lancaster.ac.uk

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 alerts 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.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; **Graphical user interfaces**; **Web-based interaction**.

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 an significant increase in the number of digital signs and displays deployed across public spaces to 81 million by 2021 [6, 13]. 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, 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. 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 of using public displays in emergency settings, appropriate content creation and dissemination technology is required to allow display and space owners to target individuals or groups with relevant information. We note that in the context of this work we consider emergencies as "an out-of-the-ordinary situation that must be managed by urgent procedures in order to stop it escalating and thus having consequences that are more serious and damaging" [1].

In this paper, we present our lessons learned from designing and developing an emergency alerts system in the context of a large public display test-bed in a University 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 over 85 with displays located both indoors (e.g. departmental buildings and colleges) and outdoors (e.g. transport hub and main pathways). With the rapid increase of displays, leveraging the display deployment to distribute content in the course of emergencies becomes increasingly important. In particular, we make the following contributions:

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

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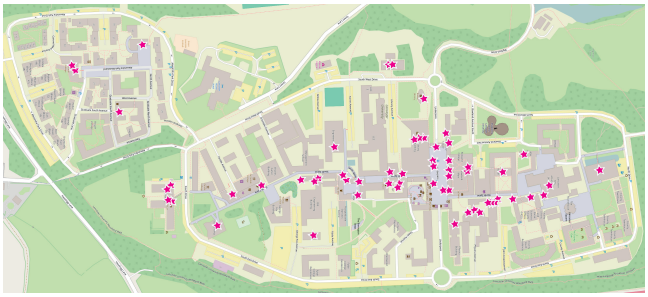


Figure 1: Display deployment at Lancaster University.

2 RESEARCH CONTEXT

Our work was carried out in the context of e-Campus, the world's largest public display test-bed located at Lancaster University [7]. Lancaster University is a collegiate campus university in the North-West England with departmental and office buildings mixed in with student accommodation and currently accommodates 13, 115 undergraduate and postgraduate, 4, 515 members of staff and a large number of visitors each day. The e-Campus display network consists of over 85 displays situated in key locations including the University's main pathway, student accommodation, departmental and office buildings and the transportation hub (fig. 1). 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.

Lancaster University has a dedicated Internal Communications team that is responsible for the dissemination of messages and has access to a number of communication channels including e-mail lists, social media accounts and e-Campus. The University has experienced a number of incidents in the past that required prompt dissemination of messages across the University campus by the Internal Communications team. For example, in 2015 Storm Desmond caused a significant and multi-day long power cut in the region that required an evacuation of buildings on campus due to the lack of functioning fire alarm systems. Members of the emergency team were required to quickly disseminate information on buildings that were accessible as temporary refuge spaces and provide frequent updates on the state of incident. Another example of incidents that require prompt information dissemination consist of temporary road closured due to accidents that impact travels to and from the University where alternative routes are communicated.

A number of systems underpin e-Campus. Display owners and content creators can manage both displays and content through the web-based e-Channels system [7]. In order to distribute content, users can create content 'channels', i.e. folders that can hold an arbitrary number of content items such as images and videos and subscribe their displays to one or multiple existing channels. E-Channels also consists of an *Emergency Alerts* feature allowing to distribute plain text messages over e-Campus. The emergency alerts feature currently supports two operational modes: users can either (1) choose to interleave the current display schedule with the emergency message, or (2) choose to prioritise the message by interrupting current display schedule. The current emergency alert system is limited to allowing a single emergency message at a time, and only allows users to select individual displays. We note that despite having been operational for a number of years the Emergency Alerts feature has never been used. Individual display nodes of e-Campus run Yarely, an open source digital signage player [3]. Yarely receives its content schedule from e-Channels through the XML-based "Content Descriptor Set" [3] (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 [14].

3 METHODOLOGY

Our lessons are informed by designing two distinct user interfaces for an emergency alerts system and conducting a focus group for each design with potential users of the system. Each focus group consisted of the same four participants that have been recruited from the Internal Communications team of the university. Participant feedback has been captured through written notes and audio recordings that have been transcribed manually.

The first design was motivated by existing approaches to disaster management that have been described previously (e.g. [8]). We first presented participants of the focus group (lasted approx 60 minutes) the current emergency alerts system as it can be found as part of e-Campus. Subsequently, we introduced participants to the new user interface design and asked the focus group a series of questions to understand the frequency in which participants have used an emergency alerts system in the past, if the complexity of the design proposed is appropriate and if the breadth of features offered would be utilised. Finally, we asked participants for suggestions for a future design. We analysed the data captured as part of the focus group by first familiarising ourselves with the responses captured by repeatedly reading the transcripts, notes and a summary that has been produced by a researcher. We then conducted a thematic analysis leading to two over-arching themes: use cases and a number of key system requirements. The themes identified have been further discussed amongst the researchers in order to inform the second design and lessons learned.

As a direct response to the insights gained from the first focus group, we designed a second user interface that focussed on separating out display communications from other aspects of disaster management. The second focus group lasted approx. 25 minutes and was focussed on capturing feedback regarding the revised design. The data captured (notes, audio recordings and a summary) was repeatedly reviewed by researchers in order to understand if feedback and requirements from the first focus group were addressed appropriately. 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.

4 DESIGN 1: MULTI-PHASE MANAGEMENT

4.1 Motivation

The management of emergencies involves taking a systematic approach towards the development of plans in order to prepare for emergency situations and prevent or minimise adverse outcomes.

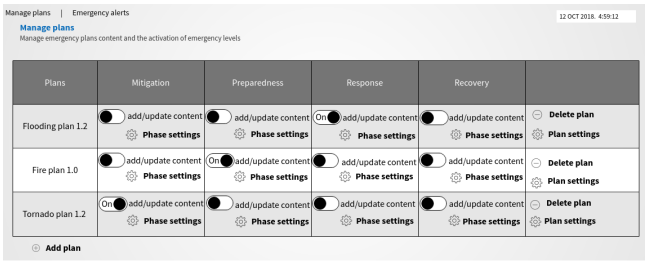


Figure 2: View of active and inactive emergency phases.

Our first design is motivated by the disaster management cycle described in [4, 8]. Whilst other disaster management concepts exist, a variation of the disaster management cycle has been described as a "core concept in environmental health management in disasters and emergencies" [18] in a practical guide published by the WHO.

The disaster management cycle is comprised of four phases: *prevention and mitigation*, *preparation*, *repsonse* and *recovery*. The *prevention and mitigation* phase is aimed at reducing adverse effects of an emergency or, if possible, preventing disasters from taking place, for example, by conducting a disaster vulnerability analysis. 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. The *preparation* focusses on applying appropriate preparations for a disaster taking place such as evacuation plans. In the context of public displays, this may include the preparation of content that informs about plausible evacuation routes. The *response* phase defines actions and plans that are activated immediately following an emergency. For displays, such plans may include the dissemination of warning messages or keeping the audience informed about events taking place. The *recovery* phase focusses on the recovery from negative effects after an emergency, e.g. actions immediately after the emergency or long-term plans. For displays, the recovery phase may consist of content that informs about the accessibility of certain parts of a building after a fire.

4.2 Design

For our first design we employed the disaster management cycle as a template for the organisation of processes and content. The user interface design (fig. 2) consists of the following key features: (1) the creation and management of plans, (2) the specification of phases for each plan and (3) the ability to add content to each phase of a plan. We consider a potential disaster to be defined as a "plan" allowing end-users of the system to prepare content in advance for different types of disasters by creating multiple plans. Users can define phases within each plan that map directly onto the phases from the disaster management cycle described above. For each phase, users can specify the level of "content priority" and choose between "normal" (content mixed into the schedule of a display) and "high" (content shown exclusively replacing the schedule of a display). Upon defining plans and phases, users can activate a predefined plan (e.g. upon detecting a fire in a building) through a toggle-switch in the user interface. Displays will then automatically show the content associated with the activated plan and phase and end-users will not be required to add content during the emergency and can potentially save time to use on other communication channels.

4.3 Stakeholder Feedback

Following the methodology described (sec. 3), 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 target audience for content communicated during an emergency is comprised by the people 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 the presentation of our first design, participants noted the relatively high complexity of the system and the requirement to prepare plans and content in advance. It was considered challenging 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) to enable an effective dissemination of appropriate content. Participants further mentioned the potential cost implications of complex systems regarding the training of staff and ensuring that staff present during emergencies are able to navigate through the system to configure appropriate plans and phases.

Participants identified 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 mentioned severe weather, traffic accidents and 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.

Participants also saw significant potential for e-Campus for the distribution of awareness messages (mainly falling into the preparation and mitigation phases). For example, participants mentioned "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).

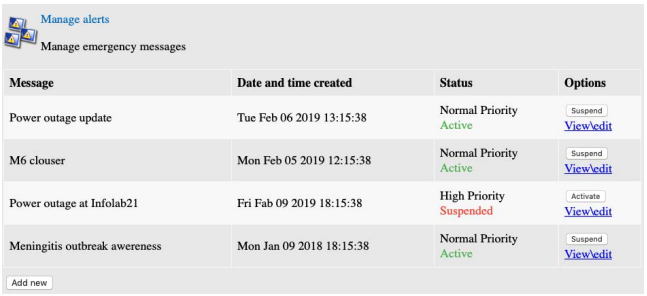
When specifically asked about the potential features of an emergency management system for public displays, participants mentioned that most importantly the content needs to become visible on displays "straight away" (P4) and that "it is the right message

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). Participants also 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).

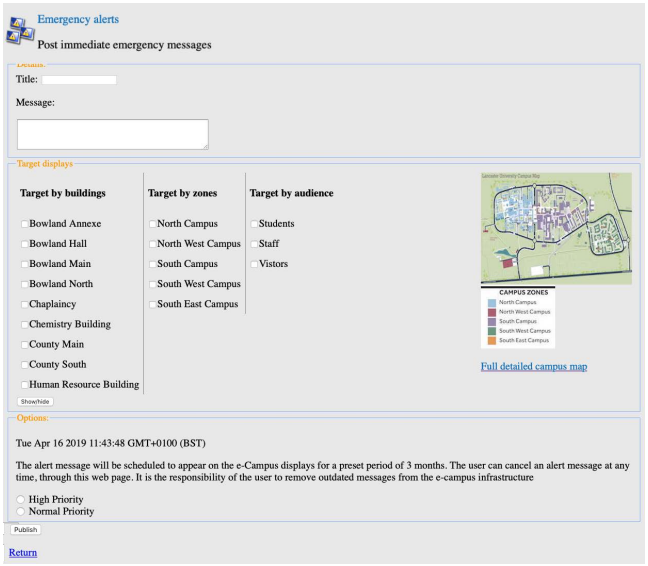
5 DESIGN 2: FOCUS ON SIMPLICITY

5.1 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: (1) the creation and management of emergency messages and (2) the targeting of emergency messages to specific geographic locations or audiences.



(a) View of active and inactive emergency messages.



(b) Adding and configuring an emergency message.

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

5.2 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 groups. In particular, users can scope messages based by selecting individual buildings 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 user interface allows users to target content to specific audiences (e.g. students, staff and visitors) where, for example, display personalisation systems such as Tacita [5] can be employed in order to identify the target group in front of displays. The approach to target specific audiences can be used 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. We note that our revised user interface does support reusing previously created content by reactivating existing emergency messages.

5.3 Feedback

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" (P3). 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" (P4) and the flexibility in supporting different types of 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." (P2) One participant expressed concerns regarding the potential ambiguity in targeting specific audience groups and demographics 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?" (P3) 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 displays.

6 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.

6.1 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 and 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 and questioned 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.*

6.2 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.*

6.3 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 desensitising 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 alert systems are required to support the targeting of content to affected areas and audiences only to support a high level of sensitivity.*

6.4 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. [5]) can be utilised to *target specific audience groups during emergencies and, for example, distribute messages in the native language of individuals.*

6.5 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.*

6.6 Displays as Part of a Communication Ecosystem

During both focus groups it became clear that the e-Campus 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.*

6.7 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 e-Campus, 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 [5]. 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.

6.8 Limitations

There are a number of limitations to our studies. Firstly, both design studies have been evaluated with a small number of participants. Secondly, we conducted our studies with a single type of stakeholder and within a single organisation. Both limitations restrict us in expressing the extent to which our results are generalisable to other entities within the University, and to other universities and organisations. Finally, we did not aim to investigate potential cultural, geographical or legal impacts. Our work was evaluated in North-West England but it is not clear if similar studies carried out in other countries would yield different results.

7 RELATED WORK

There has been significant prior work on developing emergency alert systems using radio and television [2]. 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 [2]. 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. [16] which identified "inadequacies of current communication tools" as a key 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 [17]. Using public displays as a communication medium to coordinate volunteers has also been previously explored by Ludwig et al. [12]. 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 [15] 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 [11] examined the role of displays in large scale evacuations with the development of a mobility 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" [11]. Additional work integrated displays with wireless sensor networks and RFID to appropriate alert messages [10]. 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 [9].

8 CONCLUSIONS

We presented two distinct designs for future emergency message systems for public display networks. We evaluated our designs in the context of e-Campus, 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.

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