Acceptance study on application systems to improve situational incident management through bi-directional communication between citizens and decision-makers in emergencies and crises situations

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ABSTRACT

Efficient hazard prevention and disaster control depend on situational awareness. Situational information is - among others - provided by citizens on the ground. Disaster managers are often reluctant to use such information on a large scale or in a systematic way for fear of being overwhelmed by information overload in a stressful crisis. New information technologies for crisis management are strongly dependent on the acceptance of the people using them and can only be successful as socio-technical systems. Therefore, 354 employees of public and private emergency operation centres as well as members of crisis management teams were asked to assess different information sharing technologies. 504 people from the public responded to an online survey about their willingness to use such technologies. The results indicate a high level of acceptance by both user groups for bi-directional communication technologies for situation management and the improvement of situational awareness.

Keywords

Emergency Control Centre, Situational Awareness, Acceptance of ICT, Population, Crowdsourcing, Video support, bidirectional communication.

INTRODUCTION

In the case of disaster events such as floods, extreme storms, major fires, but also accidents or attacks caused by people, it is important for the emergency response authorities to efficiently distribute available resources and to make the right decisions based on all available information. The prerequisite for this is a comprehensive overview of all relevant information as an overall situation picture, and the networking of all actors involved (Holzhüter & Meissen, 2020). Basic information in disasters includes Who? Where? Why? and How? (Bundesamt für Bevölkerungsschutz und Katastrophenhilfe, 2019), but information from data sets, e.g**.,** on population density or damage reports, are also of great interest. (Coppola, 2015). Well-founded and high-quality data can support decision-making. In addition to the quality of the information, time also plays an important role. Contrary to the alarmed emergency forces, people at the disaster site can provide information faster and intervene immediately.

Past disasters have shown a high willingness to help among the population, such as the management of the flood disaster in 2020 in the Ahr valley, Germany, with over 70,000 spontaneous helpers (The Weather Channel, 2021). Concrete figures are lacking as neither the number of helpers nor their activities have been reported and analysed in a systematic way. In addition to assisting in coping tasks, volunteers can collect information on the situation, as shown for example by a large number of communities in the field of environmental data (Holzhüter et al., 2021). Emergency, crisis and disaster communication between the population and the emergency response authorities has traditionally been asynchronous. Emergency calls are reported by telephone to emergency control centres, the on-site situation is communicated by voice. Once the situation has been established, information on how to behave is distributed by the authorities via warning media. An adaptation of the information to new findings in the situation usually did not take place, according to an interview with an employee from an emergency operations centre. Likewise, prior communication with and coordination of non-organised voluntary helpers was not possible, but only took place directly on site in an ad-hoc manner. The inclusion of first responders in large-scale crises and the associated planning of resources such as emergency vehicles and drones have been challenging so far. With the help of new communication technologies such as smartphones, however, these issues can be addressed through improved communication means. (Reuter & Kaufhold, 2018) present a communication matrix in which they identify four communication fields: between citizens (C2C), between authorities and citizens (A2C), between authorities (A2A) and between citizens and authorities (B2A).

This paper focuses on the acceptance of strategic application systems for improved situation assessment and management through bidirectional communication between authorities and citizens (A2C and C2A). The investigated application systems promise to improve the accuracy and quality of

(1) the communication of warnings, measures and situation information to the population and different decision makers,

(2) the individual emergency communication via live chat, live audio and live video functions via smartphones using voice and image analysis,

(3) first responder apps and dispatch of first responders to emergencies, and

(4) the inclusion of volunteers in the disaster management process.

The analysis focuses on application systems in the area of situation management and not in the area of prevention and aftercare. Approaches using artificial intelligence were of particular interest, as they promise an efficient extraction of information on the one hand but are also highly controversial among practitioners, e.g., due to fears of loss of control and transparency on the other hand. Citizens are directly involved in (1), (2) and (4) and were also asked about it.

The acceptance study was conducted as part of the SPELL research project. Within SPELL, decision support systems are developed that derive recommendations for the operator in the control centre from situational data on a semantic platform. These support systems shall then support bi-directional communication with the citizens via special apps, but also more broadly via alternative messaging channels. In addition, semi-automatically configurable dashboards are developed for the visualisation of situation data for and from the population, political decision-makers, and the economy, tailored to the target groups and the current crisis. For emergency communication with those seeking help, technologies which already allows chat, voice, and video communication via smartphones, will be supplemented with AI methods, in particular deep learning approaches for automated text and voice analysis as well as image analysis, to classify the emergency and automatically identify parameters relevant for decision-making. In addition to these more operationally oriented applications, a strategic planning tool is also being developed to enable decision-makers to optimise the locations of emergency resources such as defibrillators and drones, and to determine the likelihood of first responders being called upon so that appropriate levels of preparedness can be derived. The acceptance study presented here as focus of this paper will support the development process of disaster communication application systems by analysing their acceptance among citizens and authorities alike, helping to identify those applications that are most likely to be used successfully in practice. Figure 1 presents an overview of different categories of applications that are analysed as part of the acceptance study.

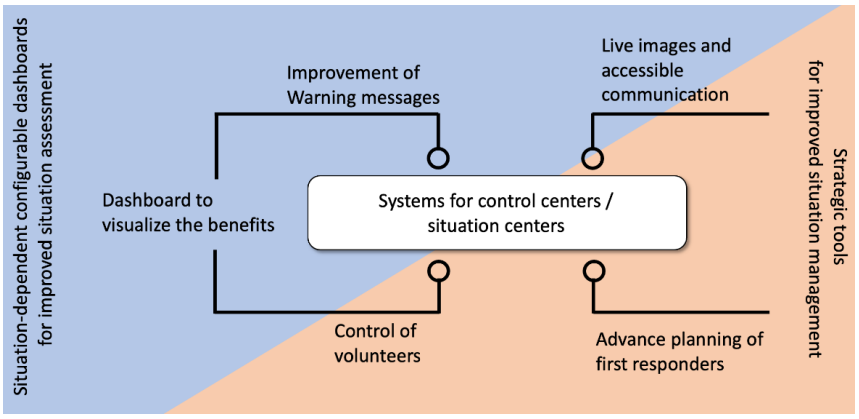

Figure 1 General overview of systems used between citizens and decision-makers focused on in the acceptance study

The remainder of the paper is structured as follows: First, the state of research and the study design are presented, followed by the analysis and results. The paper concludes with a discussion, conclusions, and an outlook on future research.

STATE OF THE ART

Data provided by citizens are currently rarely used for the expansion of situation pictures (Reuter & Spielhofer, 2017). Until a few years ago, communication by public safety authorities with the citizens was unidirectional and had an informative and warning character. However, major disasters, such as the flood disaster in the Ahr valley in Germany in 2021, have led to greater acceptance by the authorities to involve the population in disaster management. In the field of situational awareness and situational information, solutions have already been researched on how to deal with time-pressuring crisis situations (Luokkala & Virrantaus, 2014). In particular, large disasters have shown that the involvement of the population in the entire disaster management cycle - from preparedness and detection to management and recovery - is crucial. (Government of Manitoba, n.d.). A good example for the use of feedback channels from citizens to authorities is the app from the German Weather Service, which uses the user feedback to improve the forecasting process and for quality assurance (T-Online, 2020). Current research projects are also looking for ways to use feedback from the population (Ecker, Lindacher, Dressen, et al., 2020). The involvement of the population in such large-scale incidents is essential for the collection of information, possibilities, advantages and disadvantages have already been explored, concrete overarching solutions have not yet been found (Salfinger et al., 2015).

Smartphone functions allow emergency response staff to access relevant information in case of an emergency or crisis. The increasing spread of mobile phones has ensured that emergency calls are now made via smartphones in the majority of cases. Smartphones have the advantage that they can transmit information via a data connection in addition to the telephone call. After a large number of apps were developed for this case, the Web Real-Time Communications (WebRTC) standard communicated on 26 January 2021 by the World Wide Web Consortium (W3C) and the Internet Engineering Task Force (IETF) has led to a significant improvement in the operational management of live video and live audio interactions between endpoints on the Internet. With the introduction of this standard, a possibility was created to establish real-time communication between two browsers without an app, worldwide and with any end-user device.

Thus, downloading an app and maintaining it before a disaster has become unnecessary. Due to the WebRTC technology, no pre-installation is required on the smartphones of the emergency callers. Three studies (Ecker et al., 2021; Ecker, Lindacher, Adams, et al., 2020; Ecker, Lindacher, Dressen, et al., 2020) have demonstrated the direct benefits of incorporating technology into emergency calls to improve emergency management, as done by the EmergencyEye technology. In addition to a live video connection, a chat with translation and a location of the caller's smartphone are provided. The proprietary EmergencyEye technology is available in modified form in various countries. In England, for example, a corresponding function was developed for the GoodSam plattform, which also has functions for trained volunteers (Smith et al., 2017), on the same basis. In Israel, a product of the company Carbyne is now used in emergency management on this basis (Potts, 2019).

Worldwide, many different smartphone apps support pre-EMS (emergency medical services) services, for example by alerting first responders and/or displaying AED (automated external defibrillator) locations in case of

an out-of-hospital cardiac arrest (OHCA). An overview of existing apps for several countries can be found in (Matinrad & Reuter-Oppermann, 2022) or (Scquizzato et al., 2020), for example. In Germany alone, EMS regions can choose between (at least) seven different apps that can be integrated into their control system and three that send out alarms to first responders automatically, but only 31% of the regions have implemented one so far (Björn Steiger Stiftung SbR, n.d.). A main difference between first responder systems in different countries lies in the type of emergencies responders are dispatched to, e.g., OHCA, trauma, bleeding, and the type of responders used, i.e., community first responders (e.g., nurses, doctors), first responders (e.g., paramedics, police, fire fighters), volunteers or bystanders (Matinrad & Reuter-Oppermann, 2022). Standards and generic interfaces are important for further distributing first responder apps in Germany and for allowing coordination centres to dispatch first responders independently of the actually installed app. Based on a survey with 47 OHCA experts from 29 European countries, (Oving et al., 2019) state that a wide variation of initiatives exist within Europe, and they recommend that future research should focus more strongly on survival.

Data science and operations research approaches can improve the efficiency and performance of first responder apps, e.g., by determining the best responders to be dispatched and in case of an OHCA by deciding which responder should pick up an AED from which location (Matinrad et al., 2019). Nevertheless, they have not been implemented into the German apps so far.

Warning systems serve as a tool for emergency response authorities to inform the population of imminent and acute hazards and to distribute accurate and actionable warnings (UNDRR, 2016). Internationally, this is handled differently from country to country (Neußner, 2021), but what is the same is that the communication is unidirectional from the authority to the population (A2C). The literature recommends five elements that a warning should contain: Description of the hazard, location, recommended action, time and source (Mileti & Sorensen, 1990). Due to one-way communication, there is little opportunity for the emergency response authorities to determine whether the warning sent will achieve the desired response at that moment in that situation. There have been numerous studies on the linguistic structure of warnings (Künzer & Tomczyk, 2022), but these remain general studies with partly hypothetical scenarios. The direct back communication from the population to the transmitters of the warning have only been marginally considered so far. One example is the conception of "112.SOCIAL", a mobile application for bidirectional communication between emergency response authorities and the population (Kaufhold et al., 2018). Here, the possibility of communicating back to 112 emergency calls, reporting incidents by means of photos or the general collection of situation information. The direct possibility of receiving a response after sending the warning has not yet been explored. This is to be implemented within the framework of the SPELL project. As a basis for this extension, the disaster warning system KATWARN will be used. A simple method for processing population data will be designed. The aim is to improve the quality of the text of warnings and to receive feedback on the level of concern of the citizens.

As the discussion of the state-of-the-art shows, many solutions were proposed or implemented to support the communication between citizens and authorities in times of disasters or emergencies. However, few focus on bidirectional communication or analyze the acceptance of such services in quantitative studies. One exception is a study by (Kaufhold et al., 2020) which showed that citizens are in general willing to share photos and video material from disaster sites, but are somewhat more reluctant to share location information due to privacy concerns. The study presented here builds upon previous work by (Kaufhold et al., 2020) and extends it to different applications (e.g., dashboard functionalities, non-app-based bidirectional disaster communication). Furthermore, in our study, we have a broader focus on the disaster managers' perspective.

RESEARCH METHOLOGY

For the survey of decision-makers in the crisis management team, emergency control centre, industrial control centre and the citizens, it was decided not to use an established questionnaire, as this does not address the very special specifics of the application domain. The questionnaire was therefore specifically developed for this study and tested with the quality criteria reliability, validity, and objectivity.

The aim of the acceptance study was to obtain feedback from future users (both emergency managers and citizens) as to whether they could imagine using different types of systems that support the interaction between authorities and citizens. Another aim was also to find possible indications as to whether age, experience or position have an influence on the acceptance of these services. To address the two target groups in the best possible way, two different questionnaires were designed.

Questionnaire for emergency managers

The invitation to the survey was made by personalised e-mails to get as much feedback as possible for the study. The study was conducted online, and respondents were asked 14 questions about the acceptance of different system functions. In addition, participants were asked in which area (crisis team, control centre, industrial control centre) they are working and how much work experience they had in their current job and how much work experience they had in crisis and disaster management in general.

The survey was divided into the topics of live situation assessment, general information provision and first responder systems. Each topic area was introduced with a scenario to highlight the intended use of the proposed systems. The acceptance questions asked if it would be important for the respondent to use the proposed functions. A 5-point Likert scale was used to collect the answers.

The survey was conducted as a Situational Judgement Test and for each block of questions the respondents were given a short introduction to the scenario, which was supported by a photograph. For example, the introduction for the first subject area - live situation assessment – was (translated from German into English):

„Imagine you come on duty, and it seems to be a normal day. There are no known warnings from the weather service or other agencies. Suddenly the phones don't stop ringing. There has been an explosion caused by a derailed train. It is not yet known what the train was carrying, but it may be dangerous goods."

The internal validity was measured based on the individual items in which experts participated in the creation process. To ensure criterion validity, the questionnaire was administered to different groups of people (crisis team, control centre, industrial control centre).

The survey was conducted online, quantitatively evaluated, and interpreted. Reliability is difficult to assess compared to other studies, but a high number of people from the target area were reached.

Questionnaire for citizens

The citizens' survey was carried out by an opinion research institute. The aim was to survey 500 people, and participants were representative for the adult German population regarding age and sex. A total of 10 acceptance questions were asked about the different situations (citizens at a disasters site, citizens receiving warnings, and citizens providing aid spontaneously). The acceptance questions asked if citizens were willing to interact with authorities in a specific way / with specific application systems. A 5-point Likert scale was used to collect the answers.

The internal validity was measured based on the individual items in which experts participated in the compilation process. To ensure criterion validity, the questionnaire was administered to different groups of people (age groups).

The survey was conducted online, qualitatively evaluated, and interpreted. Reliability is ensured because all age groups were surveyed in the appropriate statistical ratio.

SYSTEMS INVESTIGATED

The evaluation of the systems examined was divided into the respective application systems.

These are divided into:

- Application systems for assessing the emergency,
- Application systems for optimising alerts and coordination of volunteers, and
- First responder apps.

Application systems for the assessment of the emergency

Citizens can support the assessment of a specific emergency by using bi-directional communication application systems for photo and video-sharing, such as EmergencyEye. As part of the SPELL research project, it is planned to expand this existing technology by computer-assisted image analysis and the provision of live drone images for better situation assessment. Within the framework of the study, it should be evaluated whether and under what conditions there is a willingness on the part of the citizens to provide the necessary information for these additional

services. Furthermore, it should be investigated to what extent the functions and services are assessed as important by the emergency services.

Figure 2 shows both the questions to the emergency response staff about acceptance and the results of the survey. In the case of an accident involving dangerous goods, both rapid information about the type and quantity of dangerous goods involved were rated as important. When asked about live image information from the accident site, more than 85% of the respondents rated a live drone image as important and more than 80% rated a general live image transmission from the accident site as important. Approximately the same number of respondents consider it important to be able to provide received image material to further decision-makers and experts in the decision-making process.

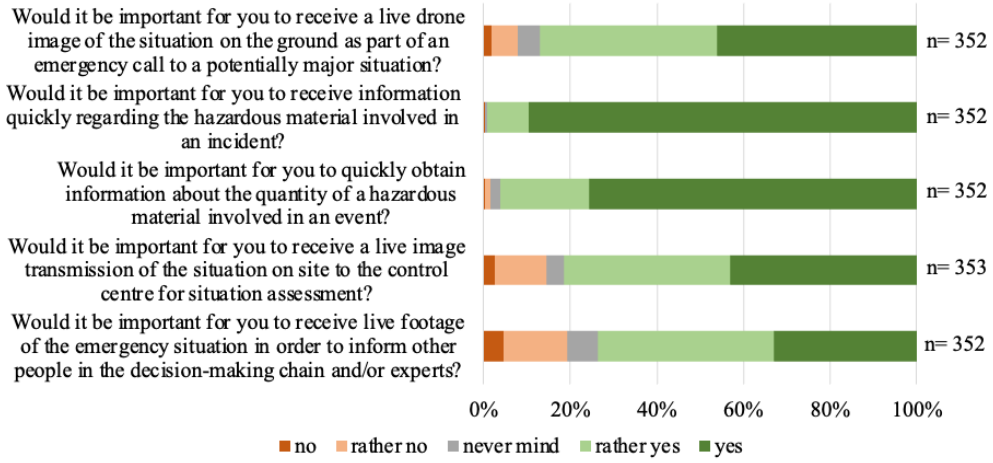

Figure 2 Results of the survey of the crisis team, emergency control centre or industrial control centre on the classification of the emergency and parameters relevant to decision-making

The basic prerequisite for the utilisation of data from the smartphones of emergency callers is the availability and the willingness of the population to make this data available. The questions and associated results of the citizen survey are summarised in the following Figure 3. Of the 504 respondents, more than 90% would be willing to send photos to the control centre and to grant staff access to the smartphone camera as well as the location data on the smartphone. However, more than 70% of the respondents demand to be asked for consent to access the smartphone camera as well as the location data on the smartphone.

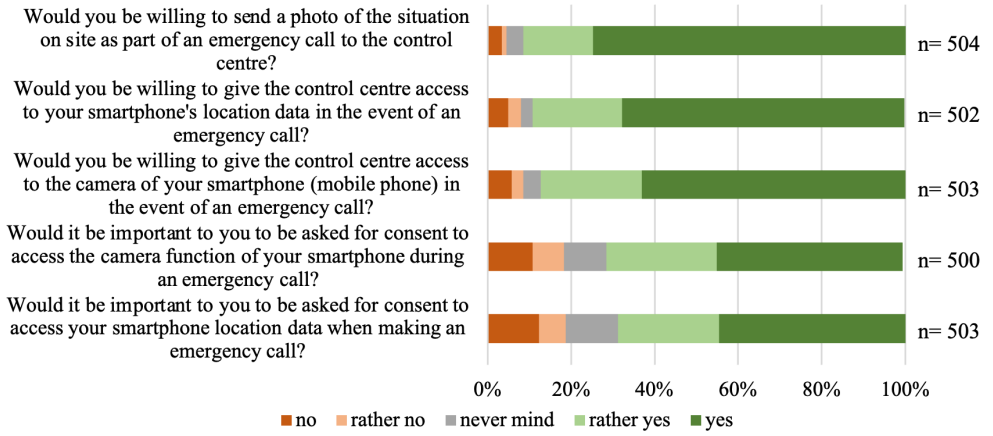

Figure 3 Results of the citizens' survey on the classification of the emergency and decision-relevant parameters

Application systems for optimising alerts and coordinating volunteers

Within the SPELL project, smartphone apps for receiving disaster alerts (such as the KATWARN app) and for coordinating volunteers in an emergency (such as the KATRETTER app) are to be extended with feedback functions and application systems to visualize citizens' feedback in dashboards in a systematic and efficient way. Dashboards to visualize citizens-generated information (such as feedback on warnings, or data provided by private

weather stations) were therefore also an important aspect of the survey.

When asked about the acceptance of such systems, the results of the survey on optimising alerts and coordinating volunteers are shown in Figure 4.

52 % of decision-makers agreed that feedback on warnings could offer added value. What is striking here is the high proportion of people who could not decide on the question. Compared to other questions, the acceptance was not as high. In the follow-up, it was found out in expert interviews that this reluctance may be based on the fact that no specific options visualising this feedback had been presented in the survey, thus making it difficult for respondents to form an opinion on this matter.

The evaluation also shows that extended situation information, such as highlighting high-risk objects in the danger zone, and integrating them into existing operational situation systems, has a high level of acceptance. The possibility of using this information in a dashboard was also rated highly. The use of data from private weather stations was rated well, but with a little more reservation. The system for the use of volunteers and the use of information from the population was rated more cautiously but still positively. In a subsequent expert interview, it was pointed out that the systems must be automated as far as possible and that AI-based filter functions for information must be used in order not to create additional work in the control centres or situation centres through their use.

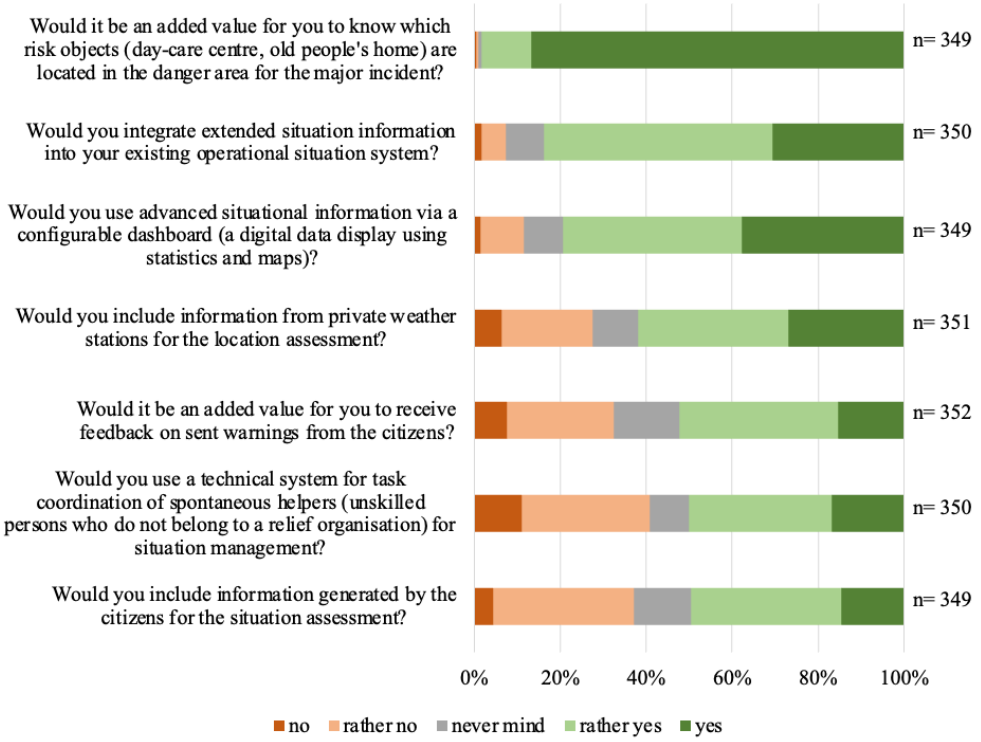

Figure 4 Results of the survey of the crisis team, emergency control centre or industrial control centre on optimised alerts and the coordination of volunteers

The evaluation in Figure 5 displays the results of the citizens' survey on the improvement of warning messages and coordination of volunteers and shows an overwhelming willingness to provide feedback on warning messages, as well as to send the user location in an anonymised way with the feedback. The use of application systems for voluntary support in disasters was also positively evaluated.

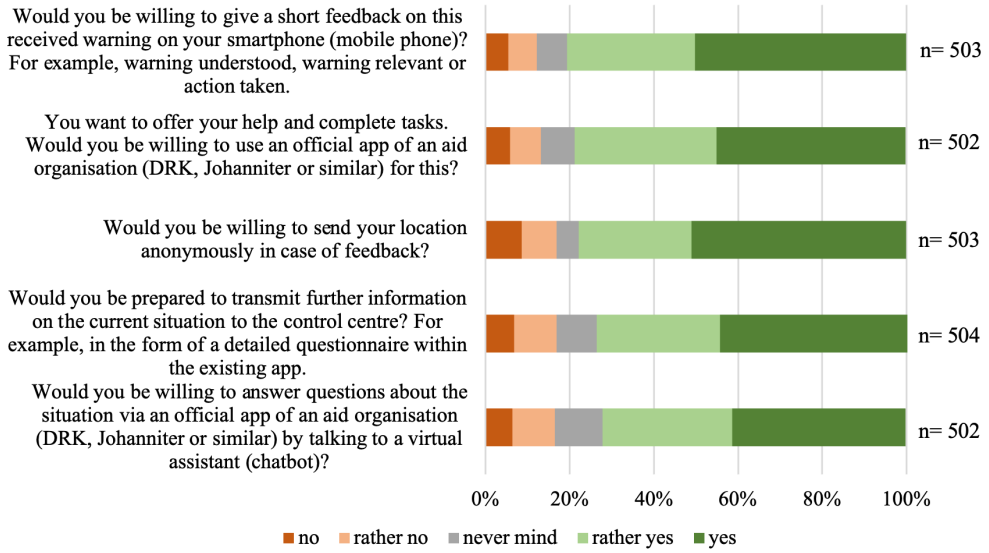

Figure 5 Results of the citizen survey for additional functions of warning messages and coordination of volunteers

First responders and extension of first responder apps

Within the SPELL project, we aim to derive generic design features for first responder apps and design decision support services based on analytics and operations research approaches to efficiently dispatch first responders to incidents, for example. Based on a literature review and interviews with experts and coordination centre staff, we derived the following ideas.

1. If an emergency occurs that can benefit from a first responder, e.g., an OHCA, an operations research approach, e.g. (Matinrad & Reuter-Oppermann, 2022) is used to determine which (and how many) first responders to dispatch and who to send to an AED pickup.
2. In case of high emergency volumes or low ambulance availability, dispatching first responders might be even more crucial for patients to receive first care as soon as possible. Currently, the actual availability of first responders and their locations is unknown. It can be of interest to coordination centres to receive anonymised information about first responder availability and locations when evaluating the current coverage of their EMS region.
3. The other way around, first responders currently have no information about the probability of being called at a specific point of time, the potential availability of other first responders and the expected times for ambulances to arrive at future emergency locations. To make informed decisions about stating their individual availability, accepting potential calls and overall volunteering as first responders, an optional app component could be designed that provides first responders either with general or real-time information about their potential contribution in case of an emergency.

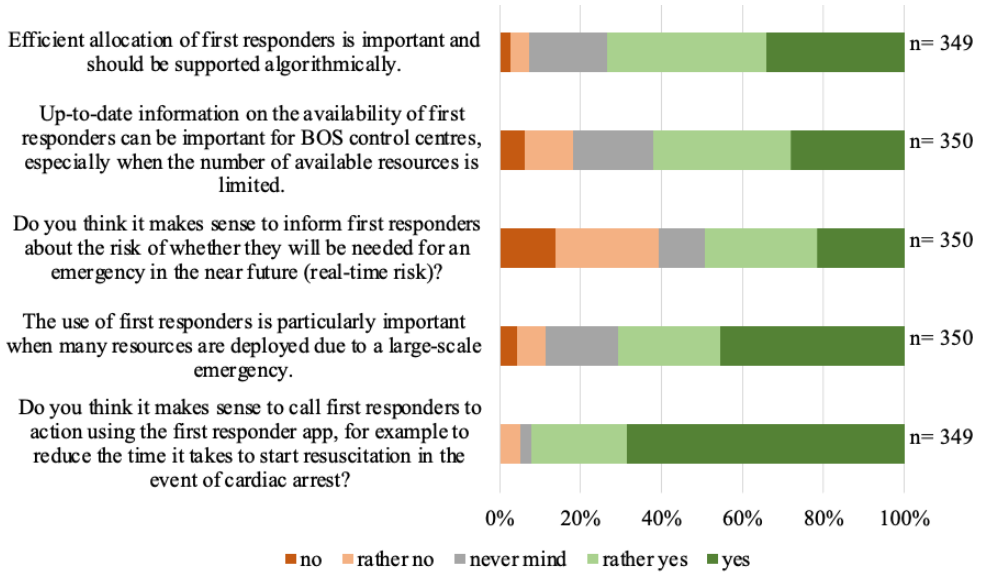

Figure 6 Results of the survey Crisis team, emergency control centre or industrial control centre for the use and expansion of first responder apps

In Figure 6, the distributions of agreements and disagreements with the five questions we posed on first responder apps are displayed.

The three ideas for extending first responder apps described above were all confirmed by the participants, although with varying levels of approval. The first idea of using algorithms for an efficient dispatch and assignment of first responders is supported by more than two-thirds of the participants. The second idea of providing availability information of first responders to control centres was approved by ca. 60%, while only half of the participants agreed with the idea of providing information to first responders about the potential risk / probability to be dispatched. Due to this result, we performed a few informal interviews with coordination centre managers and dispatchers to investigate reasons for the disagreement. One point raised was that while they understand the benefits for first responders, they see a risk for information about the availability of ambulances to reach the public and lead to misconception or even anxiety. Therefore, we aim to follow up on this point by further evaluating with domain experts if the benefit of first responders having this information can be significant enough to offer a corresponding option within first responder app systems. In addition, research is needed how to prevent information to spread or misconceptions to be developed and if this is an actual risk at all.

Around two-thirds of the participants agree that the help of first responders is especially valuable when many resources are deployed due to large-scale or mass-casualty incidents, for example. With the fifth question, we wanted to investigate the general acceptance level of first responder apps within German practitioners and domain experts. As expected, a vast majority agreed that first responder apps can play an important role. Still, a small percentage seem to not see a benefit of first responder apps. In future work, we aim to investigate the reasons for this disagreement to potentially develop countermeasures and/or further app improvements.

CONCLUSION AND OUTLOOK

Fast and timely information about what is happening on the scene is essential for emergency case management. This may include drone technologies and the rapid availability of drone images in the future, but also access to data from the smartphones of the people at the scene of the accident. In addition, feedback provided by citizens on the accuracy and relevance of alerts and warnings issued by authorities might be of value. While the population is already willing to make these data available via their mobile devices, it is just as important for the population to be asked for consent in this regard on a situational basis. This is in line with results from previous research by (Kaufhold et al., 2020).

Based on state of the art and existing technologies, services will be developed to involve in the population, such as volunteers, first responders but also simply feedback method to improve situational information for response personnel. The study revealed that most of the proposed services have been positively assessed both by professional services and citizens, which underlines the acceptance of these services among the relevant target groups. This shows that the ongoing development work as part of the SPELL project is “on the right track” and can provide added value to citizens and emergency managers. On the one hand, it increases the awareness of

disasters among the population, and, on the other hand, it increases the automated support of the emergency services.

The services to be developed will first be tested in one concrete use case within the project, with a focus on the most relevant use case for an application (e.g., train accident for the analysis of drone images, or forest fire for crowd-tasking apps). Subsequently, the transferability of the applications to other relevant use cases will be demonstrated. Finally, the demonstrators will be tested in the longer term in the everyday operation of at least one emergency control centre.

In addition, the systems will also be used in the area of preventive measures and follow-up measures. Reconstruction assistance and targeted support for the population in crisis situations can be improved, and help can be provided more quickly and in a more targeted manner. Every citizen can contribute to improving the situation in crises and disasters. Whether by providing feedback on an alert, participating in coordinated spontaneous assistance or as a first responder.

Through integration of the abovementioned services into the planned SPELL platform (a semantic platform for providing access to disaster-related data and to analytical application systems for such data), data can be better shared between organisations. This eliminates system discontinuities. In addition, it does not matter anymore which alert system or app is used e.g., for spontaneous responders, as the dashboard offers interoperability that allows different application systems to be addressed with the same purpose.

The focus is on decentralised networking of applications to ensure resilience and increase acceptance. In addition, an ano- and pseudonymisation procedure is being developed to exchange anonymised situation information, which repeatedly leads to obstacles in data exchange.

In the first step, the survey and evaluation focused on Germany. The next step is to analyse the actual situation in other countries and whether these concepts can be transferred or need to be adapted to local and cultural conditions.

With this study we were able to confirm that the services we designed so far within the project context are supported by domain experts, practitioners, and citizens alike. Besides being the bases for our future work, the results can also impact future international research in the area of disaster management.

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