A Design Theory for Spontaneous Volunteer Coordination Systems in Disaster Response

Hans Betke
Fraunhofer Institute for Open Communication Systems
hans.betke@fokus.fraunhofer.de

Martina Sperling
Paderborn University
martina.sperling@uni-paderborn.de

Guido Schryen
Paderborn University
guido.schryen@uni-paderborn.de

Stefan Sackmann
Martin-Luther-University Halle-Wittenberg
stefan.sackmann@wiwi.uni-halle.de

Abstract

Spontaneous volunteers have always played an important role in responding to major disasters. Over the last 20 years, social media and mobile devices have both increased their potential as key players in disaster management and changed the way they organize themselves. However, one main challenge, especially for public authorities and security organizations, is how to integrate such spontaneous volunteers into official disaster management activities to realize their potential. Since several IT systems for coordinating spontaneous volunteers have been proposed and first practical experiences as well as evaluations are already at hand, developing a comprehensive design theory for such IT systems is aim of this paper. The design theory presented is based on interviews and focus groups with practitioners and supported by literature. We illustrate the applicability and usefulness of the developed design theory/principles through an instantiation with the spontaneous volunteer coordination system KUBAS and first exercise results.

Keywords: disaster management, spontaneous volunteer, design theory, coordination system

1. Introduction

The work of spontaneous volunteers in crisis and disaster situations has always played an important role in limiting the impact of events and saving lives (Aguirre et al. 2016). They represent a large workforce and often can provide help while official responders have not yet arrived on site or are hindered by their vastness and lack of infrastructure (Whittaker et al. 2015). In many recent disasters, such as Hurricane Katrina or the 2013 European Flood, tens of thousands of spontaneous responders, self-coordinated by social media and mobile communication devices, have repeatedly gathered and participated in response efforts in a very short period directly after or during the event (Barraket et al. 2013, Thieken et al. 2016). Since the turn of the millennium, it has become apparent that the nature of volunteering is changing with a decrease of permanent engagement in agencies and organizations with security tasks (AOST) (Hustinx 2003).

Literature describes this type of volunteer as spontaneous, informal, unaffiliated or episodic (Basky 2013, Whittaker 2015, Hyde 2014). In this paper, we define spontaneous volunteers (SV) as civilians without affiliation to an AOST voluntarily supporting disaster and crisis response and recovery activities on-site with physical labor. Digital volunteers remain out of the scope of this paper. The large number of SV represents a great potential for AOST in managing the effects of disasters. In theory, efficient integration and coordination of SV can improve the quality of the response and contribute to saving lives and assets (Nielsen 2019). However, many AOST are hesitant to integrate SV into official activities because they fear various challenges and risks (Volunteer Florida 2005).

Fernandez et al. (2006b) have identified two main risks: The first risk involves the failure of AOST to effectively utilize and coordinate SV. AOSTs are often bureaucratic and resistant to change, which can lead to a reluctant or inadequate response to offers of assistance from SV (Daddoust et al. 2021). In this regard, a lack of guidelines, scheduling, and (mis)communication pose further challenges for utilizing the potential of SV resulting in SV working independently and in a self-coordinated manner (Larson 2004; Skar et al. 2016) which is not always effective and sometimes even dangerous. A second risk relates the liability and SV management issues with regard to the skills of untrained and uncoordinated volunteers (Fernandez et al. 2006a). According to Orloff (2011), there is uncertainty about liability due to the complexity of laws and protections

URI: https://hdl.handle.net/10125/106637
978-0-9981331-7-1

in place, which vary from country to country. To reduce these risks, recent research has focused intensively on how to coordinate and integrate SV in an efficient, effective, and structured way (Daddoust et al. 2021).

As digitalization is a major factor in the current events around SV, many approaches also propose the use of IT tools to address specific problems (e.g., Havlik et al. 2016, Kristikj et al. 2022, Sperling & Schryen 2022) or try to support the whole coordination process (e.g., Betke 2018., Fuchs Kittowski et al. 2018, Schimak et al. 2020). However, the growing number of focused approaches and (partial) IT solutions make it difficult for both theory and practice to develop IT-based systems that allow AOST to coordinate and communicate with SVs in both an effective and (time and resource-) efficient way. Although there are a lot of expectations, experiences, shortcomings, and solutions, they are not yet understood in a holistic manner. For example, there are approaches classifying organizational approaches to volunteer management (e.g., Schönböck et al. 2016) or different technical implementations of volunteer management systems (e.g., Mengistu and Che 2019). However, reality challenges building such systems, since we need to acknowledge that disaster situations, expectations of AOST and SVs, and coordination requirements can vary widely, resulting in a diversity of specifications for an information system to be designed, built, and deployed.

An established methodological solution can be found in design theory, some of whose existing information systems approaches are already being applied to the field of disaster management (e.g., Endsley et al. 2003), but which is also generating new approaches in the field (e.g., Sobiegalla et al. 2017). To our best knowledge, there is no state of the art solution for the development of "Spontaneous Volunteer Coordination Systems" (SVCS), focusing explicitly on the integration of SV into the activities of AOST and considering both user groups (spontaneous volunteers, disaster managers). Therefore, the aim of this paper is to provide a methodologically sound answer to the following research question:

RQ: *What are suitable design principles for the development of a digital spontaneous volunteer coordination system that supports both user groups in their coordination efforts?*

To derive design principles, the requirements of the user groups must be determined. So in this paper we present a design theory consisting of requirements and principles, the implementation of which is demonstrated in the SVCS KUBAS and evaluated in a disaster management exercise. The design theory represents a starting point for development but also the selection of suitable SVCS in practice and can also serve researchers in the field as a basis for the consideration of further application scenarios or analysis of best practices for instantiation.

The paper is organized as follows: In the next section, we present our research design. In Section 3, we present the design theory for SVCS. A first instantiation of the proposed design principles is presented in Section 4 using the SVCS "KUBAS". In Section 5, the results of the empirical evaluation of the KUBAS SVCS is discussed. The main findings and contributions of the presented research is concluded in Section 6.

2. Research Methodology

Design theories can be used to define design requirements (DRs) and design principles (DPs) for the design of a class of information systems (IS). While the DRs describe the general goals of the design theory and function as meta-requirements for a class of IS, the DPs provide abstract solution principles for addressing them (Baskerville and Pries-Heje 2010; Walls et al. 1992). Together, DRs and DPs embody a general design solution to a set of design problems that arise during the design of a class of IS (Baskerville and Pries-Heje 2010). DPs can be descriptive or prescriptive, with the latter specifying how an artefact should be instantiated to fulfill the DRs (Fu et al. 2016). To further specify the DPs, design features can be defined, which represent a possible set of technically oriented approaches to operationalize the DPs. Since design theories are functionally similar to reference architectures, the well-known benefits of reference architectures should also apply to design theories, i.e. reduced development time, reduced development risks, and improved collaboration through a better shared understanding of the problem domain (Cloutier et al. 2009; Martinez-Fernandez et al. 2015). With the development of a design theory in this paper, we aim to provide a generally applicable guideline for the creation of a SVCS. Since they are not necessary and can vary depending on the application context, we decided to omit design features (Baskerville and Pries-Heje 2010) and focus on DR and DP.

To develop our design theory, we used the method proposed by Möller et al. (2020). It is based on a structured literature review to derive best practices from existing approaches combined with epistemological foundations of the core design theory literature. The method prescribes a seven-step procedure. In the first step, a ***solution object*** **(S I)** should be formulated, in our case it is research question as stated in the introduction. The ***research context*** **(S II)** in our case is design science research in the context of a superordinate project to develop a SVCS that can be used in as broad an application context as possible. The next step is the ***choice of the research approach*** **(S III)**, where we follow a supportive approach, in which we want to develop a basic design knowledge as a conceptual foundation in advance of the implementation of the SVCS. From this point we started an iterative process with two iterations for which we used different ***knowledge bases*** **(S IV)**: The knowledge base for the first iteration was a group of 12 disaster managers who shared their expertise through an extended focus group interview. Participants included members of the fire department, red cross, as well as state and county disaster management from different German states. In the second iteration, 15 people who had already helped as SVs in a disaster situation were interviewed individually. The knowledge base of both iterations is supported by relevant literature from the field of disaster management. In both iterations, the ***elicitation of meta-requirements*** **(S V)**, referred to in this article as design requirements, was conducted directly during the focus group and the interviews, respectively, and were subsequently refined in the light of the literature. In the following, the ***formulation of the design principles*** **(S VI)** in both iterations also occurred directly in the focus group or interviews with subsequent consideration of the literature. The DP were also discussed in response to the DR with the respondents, but not in a way that allows direct attribution. The ***evaluation*** **(S VII)** of the design theory was also carried out in a multi-stage procedure. To demonstrate how an SVCS instance developed on the basis of the design principles could be constructed, we implemented a corresponding prototype called KUBAS. In addition, we conducted a disaster response exercise using the KUBAS system and surveyed both user groups to evaluate whether the DR were being met. A formal evaluation according to Gregory and Jones (2007) forms the final step of the evaluation.

Figure 1 provides a classification of our approach using the taxonomy developed by Möller et al. (2020) to describe instances of their method. The characteristics that apply to our paper are underlined and, if applicable, supported by numbers of participants or references.

Dimension	Characteristics				
Perspective	**Supportive**	Reflective			
Research Design	**DSR**	A(D)R	Qualitative	Case Study	
MR Source	**Literature** (23 ref.)	Theory	**Interviews** (15 part.)	**Workshop/ Focus groups** (12 part.)	None
DP Design	**Derived**	Extracted	Responsive		
Iterations	Single	**Multiple** (2 iterations)			
Evaluation	**Expert /User Feedback** (70 part.)	**Instantiation/ Field Testing**	Argumentation		
Formulation	**Free**	Based on Template			

Figure 1 - Classification of design principle development

3. Design Theory

3.1. Design Requirements

As an initial result of our SV interviews and disaster management focus groups, we propose the following four design requirements.

DR 1 - Efficiency: *The information system should enable the coordination of spontaneous volunteers as efficiently as or more efficiently than alternative methods.* One of the main expectations of the user groups for a systemic support in the coordinating of SVs is an increase in efficiency. On the disaster management side, existing processes for registering, managing, and matching SVs (e.g., citizen hotlines, manual lists) are often very resource-intensive and tie up a lot of manpower. On the SV side, people first must spend a lot of time networking and sometimes a lot of time searching for meaningful and reputable opportunities to help. An information system should therefore take advantage of automation to more quickly process and communicate both offers and official needs in the area of spontaneous volunteering (Sperling and Schryen 2022, Krstikj et al. 2022).

DR 2 - Effectiveness: *The information system should enable allocation of spontaneous volunteers to response sites as effectively as or more effectively than alternative methods.* Both user groups expect IT support to improve the quality of allocation. Given the large number of SVs and the correspondingly large amounts of information that must be processed in order to make meaningful use of this human resource, it is difficult to plan the optimal solution without specialized algorithms for disaster management. On the other hand, SVs want to be deployed to locations where they can provide the best possible support according to their capabilities. An information system should support the most effective allocation functions possible to avoid effects such as unnecessarily long travel times to response locations, overcrowded or understaffed locations, poorly deployed skills, etc. (Schönböck et al 2016, Havlik et al. 2016).

DR 3 - Inclusion: *The information system should be able to process a wide range of spontaneous assistance, both quantitatively and qualitatively.* Spontaneous responders often represent the entire spectrum of the population and bring a wide variety of capabilities, availability, and resources. Countless people are ready to help respond to major disasters. In order not to waste potential and to give everyone the opportunity to participate, an information system should be easily accessible and able to process the large amounts of data that are generated (Strandh 2019).

DR 4 - Information: *The information system should provide information and evaluation of spontaneous volunteer work.* In disaster management, an up-to-date picture of the situation is of paramount importance. Only with comprehensive and up-to-date information can decision-makers react to the dynamic events of a disaster and deploy the available resources in the best possible way or protect people and assets. As SV play an important role, disaster managers also need comprehensive information about ongoing and completed tasks to plan their response. At the same time, SV also want to be as informed as possible about the details of their assigned tasks and to be kept up to date (Schiemack et al 2020).

The design requirements identified here represent the main goals that should be pursued in the development of a SVCS. In the context of the method presented here, the requirements also served to guide the interviews and the focus group in deriving design principles, even if no direct correlation could be made in the results. As described above, the design principles were developed in a multi-stage process involving both user groups and the literature. The DPs presented here are the final results of this process.

The concept of DPs has repeatedly led to misunderstandings and to a lack of usefulness for the for the IS community. Gregor et al. (2020) have addressed this issue by providing a guideline for the development of comprehensive DPs. Thus, the DPs were formulated according to Gregor et al. (2020). However, we do not describe the *Context* and *Implementer* for each DP as they are always the same. In our approach, the Implementer is the developer of a coordination system for SVs and the context is disaster management. *Aim* **(A)**, *Mechanism* **(M)**, *Rationale* **(R),** and *Users* **(U)** are referenced in the description of each design principle.

3.2. Design Principles

DP 1 - Principle of Individual Offers: *The information system should provide the ability to create individual, spontaneous assistance offers of assistance based on defined parameters.* The crowd of SVs is composed of people from all population groups and is very diverse. Accordingly, the requirements and possibilities for providing spontaneous help are individual for each person **(R)**. To address the potential for help on a broad scale and to include a large user base **(A)**, SVs **(U)** should be able to create individual offers of help, which, at the same time, follow a certain structure or parameters in order to allow a targeted allocation **(M)** (Neubauer et al. 2013, Strandh 2019).

DP 2 - Principe of Customizable Tasks: *The information system should allow the creation of spontaneous volunteer tasks based on flexible parameters.* Disaster managers **(U)** are typically accustomed to planning the operations of official responders based on various parameters such as local information or available and necessary resources **(R)**. To ensure that the coordination and planning of spontaneous volunteer tasks fits well into familiar disaster management processes while remaining flexible enough to address the specifics of each disaster **(A)**, tasks should be created using predefined structures and parameters that can be adjusted as needed **(M)** (Betke 2018; Fuchs-Kittowski et al. 2018).

DP 3 - Principle of Decision Support: *The information system should support the assignment of spontaneous volunteers to appropriate tasks through (partially) automated decision support methods*. Thousands of SVs become active in large-scale disasters and want to assist in response **(R)**. To be able to process the large amount of information and to implement the offer of help into action quickly and effectively **(A)**, disaster managers **(U)** should be supported in their decision making by suitable optimization algorithms **(M)** (Sperling and Schryen 2022, Krstikj et al. 2022).

DP 4 - Principle of Communication Diversification: *The information system should allow the exchange of information through a variety of communication services.* SVs use all possible public communication channels (e.g. social networks, messengers, phone calls, etc.) to get information and find opportunities to help **(R)**. An information system with the ambition to broadly involve SVs **(A, U)** should make its services available through many different communication channels and offer corresponding interfaces. **(M)** (Nielsen 2019, Betke 2018).

DP 5 - Principle of Occupational Health and Safety: *The information system should include mechanisms to protect spontaneous volunteers from physical harm during their deployment.* When SVs are officially assigned to response tasks, coordinating AOSTs assume a responsibility for them and must ensure that they are not harmed by or during their work (e.g., due to overwork, supply deficiencies, hazardous locations, etc.) **(R)**. An information system should help minimize potential hazards **(A)** by providing appropriate work safety features (e.g., alerts, assignment restrictions) **(M)** for both SVs and disaster managers **(U)** (Fernandez et al. 2006b, Whittaker et al. 2015).

DP 6 - Principle of Knowledge: *The information system should provide the knowledge needed to perform spontaneous volunteer tasks.* In disaster response, even seemingly simple tasks such as stacking a sandbag dam often require specific basic knowledge to perform the activity effectively and efficiently. In addition, integration into AOST command and control structures can be difficult for SVs without prior knowledge **(R)**. To enable spontaneous **(U)** volunteers to perform their assigned tasks in the best possible way **(A)**, the information system should have functions that provide the individually required knowledge about the processes and structures of disaster response **(M)** (Whittaker 2015, Daddoust et al. 2021).

DP 7 - Principle of Monitoring: *The information system should allow monitoring of ongoing spontaneous volunteer tasks by disaster managers.* A good overview of the current situation is of utmost importance, as conditions can change quickly and require immediate responses to protect lives and assets. SVs are at the same time an important resource and vulnerable subjects **(R)**, so an information system should provide disaster managers **(U)** with comprehensive monitoring and analysis functions **(M)** to maintain a high level of information about the current SV situation **(A)** (Neubauer et al. 2013, Schönböck et al. 2016).

DP 8 - Principle of Logging: *The information system should allow for the srecording and subsequent evaluation of all spontaneous volunteer tasks.* In the aftermath of a disaster event, the evaluation of the coping measures implemented plays an important role in preparing for future situations. In some countries, SVs may also be able to make claims against the AOSTs on whose behalf they have acted (e.g., in the case of an insurance claim or for expenses) **(R)**. To enable analysis of past events **(A)**, the information system should record all relevant information on SV coordination and make it available in an easily processable manner **(M)** to the responsible disaster managers, as well as individually to each SV **(U)** (Fuchs-Kittowski et al 2018).

DP 9 - Principle of data economy: *The information system should minimize the necessary data exchange.* During disasters, the communications infrastructure is often under particular strain due to changes in usage behavior or damage. The individual coordination of many SVs also leads to a high communication volume and is dependent on a functioning information exchange **(R)**. In order to minimize the load on the communication infrastructure caused by the coordination of SVs **(A)**, an information system should make the exchange of information between the two user groups **(U)** as efficient as possible and collect only the data that are highly relevant for coordination **(M)** (Patricelli et al 2009).

DP 10 - Principle of Scalability: *The information system should be able to perform well regardless of the current workload.* Disasters can rarely be predicted, and even when, it is not clear in advance to what extent the supply of SV help will be available. In quiet times, a SVCS is not needed and may be completely shut down, but it must be quickly ramped up if necessary and provide its services consistently in real time, even if the user base and the corresponding input from SVs grows rapidly in a short period of time **(R)**. In order to work reliably for both user groups **(U)** even under spontaneous load, and to consume few resources during quiet times **(A)**, an information system should use scalable algorithms and server infrastructure **(M)** (Daddoust et al 2021).

DP 11 - Principle of Integration: *The information system should be able to integrate its services with existing disaster management software.* Depending on the organization and agency, different information systems are usually already in use in disaster management to assist with key disaster management tasks and to contain all the necessary information. Disaster managers **(U)** are familiar with these systems through training and previous experience, and the introduction of new software can be difficult and time-consuming **(R)**. To lower the learning curve and provide the most homogeneous user experience **(A)**, an information system should provide or support APIs that allow integration of SV coordination services into the interfaces of established disaster management software **(M)** (Schimack et al 2020).

DP 12 - Principle of Simplicity: *The information system should provide efficient and barrier free user interfaces.* As described above, SVs **(U)** often represent the entire spectrum of the population, so that users have very different prerequisites in terms of language, education, physical and mental abilities **(R)**. To ensure that as many people as possible can use the information system's services without encountering barriers **(A)**, user interfaces should be simple, service-oriented, and developed using universal design methods **(M)** (Havlik et al. 2016).

4. Instantiation of System Demonstrator

As described in our research methodology we evaluate the design theory in three steps, where the first step is the instantiation of a volunteer coordination system called "KUBAS" according to the design principles. In this chapter we describe the architecture and relevant features of the system and explain how the design principles were addressed.

The KUBAS system consists of a backend with functions for storing and managing SV offers and tasks, as well as their mutual assignment, and two very different frontends for the two user groups of SVs and disaster managers (see Figure 2).

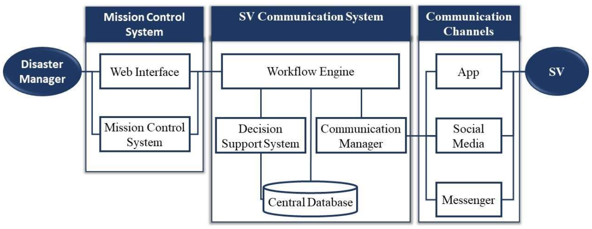

Figure 2 – KUBAS-demonstrator system architecture

Volunteers have more than one way to interact with the system **(DP 4, DP 12)**. They have both an app for mobile devices and a task-oriented chatbot that can be integrated into various messaging systems (see Figure 3). Both interfaces are used to create offers of assistance, alerts and notifications for assigned tasks, and information about the situation. Volunteers can specify one or more offers based on three parameters: location, time availability and capabilities (selection from 6 general capabilities). This solution is a compromise between being able to create offers quickly and with little data, while allowing individual specifications and not excluding anyone by being too specific **(DP 1, DP 9, DP 12)**. When a suitable task is found for a SV, he/she receives an alert with the basic information and the possibility to confirm or cancel. In case of a commitment, further information about the task (e.g. on how to get there, contact person), concrete instructions on how to perform the task (as text, image or link) can be retrieved, and the SV receives up-to-date messages (e.g. about imminent dangers or the end of his working hours) **(DP 5, DP 6)**. Information on any past, present or future task can be stored and viewed on the mobile application for an unlimited period of time **(DP 8).**

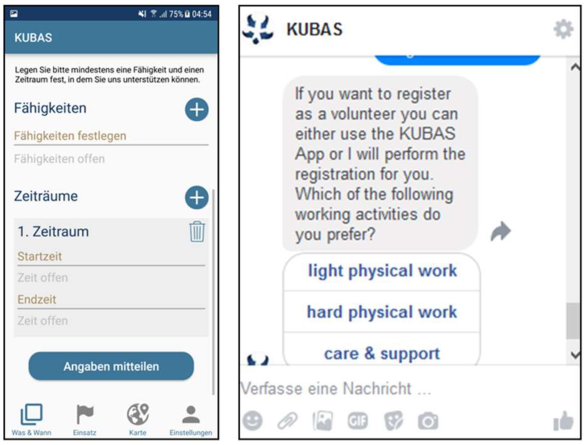

Figure 3 – Screenshots from SV user interface (mobile-app & chatbot) of KUBAS-demonstrator

Disaster managers can also choose between different interfaces. On the one hand, the KUBAS system provides its own web interface, the Task Manager (see Figure 4), which allows the creation, monitoring and evaluation of SV tasks, as well as an overview of the overall situation. On the other hand, the system provides an API to integrate all these functions into existing disaster management systems. In the context of our demonstrator, we have made this connection to the operational command system DISMA, which is used in our region. The creation of volunteer tasks is based on various parameters, such as location, meeting point, start and end time, priority and the required number of SVs per activity to be performed. In addition, further information such as instructions for the execution, contact person or possibly required equipment needed can be specified **(DP 2, DP 6)**. Once created, tasks can be viewed at any time, with additional real-time information such as the number of SVs assigned to each activity and their current status (e.g. alerted, committed, on site, completed, canceled). This information is stored even after the task has been completed and can be viewed for later evaluation **(DP8)**. In addition, there is a complete situation map and dashboard, which provides an overview of the overall status regarding SVs. **(DP7)**.

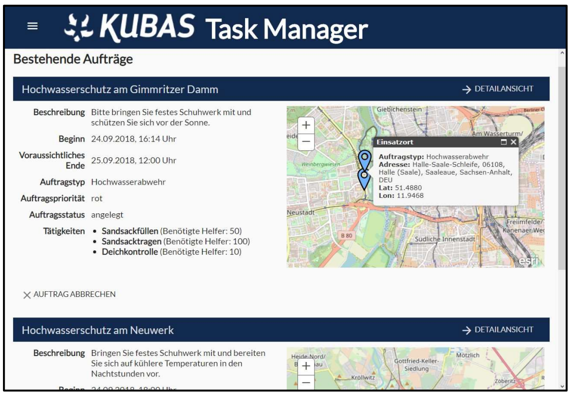

Figure 4 – Screenshot from disaster management user interface of KUBAS-demonstrator

The backend consists of four core modules. The database stores all incoming SV offers and tasks with associated status updates for processing and later evaluation **(DP 8)**. The decision support module uses special operations research methods to determine the optimal assignment of volunteers to available tasks. It takes into account not only the individual parameters of the offers and tasks taken, but also additional constraints, such as on the even distribution of workers for longer tasks or on occupational health and safety (e.g., maximum working hours) **(DP 3, DP 5)**. The Communications Manager manages the system's information exchange with the SVs. Since they can interact with the system through different communication services, the information transmitted must be prepared accordingly in both directions, so that this module includes, among other things, several APIs and a natural language processing component for communication via messenger and social media **(DP 4, DP 12)**. The central module is a workflow engine that controls system functions via individual processes. This process orientation improves the scalability of the system, since many process instances run in parallel and can be handled in their own threats by a suitable server infrastructure **(DP9)**.

5. Evaluation Findings

Now that we have shown in the first step of the evaluation that and how the design principles can be addressed in an exemplary way in an instantiated information system, the second step follows with the collection of user feedback.

For this purpose, we conducted a disaster management exercise using the KUBAS demonstrator. In this exercise we used the scenario of a flood situation of the local river Saale in the urban area of the city of Halle (Saale) (>200.000 inhabitants) together with various local AOSTs. In the past, the city has often been affected by major flood events (most recently in 2013), so a lot of experience exists on this scenario, including in relation to the involvement of SVs. Over the course of 8 hours, the AOSTs simulated various response sites for SVs at six different locations throughout the city. SVs (n = 70) were actual residents who agreed to participate in the exercise. Since Halle (Saale) is a university town, over half (n = 36) of the SVs were university students 25 years of age or younger; the remaining volunteers had very different demographics, with 37 participating females and the rest males. 19 people had already helped in a disaster as SVs. Disaster management users (n = 4) were provided by local disaster management agency staff with appropriate qualifications on disaster management but little prior knowledge of the KUBAS demonstrator. During the exercise, volunteers could receive information on the development of the disaster situation created by experienced training supervisors either "traditional" via city website and social media or the KUBAS demonstrator. The volunteers were free to choose their information system according to their preferences (57 KUBAS/ 13 traditional) and were not bound to any exercise script, so they could also choose which tasks they would go to. At the end of the exercise, the experience of the participants was evaluated by means of a questionnaire for the SVs and a group interview for the disaster managers. The main findings from of both user groups are presented below.

5.1. Quantitative Results (SV)

The questionnaire for SVs contained various statements on the perception of coordination and the coordination tools used (KUBAS system / Facebook & website). The statements were rated by the participants on a 5-point Likert scale from strongly disagree (1) to strongly agree (5). The evaluation of the statements related to the design requirements is presented below as well as frequent comments from respondents.

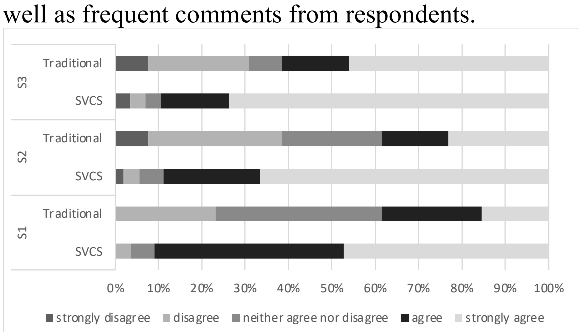

Figure 5 – Evaluation results for DR 1-Efficiency

DR 1 – Efficiency: To evaluate the efficiency of the SVCS in comparison with traditional calls for volunteers we chose three statements: **(S1)** *I knew exactly where my assigned tasks would take place*; **(S2)** *I knew exactly when I was supposed to be at the response site*; **(S3)** *The allocation process took little time*. As can be seen in Figure 5 from the relative frequencies, the approval ratings for the SVCS are higher than for the traditional information channels in all three statements. We therefore assume that the DPs are suitable to fulfill DR 1.

DR 2 – Effectiveness: We chose the two statements: *My selected coordination application has supported me very well in coordinating my activity as a spontaneous volunteer* **(S4)**; *I am very satisfied with the coordination related to my activity as a spontaneous volunteer* **(S5)** to assess how respondents rate the effectiveness of coordination. The relative frequencies in Figure 6 show that satisfaction is rated higher when using SVCS by which we consider DR 2 to be fulfilled. It is worth mentioning that S4 does not receive full approval from a single person of the traditional information providers.

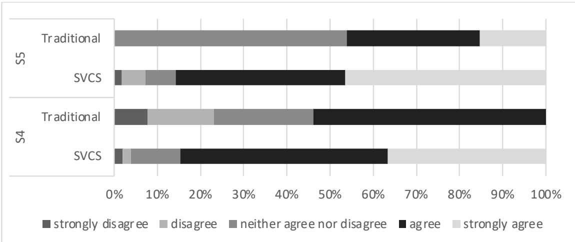

Figure 6 – Evaluation results for DR2-Effectiveness

DR 3 – Inclusion: With the three statements: *I find the coordination application easy to use* **(S6)**; *I imagine most people will learn to master the application quickly* **(S7)**, *I would recommend the application for future spontaneous volunteering* **(S8)**, we want to evaluate how respondents perceive the barriers to using the coordination tools. Again, based on the relative frequencies of the agreement scores (Figure 7) in favor of SVCS, it can be concluded that DR 3 is met.

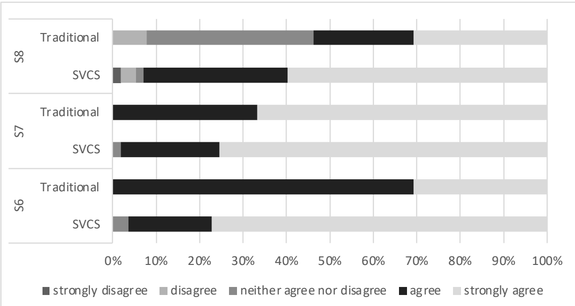

Figure 7 – Evaluation results for DR 3-Inclusion

DR 4 – Information: The final DR was evaluated using the following statements: *I knew exactly what activity I should perform* **(S9)**, *Thanks to the information provided, I was able to reach the response site quickly*

(**S10**), *I receive unnecessary information through the coordination tool* (**S11**). Figure 8 shows that the approval rates for S9 and S10 are in favor of SVCS, but for S11 they are nearly similar.

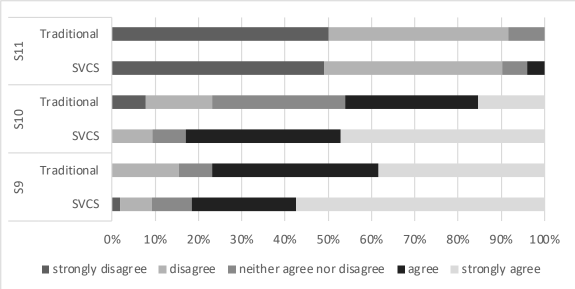

Figure 8 – Evaluation results for DR 4-Information

5.2 Qualitative Results (Disaster Management)

After the evaluation of the SV indicates that an SVCS developed based on the DP is suitable to meet the DR, we consider the second user group. A group interview was conducted with the four disaster managers who operated the SVCS to receive qualitative feedback. Among others we asked four questions related to the design requirements. The most significant statements on these questions are presented below.

Question on DR 1: *How did you perceive the efficiency of the SVCS in general and compared to approaches in previous situations?* The efficiency was perceived as very positive by the respondents. In particular, the greatly reduced effort required for the selection of suitable SVs and to alert them through automated communication was praised, compared to the usual use of a hotline and the working time required for this. The quick creation of the volunteer tasks was also positively mentioned. It was critically noted that the system features mainly support allocation and monitoring of SVs, while other tasks related to coordination, such as supplying SVs, are not supported. This leads to system discontinuities in processes, potentially creating inefficiencies.

Questions on DR 2: *How did you perceive the effectivity of the SVCS in general and compared to approaches in previous situations?* The effectiveness was also perceived positively across the board. Disaster managers assume that SVs suitably selected using decision support algorithms will impact effectiveness at the scene. They also praised the fact that only the number of SVs showed up that was needed. The provision of information on performing the activities was also highlighted positively, as it means that the SVs are better prepared, and the official responders can spend less time on briefing and more on response activities. It was noted that impacts on the effectiveness of processing volunteer tasks can only be evaluated by field personnel.

Questions on DR 3: *How did you perceive the SVCS's ability to process a qualitatively and quantitatively wide range of spontaneous help in general and in comparison to approaches in previous situations?* Disaster managers praised the ability to consider individual parameters for each volunteer opportunity and the accompanying ability to incorporate many different people. Quantitatively, an improvement over the previous approach is also assumed, since, for example, fewer people lose motivation due to long waits at the hotline and the assignment algorithm more reliably ensures that SVs rotate in processing tasks.

Questions on DR 4: *How did you perceive the ability of the SVCS to inform about and evaluate spontaneous volunteer work in general and in relation to approaches in previous situations?* The disaster managers particularly emphasized the automatically guided situation map and the overview of the status of the individual volunteer tasks as helpful. Two respondents expressed privacy concerns with individual tracking of SVs during their engagement. The ability to pass on relevant information to the SVs in the course of their alerting was also perceived as positive, as the official task forces can now assume a uniform level of information among the SVs.

5.3 Formal Evaluation

Table 1 – Formal evaluation following Gregor and Jones (2007)

Component	Description
Purpose and scope	The goals of a spontaneous volunteer coordination system are: DR 1 – Coordination of spontaneous volunteers as efficiently or more efficiently than alternative methods; DR 2 – Allocation of spontaneous volunteers to response sites as effectively or more effectively than alternative methods; DR 3 - Processing of a wide range of spontaneous assistance, both quantitatively and qualitatively; DR 4 – Provision of information and evaluation of spontaneous volunteer work.
Constructs	Volunteer Coordination System, Spontaneous Volunteer, Disaster Manager, Volunteer Task, Task Assignment
Principles of form and function	DP 1 - Principe of Individual Offers, DP 2 - Principe of Customizable Tasks, DP 3 - Principle of Decision Support, DP 4 - Principle of Communication Diversification, DP 5 - Principle of Occupational Health and Safety, DP 6 - Principle of Knowledge, DP 7 - Principle of Monitoring, DP 8 - Principle of Logging, DP 9 - Principle of data economy, DP 10 - Principle of Scalability, DP 11 - Principle of Integration, DP 12 - Principle of Simplicity
Artifact mutability	The design theory can easily be extended to include more requirements and principles. The level of Design Features was not considered in the approach presented here and can be added to the Design Theory when best practices have emerged after several successful implementations. The previous elements are designed so that developers are not bound to specific technologies when instantiating in an information system and have a lot of freedom to react flexibly to the application context or technical advances.
Testable propo-sitions	By means of a comparison test to the previous situation, it can be tested whether an instantiated information system fulfills the task of coordinating spontaneous volunteers better. Suitable measures are, for example, the perceived usefulness or the time and resources required for coordination.
Justifica-tory know-ledge	The design theory was developed based on interviews and focus groups with the user groups of their instantiated information systems using scientific best practices in design science and supported with literature.

In addition to the empirical evaluation, we formally evaluated the quality of the design theory using the framework proposed by Gregor and Jones (2007), which defines six mandatory and two optional components that a design theory should contain. Table 1 shows how our design theory addresses all core components of the framework and provides corresponding explanations. The optional components are not presented because they do not fit the chosen level of abstraction of the design theory presented here.

6. Conclusion

We presented the results of the methodological development of a design theory for the development of coordination systems for SVs in disaster situations. As main contribution, we propose 4 design requirements and 12 design principles. We demonstrated the feasibility of our DPs by instantiating them in an evaluated software prototype. Through a field test and evaluation with the participation of SVs and disaster managers, we were able to show that the design theory can contribute to the development of software systems that meet the requirements and have positive impact on the current situation in disaster management practice.

However, some existing limitations should also be considered when interpreting and using the results. A common weakness of any design theory is the subjectivity of design decisions. Although the definition of DRs and DPs in this paper is based on interviews and focus groups with both user groups, theoretically supported by the literature, and complemented by existing design knowledge, the conceptualization of our design theory is characterized by subjective influences. However, this is consistent with the design science philosophy of seeking useful, not necessarily optimal, solutions (Hevner et al., 2004). In addition, the formulation of our design theory is influenced by the methodological guidance provided by Gregor and Jones (2007). Another typical limitation is the selection of participants for the interviews and focus groups to build the design theory. We addressed this limitation by including both user groups in the form of SVs who have been active in past situations, as well as disaster managers with training and field experience in coordinating SVs. The number and composition of participants in the field test evaluation may also subjectively influence the results. The thousands of SVs who typically participate in disaster response were not available for the exercise conducted. However, since the main objective of the exercise was to verify, through user feedback, whether the requirements for a SVCS can be met by a prototype developed on the basis of the DP, we believe that we will be able to achieve practice-relevant results with the available sample size.

Our design theory contributes to the theoretical foundations of information systems research and helps expand the knowledge base of the field. In contrast to many other approaches that tend to propose concrete processes or systems (e.g. Batard et al. 2019, Betke et al. 2018), our approach offers a more abstract view and focuses on the design principles and requirements, while the instantiation in the KUBAS system serves only the evaluation. Thus, it provides a theoretical framework on which further research and development in the field can build, e.g., with regard to technological and organizational innovation, and to extend the applicability of the design theory to new contexts. Practitioners can use the results as a starting point for developing their own coordination systems or for evaluating existing solutions for their purposes.

This research is part of the overarching design science project KatHelfer-PRO. In future work, the design theory will be extended to include the level of design features, taking into account existing approaches from the scientific state of the art. We will also present a taxonomy to classify existing and new approaches.

7. References

Aguirre, B. E., Macias-Medrano, J., Batista-Silva, J. L., Chikoto, G. L., Jett, Q. R. and Jones-Lungo, K.(Hg.) (2016). The Palgrave Handbook of Volunteering, Civic Participation, and Nonprofit Association, Palgrave Macmillan, London.

Barraket, J., Keast, R. Newton, C. Walters, K. and James, E. (2013). Spontaneous Volunteering During Natural Disasters. Working Paper No. ACPNS 61, Queensland University of Technology, Brisbane.

Barsky, L. E., Trainor, J. E., Torres, M. R. and Aguirre, B. E. (2007). Managing volunteers: FEMA's Urban Search and Rescue programme and interactions with unaffiliated responders in disaster response. Disasters 31(4), 495–507.

Baskerville, R. and Pries-Heje, J. (2010). Explanatory Design Theory. Business & Information Systems Engineering, 2(5), 271–282.

Batard, R., Montarnal, A., Bénaben, F., Rizza, C., Prieur, C., and Tapia, A. (2019). Integrating citizen initiatives in a technological platform for collaborative crisis management. Proceedings of the 16th ISCRAM Conference, Valencia, Spain.

Betke, H. (2018). A Volunteer Coordination System Approach for Crisis Committees. Proceedings of the 15th ISCRAM Conference, Rochester, USA.

Cloutier, Robert; Muller, Gerrit; Verma, Dinesh; Nilchiani, Roshanak; Hole, Eirik; Bone, Mary (2009). The Concept of Reference Architectures. Business & Information Systems Engineering, 2(2), 14-27.

Daddoust, L., Asgary, A., McBey, K. J., Elliott, S. and Normand, A. (2021). Spontaneous volunteer coordination during disasters and emergencies: Opportunities, challenges, and risks. International Journal of Disaster Risk Reduction, 65, 102546.

Endsley, M. R., Bolté, B., & Jones, D. G. (2003). Designing for situation awareness: An approach to user-centered design. CRC press.

Fernandez, L., Barbera, J. and van Dorp, J. (2006a). Strategies for Managing Volunteers during Incident Response: A Systems Approach 2006. Homeland Security Affairs, 2(3).

Fernandez, L, Barbera, J. and van Dorp, J. (2006b). Spontaneous volunteer response to disasters: The benefits and consequences of good intentions. Journal of Emergency Management, 4(5), 57-68.

Fu, Katherine K.; Yang, Maria C.; Wood, Kristin L. (2016). Design Principles. Literature Review, Analysis, and Future Directions. Journal of Mechanical Design 138 (10), 101103.

Fuchs-Kittowski, F., Jendreck, M., Meissen, U., Rösler, M., Lukau, E., Pfennigschmidt, S. and Hardt, M. (2018). ENSURE-Integration of volunteers in disaster management, Environmental Software Systems. Computer Science for Environmental Protection: 12th IFIP WG 5.11 International Symposium, ISESS 2017, Zadar, Croatia, Proceedings, 247-262.

Gregor, S., Chandra Kruse, L., & Seidel, S. (2020). Research perspectives: the anatomy of a design principle. Association for Information Systems.

Gregor, S., & Jones, D. (2007). The Anatomy of a Design Theory. Journal of the Association for Information Systems, 8(5), 312–335.

Havlik, D., Pielorz, J., and Widera, A. (2016). Interaction with citizens experiments: from context-aware alerting to crowdtasking. Proceedings of the ISCRAM 2016 Conference, Rio de Janeiro, Brazil.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. MIS quarterly, 28 (1), 75–105.

Hustinx, L. (2003). Collective and Reflexive Styles of Volunteering: A Sociological Modernization Perspective. VOLUNTAS: International Journal of Voluntary and Nonprofit Organizations, 14(2), 167–187.

Hyde, M. K., Dunn, J., Scuffham, P. A. and Chambers, S. K. (2014). A systematic review of episodic volunteering in public health and other contexts. BMC public health, 14, 1-16.

Krstikj, A., Contreras Ruiz Esparza, M. G., Mora-Vargas, J., and Hervert Escobar, L. (2022). Volunteers in Lockdowns: Decision Support Tool for Allocation of Volunteers During a Lockdown, Humanitarian Logistics from the Disaster Risk Reduction Perspective: Theory and Applications, 429-446, Springer International Publishing.

Larson, L. (2004). Volunteers: help in plain sight. Trustee: the journal for hospital governing boards, 57(8) 6-10.

Nielsen, L. R. (2019). Embracing and integrating spontaneous volunteers in emergency response – A climate related incident in Denmark. Safety Science, 120, 897–905.

Martinez-Fernandez, Silverio; Medeiros Dos Santos, Paulo Sergio; Ayala, Claudia P.; Franch, Xavier; Travassos, Guilherme H. (2015). Aggregating Empirical Evidence about the Benefits and Drawbacks of Software Reference Architectures. In: ESEM. ACM/IEEE International Symposium on Empirical Software Engineering and Measurement. Beijing, China, 22-23 Oct. 2015, 1–10.

Mengistu, T. M., and Che, D. (2019). Survey and taxonomy of volunteer computing. ACM Computing Surveys (CSUR), 52(3), 1-35.

Möller, F., Guggenberger, T. M., & Otto, B. (2020). Towards a method for design principle development in information systems. In Designing for Digital Transformation. Co-Creating Services with Citizens and Industry: 15th International Conference on Design Science Research in Information Systems and Technology, DESRIST 2020, Proceedings, 208-220

Neubauer, G., Nowak, A., Jager, B., Kloyber, C., Flachberger, C., Foitik, G., & Schimak, G. (2013). Crowdtasking–a new concept for volunteer management in disaster relief. In: Environmental Software Systems. Fostering Information Sharing: 10th IFIP WG 5.11 International Symposium, ISESS 2013, 345-356.

Orloff, L. (2011). Managing spontaneous community volunteers in disasters: a field manual, CRC Press, Boca Raton, Fla.

Patricelli, F., Beakley, J. E., Carnevale, A., Tarabochia, M., & Von Lubitz, D. K. (2009). Disaster management and mitigation: the telecommunications infrastructure. Disasters, 33(1), 23-37.

Schimak, G., Ignjatović, D., Vullings, E. and Sammels, M. (2020). Interoperability of Solutions in a Crisis Management Environment Showcased in Trial-Austria, Athanasiadis, I., Frysinger, S., Schimak, G., Knibbe, W. (eds) Environmental Software Systems. Data Science in Action. ISESS 2020. IFIP Advances in Information and Communication Technology, 554.

Schönböck, J., Raab, M , Altmann, J., Kapsammer, E., Kusel, A., Pröll, B., Retschitzegger, W. and Schwinger, W. (2016). A survey on volunteer management systems. 49th Hawaii International Conference on System Sciences (HICSS), 767-776.

Sobiegalla, F., Posegga, O., and Fischbach, K. (2016). Connecting Disaster Volunteers and Relief Organizations: A Design Science Approach. 37th International Conference on Information Systems

Sperling, M. and Schryen, G. (2022). Decision support for disaster relief: Coordinating spontaneous volunteers. European Journal of Operational Research, 299(2), 690-705.

Strandh, V. (2019). Crisis volunteerism is the new black?—Exploring the diversity of voluntary engagement in crisis management. Risk, Hazards & Crisis in Public Policy, 10(3), 311-331.

Skar, M., Sydnes, M. and Sydnes, A. K (2016). Integrating unorganized volunteers in emergency response management. International Journal of Emergency Services, 5(1), 52–65.

Thieken, A.H., Kienzler, S., Kreibich, H., Kuhlicke, C., Kunz, M., Mühr, B., Müller, M., Otto, A., Petrow, T., Pisi, S. and Schröter, K. (2016). Review of the flood risk management system in Germany after the major flood in 2013. Ecology and society, 21(2).

Volunteer Florida (2005). Unaffiliated Volunteers in Response and Recovery. Online accessed on 12.03.2023 via: https://www.volunteerflorida.org/wp-content/uploads/2013/03/UnaffiliatedVolunteers.pdf

Walls, Joseph G.; Widmeyer, George R.; El Sawy, Omar A. (1992). Building an Information System Design Theory for Vigilant EIS. Information Systems Research, 3(1), 36–59.

Whittaker, J. McLennan, B. and Handmer, J. (2015). A review of informal volunteerism in emergencies and disasters: Definition, opportunities and challenges. International Journal of Disaster Risk Reduction, 13, 358-368