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Cell broadcast trials in The Netherlands: Using mobile phone technology for citizens' alarming

H.M. Jagtman *

Safety Science Group, Faculty of Technology Policy and Management, TU Delft, P.O. Box 5015, 2600 GA Delft, The Netherlands

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A B S T R A C T

In emergency situations authorities need to warn the public. The conventionally used method for warning citizens in The Netherlands is the use of a siren. Modern telecommunication technologies, especially the use of text-based features of mobile phones, have great potential for warning the public. In the years 2005–2007 cell broadcast was tested during several large-scale field trials with citizens in The Netherlands. One of the questions was to determine the penetration of cell broadcast for citizens' alarming. This article argues that the definition of penetration in the light of warning citizens in case of emergencies should include the citizens' responses to warning messages. In addition, the approach to determining the penetration, the data and validity issues regarding these data is discussed. The trials have shown cell broadcast has potential to become an effective citizens' alarming technology. This however requires the entire technological and organisational chain of the warning system to function correctly. Attention is required to network management, handset improvements and correct communication to the public about the conditions under which a cell broadcast message can be received. The latter includes managing realistic expectations including circumstances in which cell broadcast will not reach a citizen.

1. Introduction

In life-threatening situations governments have the duty to alert the population. Since the government cannot bring all people to safe places, alerting the population should convince people to stop their current matters and get to a safe location. In the early days citizens were warned by means of a town crier or by the sounding of church bells. Nowadays, the conventionally used method for citizens' warning in The Netherlands is the sounding of a siren. This is the case for many other countries as well [1]. This siren in itself has limitations since the people who are warned should be aware of the actions they might need to take to avoid being exposed to the risk for which the siren is horned [see e.g., 2]. Additionally, for example, cars equipped with PA systems, radio and television are used to explain the necessary precautions. Due to the use of one tone in the siren in The Netherlands, the siren can only be applied for one type of citizen's action, which in the Dutch case is to go inside, close doors and windows and tune to the local radio or television for further information. For various emergencies in which other actions are required (e.g., danger of explosion and evacuation in case of large fires or floods) the siren should not be used. Another problem of using the siren is the limited design context of this system. It is not designed for alarming people who are indoors and in situations with a lot of background noise (e.g., big cities, TV or traffic) [3,4]. Moreover, not the whole country is well covered with siren installations. Siren installations , for example, lack in newly built residential areas, in remote areas and some industrial areas. de Hond [5] found that together these limitations cause on average 37% of people not hearing the siren.

Although appyling the sirens make people aware of an emergency only, new media can simultaneously mention the danger and required actions. An option is the use of mobile phone technology. A mobile phone can make noise (ring tone) to make citizens aware of an emergency together with textual information. The emergency situation, location at danger, actions and other information can be given in a textual warning message. In the last decades the coverage and market penetration of mobile phones have grown rapidly [6–8]. However, mobile phone technology has its own general limitations in, for example, running out of battery and not constantly carrying a mobile with you. For that sake, new warning systems using mobile phone technology have been studied as an addition to the current warning system.

In general one can implement two variations of warning systems that can be received with a mobile phone. Although for the user the text messages that appear on their mobile screen seem to be similar, the technology behind the services is different [9]. The first alternative uses the text message function, also

* Tel.: +31 15 2782759.
E-mail address: h.m.jagtman@tudelft.nl

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known as short message service (sms), in which a textual message is sent to a specific predefined set of phone numbers (point-to-point communication). Numbers to which a warning is sent should be known either by subscription to a warning service or by retrieving information from the GSM network. In case of a service to which citizens subscribe, warnings are received regardless of the actual location at the moment a warning message is sent. Delft University of Technology has been involved in evaluating a warning service especially for the auditory impaired based on the text message service technology [10,11]. The second alternative uses info message services, also referred to as cell broadcast, in which a message is sent to an unknown group of mobile phones inside a selected geographical area. Cell broadcast is sent via radio cells (channels) in the mobile phone network [12,13]. To receive a cell broadcast text message the warning channel should be predefined in a mobile phone. Additionally, the mobile phone should be switched on and connected to one of the radio cells from which the message is sent, at the moment of broadcasting [13]. It is a one-way communication and is thus unconfirmed [14]. As a result it is not exactly known how many and which mobile phones received the message. The characteristics of cell broadcast show more similarities with a general population-wide warning service [9,15]. In theory, everybody with a mobile phone in an area at danger can be reached. The technology does not discriminate between citizens who are generally present or only in a special occasion.

The cell broadcast technology has been tested in various trials with citizens in the years 2005–2007 in the Netherlands. Delft University of Technology has been involved in evaluating these trials. The evaluation [see 16] focused on the penetration of cell broadcast for citizens' warning purposes, technological issues, acceptance by the population as well as authorities responsible for warning the population and the content of warning messages. This article discusses the methods used to determine the penetration and the methods to analyse the population that was not effectively alarmed. Other publications discuss results and methods applied to evaluate the role of authorities, the acceptance by the public and the content of warning messages [9,11,17,18].

Apart from the Netherlands, other countries have also shown interest in cell broadcast. The technology has been used in Sri Lanka in warning about the tsunami in December 2004 [13]. Another recent example is testing cell broadcast as part of the nationwide drill in Israel in June 2009 [19].

2. Alarm functions and alarm chain using mobile phone technology

Citizens alarming can be divided in two generic functions: the alert messages and the informative warning messages [17]. Alert messages require the receiving citizens to take action, for example, take shelter or evacuate. Informative warning messages should update citizens about consequences of the emergency. The informative messages do not necessarily require a response. While the siren is used only for alerting, mobile phone technology can be used for both functions. As explained in the introduction, the siren has limitations regarding its alerting function. Mobile phone technologies can supplement to the alert function. In case of an emergency, the mobile phone technology can be used to communicate to citizens in order to safeguard the population (see Fig. 1). Similar to the use of the siren, the alarming system is activated after an emergency has arisen (except for regular testing of the warning system). This exact moment of activating an alarming system is therefore, by definition, unknown. After activating the system, resulting in the siren or warning text messages, the population should become aware of the warning. Finally, citizens should properly act upon the warning.

Although the alarming chain using a warning system has generally the same propagation, the underlying actions of various parties are different. Most obvious is the difference in activating a response from the population. In case of the current warning system using the siren, the citizens have to know what their proper action is in case of an emergency. The national government uses campaigns to inform people on the required response [20]. Using a textual warning system offers the opportunity to explain the required behaviour in the text message itself. A second difference is related to the technology that provides the warning. The current warning system uses a network of sirens throughout the country. These sirens are activated from a central point often within a region. The use of mobile phone technology to send a text message includes an additional step. Similar to the siren system a country-wide network is used, namely the mobile phone network. However, this network alone cannot reach individual citizens: the warning messages have to be transferred to the mobile phones of individual citizens. Both components, network and the mobile phone, have to function in order to reach an individual.

Apart from differences in the knowledge of citizens about the proper response and differences in the technology to provide the warning to citizens, these characteristics of the system also have differences regarding deciding about the use of the warning device. When the siren system is used to warn the population, the area that needs to be warned should be determined. This applies to the use of textual warning messages on mobile phones as well. However, during the decision-making process, an additional function should be included. This function relates to deciding about the contents of the textual warning.

Fig. 1 shows the alarming chain when text messages are sent to alert the population. The three general phases are visualised by means of the letters A, B and C. The numbers 0–4 further specify the phases when using mobile phone technology as a citizens' warning system. These phases imply the following:

A. Occurrence of emergency (this moment is always unknown)
   0. Identification of emergency situation and decision about the necessity to send a text warning message using citizens' warning system
   1. Decision of type and contents of text message based on the emergency characteristics
B. Activating the alarm system
   2. Sending of text warning message via the antenna system of the mobile phone network to individual mobile phones
   3. Reading and understanding text warning message by individual citizens
   4. Decision of citizens to act upon received text warning message
C. Citizens actions as a result of text warning message

3. Dutch cell broadcast trials for citizens alarming

In the period 2005–2007 large-scale field trials were carried out to study the effectiveness of cell broadcast for citizens alarming. Table 1 shows all the trials and related studies. The first column shows the year and order in which the trials took place. The large-scale trials were conducted in four areas in the Netherlands. Each trial lasted about 4–6 weeks. The number of participants varied from just over a hundred to almost 6500. In the trials, participating citizens were sent various messages via cell broadcast at unexpected moments. Participants had to

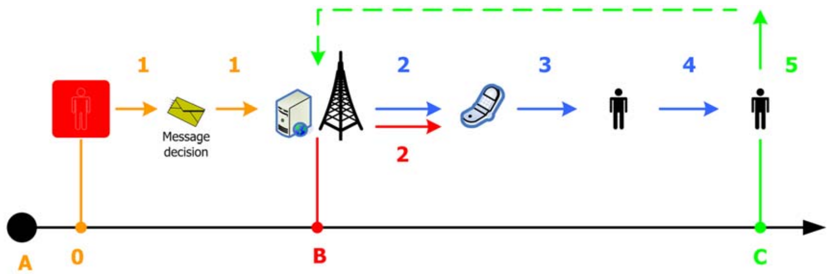

Fig. 1. Operation alarming chain when using mobile phone technology for citizens' alarm [9].

Table 1
Overview of cell broadcast trials conducted in The Netherlands.

Trial	Area	Citizens participating	Main goals and experiences
2005-I	City: Zoetermeer	102	Get acquainted with cell broadcast
2005-II	City: Zoetermeer	1135	Large-scale citizens trial
(Lab)	–	(44)	Study message content and special needs for death and auditory-impaired people
2006-I	Region: Zeeland	391	Explore cell broadcast technology receiving on mobile phones
2006-II	Region: Zeeland	6436	Large-scale citizens trial
(Demo 2006)	Two holiday parks	(196)	
(Web)	–	(418)	Study message content using a website
2006-III	City: Amsterdam	503	Large-scale citizens trial
(Demo 2006)	Conference Hotel	–	Fire evacuation of a hotel. Participants were attending a conference on cell broadcast
(Authorities)	–	–	Study acceptability amongst the responsible stakeholders for citizens' warnings
20006-IV	Region: Zeeland	1317	Multiple services to analyse potential synergy and spam effects
(Pre-test 2007)	Region: Walcheren/Zuid Beveland	(–)	Explore network and handset technology for the large-scale test
2007	Region: Walcheren/Zuid Beveland	621	Large-scale citizens trial

respond by sending a keyword via sms. The number to respond to and the keyword were prescribed in the text of these cell broadcast messages. The experiments and demonstrations placed between brackets in Table 1 were supporting studies. The results discussed in this article consider the trials of 2005-II, 2006-I, 2006-II, 2006-III, 2006-IV and 2007.

During the 2005 and 2006 trials, three of the by then five existing Dutch telecom operators had made their network available to dispatch cell broadcast messages. A broker arranged the messages to be sent to mobile phones linked to the networks of the three telecom operations in the trial areas. The conditions in these trials were based on a 'best effort' contract. The network infrastructure to broadcast a message (marked with 2 in Fig. 1) was designed as a proof of concept. In other words, it could be demonstrated that cell broadcast messages can be dispatched and received on a number of mobile phones. In these trials citizens could participate as long as they lived or worked in the trial area and had a mobile phone with a sim-card of one of the telecom providers active in the trials. The 2005 and 2006 trials provided rich information on emergency warning using mobile phone technologies, but the effectiveness of the system for the real case network infrastructure could not be determined. Large-scale testing prior to introduction complicates the budgets available to carry out necessary investments in the telecom networks. A solution was found for the 2007 trials. The telecom network itself was hardly changed, although each individual BTSC in the trial area was tested to check whether it can dispatch a cell broadcast message. Additionally safeguards were arranged in which the network operators knew when the test messages (at, for participants, unexpected moments) were to be sent. Prior to these moments the network linkages were tested. Moreover a feature was programmed and installed on mobile phones that logged essential information to analyse failures in receiving messages or responding to messages. The logging included two functions: storage of received cell broadcast messages and log of relevant status of the mobile phone in the 15 min around test moments. Each participant obtained a mobile phone with this feature and cell broadcast preinstalled.

4. Determining the effectiveness of citizens alarming

Central in each of the large-scale trials was to determine whether cell broadcast is an effective means to warn citizens in order to have citizens adequately act to get or stay out of danger. To analyse its effectiveness, the penetration of the technology is measured. Before discussing the results regarding the approach to analyse the penetration, the data that were used and the main validation issues concerning the available data are explained.

4.1. Definitions for determining penetration

The effectiveness was determined based on the number of people who acted in accordance with the instructions in the cell broadcast alarm messages. For a commercial mobile phone service, penetration is measured as the number of terminals reached, which is sufficient to determine its effectiveness. Since an emergency warning system was evaluated, reaching citizens is not enough, because this gives no guarantee that the message was noticed in the first place, then read and finally adequately acted upon according to the instruction in the text. For the emergency service it is not primarily to reach the mobile phones, but it is the real penetration of the service that counts. The penetration of a cell broadcast alarm message therefore includes noticing, reading and acting adequately. According to this definition, a cell broadcast reaches the individual member of the public when all links in the alarm chain (see Fig. 1) function:

1. The message must be sent properly.
2. The message must be received properly on the mobile phone.

3. The individual must read the message.
4. The individual must act accordingly.

Stage four, i.e. act accordingly, has two dimensions, namely the correct response that should be taken in time. Since, the trials are conducted under normal non-emergency conditions, having a tight time interval for adequate response would not suit the test conditions. Participants committed to a trial in which they received a number of unknown messages at unknown moments. Receiving a message while at work may be less convenient than receiving a message on a free evening. Since there is no real emergency, the moment of receiving a message can influence a quicker or slower response. To have the potential penetration of cell broadcast for citizens' alarming not influenced by the exact moment when the message was dispatched, the study included all correct responses that have been received within 24 h. To get an impression of time-limited adequate responses in case of a real emergency, the pace in which responses were received was analysed. Therefore the proportion of participants that responded in the first 7 min and the first 2 h after each message was broadcasted was determined.

Only the people present at the moment of broadcasting the message are taken into consideration. This complies with the technology, which is geographically orientated. If a person is not connected to one of the cells at the moment of broadcasting the message, this person will not receive the message. This also complies with the need of citizens' warning since only those in danger should receive an alarm message, which tells us what to do.

Since messages were sent on different days (both weekdays and weekend days) and at moments during the day, the number of people present at the moment of broadcast differs between the messages. As a result messages have varying target groups. The 2005 trials, for example, took place in a dormitory town. Many people living in this municipality work elsewhere. Participants were asked on the registration form to indicate at what times (weekday mornings, afternoons, evenings and nights, and during the weekend) they are in general present in the trial area. In the 2005 trials 63% of participants were in general present during regular working hours (morning and afternoon), while 99% of the participants were said to be present during evening and at night time. As a result, for the daytime messages, only 63% of the total group of participants is actually relevant. In the region trials in 2006 participants were asked the same question for the entire region. Since the region is much large, the proportion of participants in general present during working hours was 92–94%, while in the evenings, nights and during weekends it was between 97% and 99%.

Given the differences in the relevant proportion of the participant groups and the different total number of participants in trials, the number of people reached is not expressed in terms of a number but in terms of a proportion. Since this is a proportion of the people that should have been reached, these facts can be compared between messages from the same trial and over different trials.

4.2. Data availability for analysing penetration

To analyse the penetration of cell broadcast alarm messages data are used from various sources. Data are gathered prior to the trials, during the trials and after the trials. Calculation of the penetration for one message includes multiple steps. The stages are visualised in Fig. 2. The light-gray boxes include the use of data other than the response participants sent via sms. The dark-gray boxes exclude those sms messages that are not considered as a response to the alarm message. The black-coloured boxes show classifications used to calculate the proportion of people reached and the speed at which responses are given. The white boxes finally represent the analysis of the responses in order to determine the penetration.

The response of participants to cell broadcast messages is determined using sms messages. Each sms received included a time component and a content component, from which the response time and exact response are extracted. An example of the output of a received sms is: *00316xxxxxxxx,204xx*, *tu alarm,2006-03-16,19:45:59*.[1] The output contains successively the mobile number, the provider of the sender, the context sent by the participant in his or her text message, and date and time when the response via sms was received. Using the start time at which the message is dispatched to the network and the time of the response via sms, the reaction time for each individual participant is determined. The content in the sms response is compared to the instruction given in the cell broadcast alarm message. If the word combination requested in the alarm message was indeed part of the response, an adequate response is given. Only an adequate response with the appropriate response time is considered as a response.

To determine the number of people present at the moment of dispatching the message (target group), different methods have been used for earlier and later trials. Since cell broadcast is a one-way communication technology, there is no direct feedback information on which mobile phones receive a message. For the messages sent in the 2005 and 2006 trials, no data on individual participants other than their potential response were available. The target group per message was estimated based on the information about presence in the trial area given by the participants on the registration form. In the 2007 trial all participants used the same mobile phone on which an application designed for the trial was installed. This application, among others, stored log information 10 times a day. A cell broadcast test message was sent in between two log moments. The logging information included information on the cellID to which the mobile phone was connected, if any. For those participants who did not respond to the cell broadcast test message, it was determined whether they were possibly not in the trial area at the moment of dispatching the message. First the logging was checked for receiving the test message. If that was the case, the participant was assumed to be in the area. For the other participants the connection to the network on the two nearest log moments was analysed. If a mobile phone was connected to a cell not in the trial area at the moment just before and/or after the message was broadcasted, it was assumed that the mobile phone and its user were not in the area in the time in between.

To finally determine the penetration, the number of people who responded within 24 h was divided by the number of relevant people for the specific message. The reaction time is a derivative of the penetration, namely the share of the responses received in seven minutes and in 2 h.

4.3. Analysing non-response

Only if each step of the alarm chain (see Fig. 1) is successfully completed, the warning system is fully effective. Failure at a single link results in loss of penetration. The scope of this loss depends on the link that fails. Errors in the dispatching of the message (between the cell broadcast infrastructure and the providers' networks) have a larger impact than errors on the level of separate

[1] The mobile number and the accompanying telecom operator are made anonymous in this example.

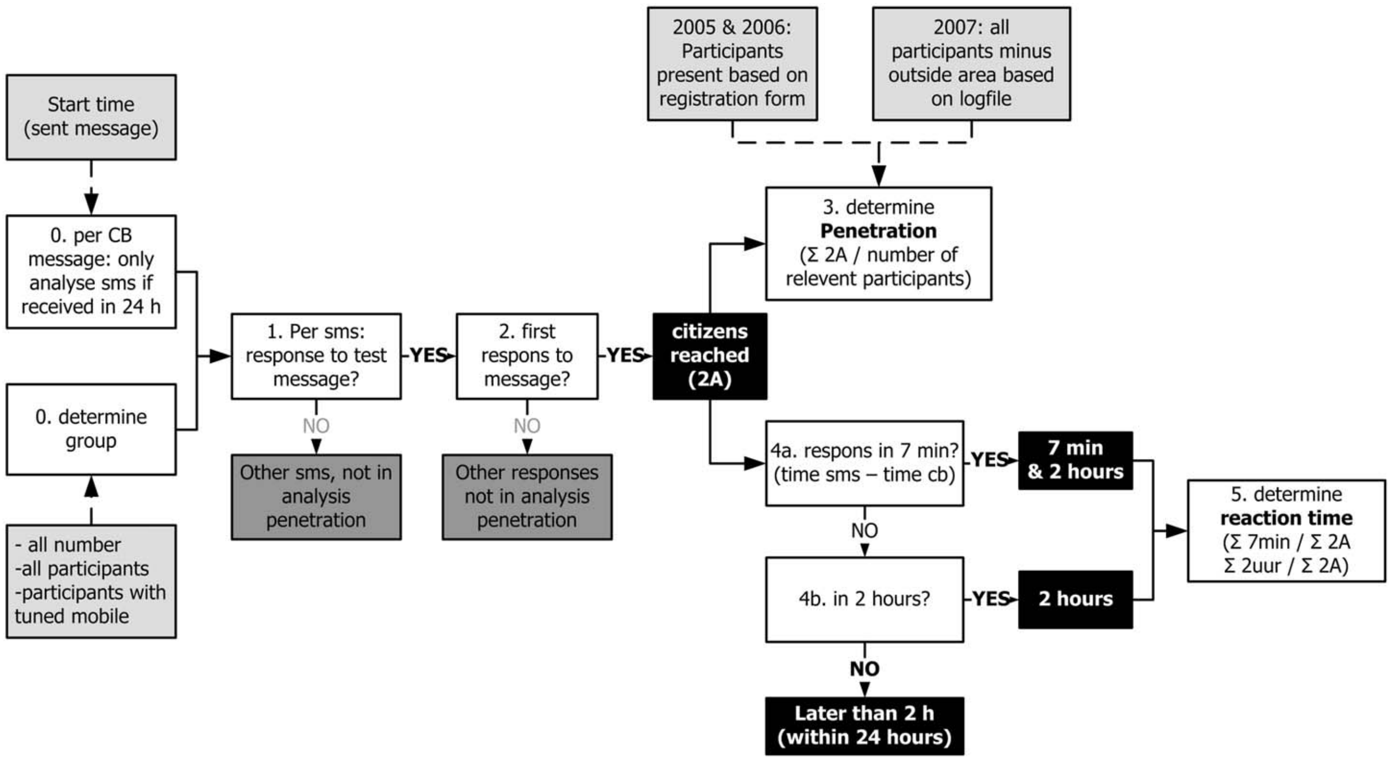

Fig. 2. Analysis scheme for determining penetration of one message.

mobile phones. Receipt failure on a single mobile phone only has an impact on the owner of the phone in question. Similar to estimating the number of people present at the moment of dispatching the message, various data sources have been used to study which of the chains caused the failure. In all trials the starting point was the sms response. Using this response it was determined which participants were not successfully warned. Different data sources were available to estimate the problems that may have caused one or multiple failures in the alarm chain.

Available data to analyse the non-response in the 2005 and 2006 trials were notifications from telecom operations on (partial) failures of the network, data from a survey conducted after the trial and telephone inquiries to subsets of participants after several test moments. Since these data sources do not cover all participants per individual test moment, the data can only show the relative importance of potential failures in the alarm chain. In the 2007 trial the logging data, discussed in the previous paragraphs, were available. In addition, data per dispatched message were available on the individual addressed cells of the telecom operator's network.

4.4. *Validity of analyses*

Apart from participants not being in a real emergency, the analysis is limited due to the data availability. The validation of three data sources is discussed here. For all trials, this includes the choice to use sms as an adequate response in all trials. For the 2005 and 2006 trials, it includes the use of surveys and telephone inquiries. For the 2007 trial it includes the data logging on the mobile phone provided to the participants in the trial.

4.4.1. *Use of sms to determine adequate response*

Having participants send a text message as response has several advantages for analysis. Every received sms message (see Section 4.2) contains the same elements in a fixed structure. One of the elements is the timestamp, which is based on the same clock for every response. The use of sms for measuring the response can have drawbacks with regard to multiple perspectives. The most important ones relate to appropriate responses in case of an emergency and familiarity with using text messaging. An appropriate response in an emergency is, for example, shelter (in an ordinary building or special shelter cases), stay outside away from buildings or evacuate. Sending a text message is a very different action. Apart from the response, the entire trial is held under non-emergency conditions. The adequate response in the trials, however, includes one similarity to a real emergency, namely (temporary) stopping the current matters to do as requested in the alarm test message.

The other criticism is that unfamiliarity with using text messaging could be an obstruction for some participants. The familiarity with use of sms hardly had noticeable influence on the penetration of cell broadcast for citizens' alert. No difference was found in responses between citizens who sent sms messages regularly and citizens who send an sms once a month or less. The proportion of citizens who had never sent an sms before the trial was a little less than for those who had used sms before. In addition, it should be kept in mind that even in a real emergency not everybody receiving and notifying the alarm will act accordingly. When using a bell, for example, people after hearing the alarm should know what to do and act accordingly.

4.4.2. *2005 and 2006 trials: use of surveys and telephone inquiries for individual test moments*

In the 2005 and 2006 trials other data from participants included surveys and telephone inquiries. Participants filled out a registration form prior to the trial, which hold some additional survey questions (e.g., familiarity with receiving and composing textual sms messages). Not all participants should have been reached by all messages. The analysis of penetration therefore includes determining the relevant participants per test message. It is not always clear as to how many people are in the area. A conservative estimate is that everybody, even for whom it is not known that they are elsewhere, is present in the area. In this way, the number of people at risk is rather overestimated than underestimated. In the 2005 and 2006 trials information from, the registration form (see Section 4.2) was used to do so. In this form participants indicated when they, in general, are present in the area of the trial. For several reasons a participant, although indicated to be present on the registration form, may not have been present at the moment a test message was dispatched. Since the trials included hundreds and in some cases over a thousand participants, it is assumed that participants accidentally being not present will balance those in generally not present but accidentally present at the moment of broadcast.

Participants were sent a survey at the end of the trial in which questions related to their experiences during the trials and their attitude towards cell broadcast for citizens' alert were measured. The return rate for this survey varied between 57% and 68%. In the large-scale trials telephone inquiries were held to obtain information about experiences at specific test moments. A subset of participants was asked whether they had received the message; if they did not, the inquiry was used to find an explanation for not receiving the message. The number of participants in the trials is too large to contact all about receiving the specific messages. As a result the telephone inquiries can only be considered as indications for failures of the alarm chain.

4.4.3. 2007 trial: logging data

In the 2007 trial data, the log on the mobile phone was used to determine the number of participants present at the test moments and to analyse potential failures in the alarm chain. In this trial every participant was given a prepared mobile to do so, while in the earlier trials people used their own mobile phone. As will be explained in the remainder of this paragraph, the use of one mobile phone with an application designed for the trial collected more data to analyse both the response and the non-response to the test warning messages. However, in practise there will always be a huge variety of mobile handsets with various implementations of cell broadcast. The logged data hold more up-to-date information than the registration form and the survey from the earlier trials. However, it introduces other problems related to the location of the person holding the mobile phone and the timing of the logging. If a person is located near the border of the broadcast area, his or her mobile phone can be linked to a cell outside the area and consequently not receive the message. On the other hand, somebody outside the area can be connected with a cell that is in the area and thus receive the message. These failures of not receiving a message when in the area or receiving a message when outside the area may be a problem using mobile phone technology in a warning system. Similar to the use of the indication of presence in the area on the registration form, it is assumed that connections near the border balance each other.

The timing problem is related to the moment when the relevant status of the mobile phone is logged. Since the status of all mobile phones are not logged at the exact moment of dispatching the message, but 5 min before and 10 min after this moment, the information can be wrong. For this sake, it is only considered that a participant is not in the area if the mobile phone has not stored the warning message and if the statuses at both log moments show a cellID outside the trial area. Despite this definition, the analysis shows that some participants have received and responded to a cell broadcast message, although according to both log moments they were not connected to a cell in the area prior to and after the message was dispatched. To solve this problem it was first determined whether a mobile phone had stored the cell broadcast test message. Only if it had not, the logging file was checked.

Having more up-to-date data, but from different sources in the 2007 trial, thus holds other validity problems than the problems in the earlier trials. In the 2005 and 2006 trials no data were available for all non-responding participants per message and thus only estimations of the problems were possible. In the 2007 trials data for every participant about all messages were available. However, these data showed conflicting results such as not being present in the trial area but receiving and responding to a warning message. Despite these validity issues the data could show the effectiveness of the use of cell broadcast.

5. Results of the Dutch trials with cell broadcast

The cell broadcast trials included many analysis [see 16]. The results shown in this article include the penetration of the cell broadcast technology to be used for citizens' warnings, the reaction time in perspective of emergency warning, analysis of the causes for non-response and the general reactions of participants during the trials.

5.1. Penetration of cell broadcast for citizens' warnings

During the trials, in total almost a hundred cell broadcast warning messages were sent to citizens. The participants' responses to the warning messages in the 2005 and 2006 trials varied strongly. The penetration varied between 0% and 29% (see row 'Total' in Table 2), except for the fourth trial in 2006. The participants of this trial met different criteria, as will be explained later. Thus, a maximum of 3 out of 10 participants present at the moment of dispatching the message responded to the warning. Table 2 shows the results for the separate trials. For each trial the total number of participants is mentioned and the number of messages out of the trials that were included in the analyses. The percentages mentioned are relative to the number of participants estimated to be present at the moment of the broadcast (see Section 4.1 for explanation). In every trial additional messages were sent that were announced in advance to the participants. The first trial in 2006 (see row '2006-I') was focused on technological issues and finding explanations for the non-response of the 2005 trials. Therefore participants were informed about the dates and times most of the messages were planned. These messages are not used to determine the penetration.

Analysis of the unresponding participants (see Section 5.3) showed that some of the messages had not been broadcasted at all or were only dispatched by a part of the telecom operators' network. When only those messages are analysed that were most likely broadcasted in the whole trial area, the penetration varies between 14% and 29% (see Table 3). Notice that this analysis affects only the lowest penetration found in each of the 2005 and 2006 trials. As a result the average increases from 19% for all messages to 23% if only the correct broadcasted messages are considered. The highest penetration found per trial is not affected. Considering only correct broadcasted messages reduced the number of messages in the analysis from 41 (see Table 2) to only 19 (see Table 3).

Apart from problems in dispatching some of the test messages, problems were found in correct tuning mobile phones to be able to receive a cell broadcast message at all. For this reason example messages were broadcasted before each of the trials in 2006.

Table 2
Penetration of cell broadcast warning messages sent at unknown moments.

Trial	Number of participants	Number of messages analysed	Average (%)	Minimum (%)	Maximum (%)
2005-II	1135	11	19	10	29
2006-I	391	2	20	14	27
2006-II	6436	13	16	0	25
2006-III	503	15	21	0	28
Total		**41**	**19**	**0**	**29**
2006-IV	1317	9	31	5	43
2007	621	8	72	32	88

Table 3
Penetration of cell broadcast warning messages correctly broadcasted at unknown moments.

Trial	Number of participants	Number of messages analysed	Average (%)	Minimum (%)	Maximum (%)
2005-II	1135	5	23	20	29
2006-I	391	1	14	–	–
2006-II	6436	5	22	17	25
2006-III	503	8	24	20	28
Total		**19**	**23**	**14**	**29**
2006-IV	1317	5	38	33	43
2007	621	8	72	32	88

Together with the instructions for tuning their mobile phone, participants were sent a letter announcing these example messages. In the same letter, participants were asked to respond to at least one of these example messages. All participants who have actually sent an sms response to one of these message are considered as one subset of the participants. These people have in common that their mobile phone can receive a cell broadcast message and that they are able to respond by sending an sms text message. For all of the 2006 trials such a subset of participants is defined. For the fourth trial in 2006 all participants who had responded to the second trial were invited. The subset for the 2006-IV trial as a result is the same as the whole participants group.

When moreover only the subset of participants that have responded to an example message is considered, the penetration is between 25% and 51% (see Table 4). The maximum number of participants reached is increased from 3 to 5 out of 10 people. However, less than half of all participants have responded to the example messages send in advance of the trials and are thus considered for here (see second column of Table 4).

The 2007 trial was conducted under different conditions (see Section 3). The 2005 and 2006 trials were conducted under 'best effort' contract with telecom providers. Such an agreement is not sufficient for a citizens' warning system. The 2007 infrastructure contract better represented the real-world conditions. Lessons from the failures in 2005 and 2006 were used to prescribe the required data for the 2007 trial to be able to analyse both the penetration and the unresponding participants. Moreover, all individual cells in the network were tested prior to execution of the test in which citizens participated. The trial showed completely different results. On average 72% of the participants present in the area were reached. However, the maximum and minimum penetration still varied widely (see last row of Table 4). For this trial all participants had obtained a tuned mobile phone. Moreover, the messages were all broadcasted without major network failures. In Section 5.3 it is shown that this is due to bad presentation of certain messages on the mobile phone used during this trial.

5.2. Reaction time to warning messages

The penetration shows the portion of participants present in the area that can be directly reached via cell broadcast. For threats in which a quick response is required to get out of danger, the share of responses received in 7 min has been analysed. A time frame of 7 min was chosen since the Dutch siren can continuously sound for this time period. Table 5 shows that from a third up to almost half of the responses during the 2005 and 2006 trials were received in the first 7 min. An exception is the second trial of 2006. The two messages in this trial directed the participants to other media (teletext and radio) to obtain further instructions. The responses were delayed due to the intermediate step before finding the correct reaction (namely the keyword that needed to be sent via text messaging). The share of responses within 7 min in the 2007 trial was considerably higher, namely almost 60%. The mobile phone that participants obtained for this trial sounded a clear audible tone when a cell broadcast message was received. This in contrast to the mobile phones used by some participants in the earlier trials. Additionally the messages in the 2005 and 2006 trials were most likely not dispatched at exactly the same moment.

Since some emergency situations require a response but not immediately, the share of reactions received within 2 h of dispatching the warning was also analysed. Table 5 shows that about three quarter of the responses during the 2005 and 2006 trials were received within 2 h. The 2007 average was a bit higher. The difference though is less than in the first 7 min. This supports the better recognition due to a clear audible sound, which resulted in quicker responses in the last trial.

Table 5 shows the results for all the messages and all participants, thus including the messages that have not been sent to the entire trial area and also messages sent to participants who had not reacted to an example message. Analysis of the share of responses in the first 7 min of only the correct broadcasted messages (thus the messages analysed for Table 3) and of the subgroups who responded to an example message (messages analysed for Table 4) did not show differences from the results of

Table 4
Penetration of cell broadcast warning messages correctly broadcasted at unknown moments for subset of participants with a correct tuned mobile phone.

Trial	Number of participants in subset	Number of messages analysed	Average (%)	Minimum (%)	Maximum (%)
2006-I	169	1	25	–	–
2006-II	2556	5	46	35	51
2006-III	245	8	35	26	49
2006-IV	1317	5	38	33	43
Total		**19**	**38**	**25**	**51**
2007	621	8	72	32	88

Table 5
Reaction time expressed in percentage of all responses received in 7 min and 2 h.

	Number of participants	Number of messages analysed	7 min		2 h	
			Average (%)	Standard deviation (%)	Average (%)	Standard deviation (%)
2005-II	1135	11	39	10	77	7
2006-I	391	2	5	7	77	12
2006-II	6436	14	34	11	74	3
2006-III	503	15	46	11	79	5
2006-IV	1317	9	43	10	75	16
2007	621	8	59	9	82	8

all messages shown in Table 5. The same holds for the share of the penetration reached within 2 h after broadcasting the warning message.

5.3. *Problems in reaching citizens*

The results from the analysis of the penetration showed great variety between the trials and also within the trials. Since the penetration for none of the individual test messages was 100%, all cell broadcast messages suffered losses. The reason for not responding by all participants present at the moment of broadcast the message varies and can be classified in errors in dispatching the message from the decision maker through the telecom operators' networks (1 and 2 in Fig. 1), problems and errors in receiving a message on individual mobile phones (end of linkage 2 in Fig. 1) and problems with respect to the usage of the mobile phone technology by individual participants (3 and 4 in Fig. 1). For the early trials (2005 and 2006) data are available to indicate the size of problems (see Section 4.4). Data from all mobile phones used in 2007 are available to analyse every non-responding participant.

5.3.1. *Problems in the alarm chain in 2005 and 2006 trials*

During the trials it was experienced that these conditions were not suitable to conduct long-run trials. In the 2005 and 2006 trials errors in dispatching messages were not structural reported. The messages were analysed using the participants' responses. Under the assumption of no relevant differences between participants, the distribution of responses over the telecom operators is expected not to differ for a correctly dispatched message from the proportion of participants having a connection via each operator. A χ^2-test was used to check this hypothesis. A criterion of 95% change of similarity was used. Each message for which the hypothesis is rejected is considered to be incompletely dispatched. This means the following: not sent at all, sent by only one or two operators or sent in only a part of the trial area. From all test and example messages in the 2005 and 2006 trials 46% met the criterion of being correctly dispatched. In the 2007 trial a different monitoring agreement was set, which resulted in hardly any errors in dispatching cell broadcast messages [21].

Other failures in the alarm chain relate to receiving cell broadcast messages on mobile phones. Although cell broadcast is part of GSM specifications [14,22] it is not turned on standard. The implementation of cell broadcast on the mobile phones was found to be different between branches and different handset types [see also 23]. On some mobile phones tuning of cell broadcast is impossible despite the GSM standards. Surveys distributed after each trial showed that about 4 of 5 participants were able to prepare their mobile phone for cell broadcast. Those who were not able to do so had permanent failures and could not receive any message throughout the trial. Others could have experienced temporary failures in receiving messages. A telephone inquiry under a subset of participants was held to find the causes (see Table 6). The results only concern messages that are most likely sent in the entire trial area and only participants who responded to an example message. The results show three causes (columns 3, 4 and 5 in Table 6). The first group, not in the area, actually does not have any problem. In case of a real warning the other two groups should be warned. To reduce the second group, mobile phone switched off, citizens should be educated about the conditions an individual should meet to be able to receive a message. The third group, who were in the area and had their mobile phone switched on, should have received the message. In the 2005 and 2006 trials this group holds the largest portion of participants.

Finally errors can be attributed to the use of mobile phones, since not all participants receiving a message necessarily respond. The earlier mentioned telephone inquiries are used to indicate how many of the participants who notified a message did not respond immediately or not at all (see Table 7). The analysis includes all test messages in the trials, but only participants who said to have received and read the cell broadcast message. Give the noncritical situation in which people received the test messages the proportion of responding participants, 80–86% of the participants (column 3 and 4), is high. Almost half of the people, who responded not immediately or not at all (column 4 and 5), declare that the message was received at an inconvenient moment.

Table 6
Temporary failures found via telephone inquiry (only correct dispatched messages and particpants with a correctly tuned mobile phone).

Trial	No message received	Not in the trial area (%)	In the area, phone off (%)	In the area and phone on (%)	Unknown (%)
2006-I	174 (40%)	28	10	61	–
2006-IV	421 (56%)	26	8	65	1

Table 7
Response after reading a message (via telephone inquiry).

Trial	Message read	Response directly after reading (%)	Response later (%)	No response (%)	Does not know (%)
2006-I	562	68	12	16	4
2006-IV	333	71	15	12	2

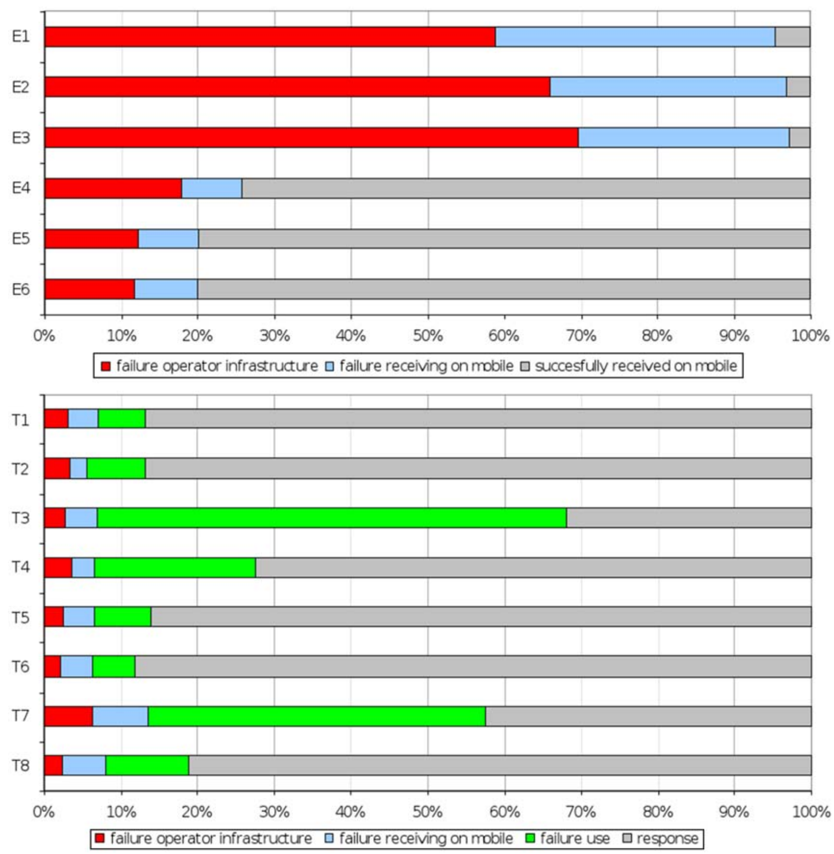

Fig. 3. Functioning of the alarm chain during example messages (E1–E6) and test messages (T1–T8) in the 2007 trial.

5.3.2. Controlling the alarm chain in the 2007 trials

The messages sent in the 2007 trial to participants can be analysed on individual basis using the logging data from the mobile phones handed to the participants. Using these data it is determined for every message where the alarm chain failed for each participant who had not responded. Fig. 3 shows the results for the example messages (E1–E6) and the test messages dispatched at unexpected moments (T1–T8). The failures are shown in the same order as the alarm chain in Fig. 1. The figures only include the participants present in the area at the moment of broadcasting the message (see Sections 4.1 and 4.4). All these people should have received the message. From the previous paragraph it is already known that the penetration for none of the test messages was 100%. For the test messages (T1–T8) the three error classes that have been discussed for the 2005 and 2006 trials above are shown in the figure. For the example messages only the errors in the telecom network and errors causing not receiving the messages on the participant's mobile phone are shown. Since participants were told they had to respond to only one of the example messages, errors in use (not noticing a message or receiving but not responding) cannot be attributed to citizens for these messages.

Example messages E1, E2 and E3 show many failures addressed to the network or the mobile phone. A maximum of 5% of the participants in the trial area had received these example messages. After checking the mobile phones used by participants in this trial it was found that the software had a serious error. Due to this error a mobile could only receive a cell broadcast message once. Settings in all mobile phones handed to the participants have changed and extra example messages E4, E5 and E6 are broadcasted. The results show a large reduction in failures. 74% up to 80% of the mobile phones have shown these example messages on the screen. The example messages show that controlling the alarm chain is possible but a small error has tremendous effect on the functioning of the entire chain.

The test messages (T1–T8) sent at unexpected moments showed fewer failures in the network and errors causing not receiving the message compared to the example messages. The errors in use have in common that the participant present in the trial area has received the message on his or her mobile phone. Not responding to the message is either caused by not noticing the message and therefore not having read it or is caused by not responding after having read the message. Table 8 shows that for messages T3 and T7 a significant larger proportion did read the message but did not respond to it. The cause has to be found in the message content of these two test messages. Unlike the other messages these two messages were so-called multipaging messages. To read the entire message texts participants need to scroll down. The instruction explaining the correct response was given near the end of the message. Many participants did not know how to scroll the text on the mobile phone, which was handed to them for the trial. As a result many participants noticed these longer text messages but did not know what to do and therefore did not respond. The results show the importance of a clear design of the interface.

5.4. Participants' responses throughout the trials

The previous paragraphs discussed results on penetration, reaction time and causes of non-response per warning test message. Since each of the trial included multiple messages, combining the reaction of all messages in a trial provides additional information. The first column of Table 9 shows how many of the participants have never responded to a test message. More than half of the participants have never responded in the first three trials. Some of these people did not succeed in tuning their mobile phone but others never received a message due to failures in the operators' networks. In the fourth trial in 2006, in which only citizens participated who had responded to an example message in the 2006-II trial, almost one-third never responded. The safe-guarded infrastructure use in the 2007 trial shows off, since only 3% of the participants never responded in this trial. In contrast to all other trials most participants responded to more than two of the test messages sent at unexpected moments.

In the 2006-III trial not only cell broadcast messages were sent but also twice a test message was sent via sms. In contrast to the responses of the 2006-III participants shown in Table 9, only 21% did not respond to these messages. 52% of the participants responded to both messages sent via sms. Amongst the respondents to the test messages sent via sms were 122 participants who had not responded to cell broadcast messages in the same trial.

6. Discussion

This article explains the methods used to evaluate a new warning technology based on mobile phone technology. Analysing the penetration for citizens alarming shows the importance of every single linkage of the alarm chain to function. This involves the telecom operators' network, the mobile phones and the citizens who should notice, read and act according to the message. To have a successful citizens' alarming system using cell broadcast all stakeholders involved should acknowledge the definition of penetration, which includes the citizens' actions. Since the telecom sector is not primarily focused on emergency warning systems the use of their mobile communication networks for this purpose requires special attention. Typical for an emergency warning system is the need of the alarm chain to function at the moment a citizens' alarm needs to be sent, and this requires a different management from telecom operators than that for their commercial communication services [17]. The 2007 trial has shown that network management tuned for emergency situations is possible. In addition to the operators' involvement in this trial, a monitoring system that diagnoses the success and failures in case of a real warning should be established. The 2007 trial succeeded with the use of one type of mobile phone. In reality, citizens will have diverse mobile phones, which should all be able to receive a cell broadcast message and clearly notify this to the user. The 2005 and 2006 trials showed that the suitability of mobile phones to receive the full message varies. Although cell broadcast is part of GSM standards, the implementation on several types of mobile phones currently is insufficient for citizens' alarming purposes. Use of cell broadcast in practise will urge manufacturers to pay more attention to cell broadcast in the design of new mobile phones. At the same time the old versions are on the market. If cell broadcast is to be used for citizens' alarming it should be clear to people whether their own mobile phone is capable of receiving a cell broadcast alarm message. Since an effective alarming system should contribute to citizens bringing themselves in safety after being warned, comprehension amongst individual citizens of the warning system is required. A warning system using mobile phone technology requires a more active involvement of people than the use of a siren system. Citizens should be aware of the

Table 8
Receiving and response to test messages in the 2007 trial (total in this table represents the green and gray part of message T1–T8 from Fig. 3).

	T1 (%)	T2 (%)	T3 (%)	T4 (%)	T5 (%)	T6 (%)	T7 (%)	T8 (%)
Received not noticed	3	6	8	11	6	5	9	9
Received and read	3	2	53	10	1	1	35	2
Received, read and responded	87	87	32	72	86	88	43	81
Total received on mobile	93	94	93	93	93	94	86	92

Table 9
Response to test messages during the trials.

Trial	Number of participants	Number of messages	None of the messages (%)	One or two messages (%)	More than two messages (%)
2005-II	1135	11	52	21	27
2006-I	391	4	55	29	16
2006-II	6436	7	59	20	21
2006-III	503	14	37	21	42
2006-IV	1317	9	30	24	47
2007	621	8	3	5	91

requirements for receiving a message, such as tuning their mobile phones and having it switched on at the moment a message is broadcasted. Moreover, the expectations of individuals should be managed. Governments should explain what citizens may realistically expect, which involves the type of emergencies for which the system will be used. Most likely a warning system will not be activated for a local accident in which the number of people threatened is limited.

7. Conclusions

The Dutch cell broadcast trials for citizens alarming have shown that a warning system can function as long as all stakeholders involved acknowledge all linkages of the alarm chain. Different from currently available mobile phone services, an effective alarming system does not stop at showing the warning message on the mobile screen, but includes the citizens to notice, read and act in line with the warning given. To have a fully functional alarm chain with cell broadcast requires the following:

- telecom networks to be operated and managed in accordance with emergency warning needs,
- handsets implementations to be improved in accordance with the use of the technology for warning purposes,
- citizens to understand when they will or will not be warned in case of an emergency, and
- governments to manage realistic expectations of citizens and have telecom operators and handset manufactures provide services for citizens' alarming purposes.

The main future challenges will be to get a grip on the various mobile phone implementations and also correct communication to citizens about the possibilities and limitations of the emergency warning system.

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