RESEARCH

Christian Reuter

Emergent Collaboration Infrastructures

Technology Design for Inter-Organizational Crisis Management

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Technology Design for Inter-Organizational Crisis Management

Foreword by Prof. Dr. Volkmar Pipek
and Prof. Dr. Volker Wulf

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Christian Reuter
Siegen, Germany

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Foreword

Christian Reuter's PhD thesis deals with the research on software infrastructures for emergent collaboration. Over the past 4 years, Christian has carefully analyzed collaborative work in inter-organizational crisis management – such as the police, fire departments and energy network operators – in order to inform the design of supportive technology in these contexts.

The dissertation explores most excellently the challenges facing and the opportunities arising for technology design in emergent environments. The characteristics of the application field "crisis management" (e.g. time pressure, uncertainty, complexity, need for collaboration, disruption of infrastructure support) offered a rich problem space. They resemble the dynamics of many other fields of business dealing with complex collaborative tasks in unstable settings. The utilization of classical empirical methods in this field is much more complex. Both the empirical results with regard to the (improvisational) work practices, which sometimes complement official work processes, as well as the related design case studies showed interesting findings for the field of Computer Supported Collaborative Work (CSCW).

This thesis contributes not only to the identification of collaboration practices that reveal work infrastructure limitations but also to the design of novel concepts and artifacts towards enabling emergent collaboration as well as to the discovery of potential organizational effects on the ability to deal with emergence. Furthermore, it provides methodological implications for technology design. These can help to improve the process of infrastructuring generally, but also specifically to design emergent infrastructures such as tools and systems for emergency management. The designed, implemented and evaluated applications ISAC, MoCo and MoRep illustrated different aspects: they allow inter-organizational self-organized aggregation, visualization and exchange of geo-referenced information resources (ISAC); they provide the possibility to integrate actors ad hoc with different locations, organizations and devices in situation assessment (MoCo); and they offer the possibility to articulate information needs, such as pictures or textual information, to forces on site (MoRep).

Christian Reuter's dissertation presents outstanding work in targeting the methodological challenges in a difficult research context, and in connecting a macro perspective on inter-organizational crisis management with a micro perspective on the actions and processes of individuals. It provides examples and insights for usable collaboration technology in a setting, which places improvisation above process while maintaining a high level of responsibility. The methodological implication – to analyze dimensions of infrastructure use and not just individual use breakdowns – might well help to address existing constraints in emergent technology use. This work connects and consolidates research discourses in CSCW, HCI and IS, which have also been addressed in more than 40 publications arising in the context of this thesis. Based on its action research methodology, these results also provide examples for practitioners as well as software developers in similar complex environments.

Prof. Dr. Volkmar Pipek

Prof. Dr. Volker Wulf

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This dissertation describes my research activities from 2010 to 2014 at the Institute for Information Systems at the University of Siegen. These activities were carried out in the course of different projects: Firstly, during my PhD scholarship at the Research School of Business and Economics (2010-2013). Secondly, as part of the joint research project *InfoStrom* on information infrastructures for crisis management (2010-2013), funded by the German Federal Ministry for Education and Research (No. 13N10712). Lastly, during the project *EmerGent* on social media in emergency management (2014), funded by the European Union Framework Programme for Research and Technological Development (No. 608352).

This work would not have been possible without others. With deep gratitude, I would like to thank my doctoral advisor *Prof. Dr. Volkmar Pipek* for our discussions and his supportive guidance in the research field. I also would like to thank my co-advisor *Prof. Dr. Volker Wulf* for his helpful support and *Prof. Dr. Petra Moog* who kindly agreed to join the doctoral committee.

Furthermore, I am grateful to my InfoStrom colleagues *Benedikt Ley*, *Thomas Ludwig* and *Torben Wiedenhoefer* with whom I cooperatively executed a large part of my research allowing me to study emergent collaboration infrastructures. I also like to thank my colleagues at the institute, especially *Dr. Dave Randall* for his advice, and the research school, especially *Désirée Christofzik*, as well as my (former) students, especially *Oliver Heger*, *Marc-André Kaufhold*, *Alexandra Marx*, *Michael Ritzkatis* and *Tim Siebigteroth*, who contributed in several ways to this thesis, for example by practical work leading to the realization of concepts, joint research, co-authorship or proof-reading of publications.

Among the afore-mentioned colleagues, I would particularly like to thank the co-authors of my journal articles and conference papers, which form part of this thesis, for the fruitful collaboration and for their contribution to the work. Moreover, I would like to thank the participants in my empirical studies, especially from the police and fire departments as well as the energy network provider in the districts Siegen-Wittgenstein and Rhein-Erft, who patiently allowed me to conduct interviews and observations at their workplaces, and who participated in discussions and evaluated designed ICT artifacts.

Finally, I would like to thank my parents, my family and friends, and most especially my wife *Lena* and our daughter *Julina Leonie* for their support throughout this exciting adventure.

Christian Reuter

Abstract

The complexity and interconnectedness of current working environments encourages organizations, businesses and individuals to collaborate beyond spatial, temporal as well as organizational boundaries. These collaborations are potentially supported by *information and communication technology* (ICT) among mobile and ubiquitous systems. The academic field *Computer-Supported Cooperative Work* (CSCW) is primarily recognized for focusing on ICT support for collaboration *practices* as opposed to the computerizing of *formal procedures*. ICT, in this view, needs to reflect the dynamic nature of cooperation and collaboration. The notion *emergence* as coined by Lewes (1875) and interpreted by Goldstein (1999) refers to dynamic contexts that cannot be anticipated in their full extent before they actually occur. *Emergent collaboration* refers to the need for spontaneous collaboration in novel and changing structures and occurs in application fields such as inter-organizational crisis and emergency management, which by definition contain the unforeseeable.

This dissertation contributes to research into *infrastructures for emergent collaboration*. Using the example of crisis management, it addresses (1) emergent collaboration practices and how they reveal work infrastructure limitations, (2) novel concepts and artifacts to support emergent collaboration, (3) their effects on the ability to deal with emergent situations and (4) methodological implications for technology design for emergent collaboration infrastructures in inter-organizational settings.

Design case studies (Wulf et al., 2011), inspired by *action research* (Lewin, 1958) and following Hevner and Chatterjee's suggestion (2010) to integrate action research with *design research,* are applied as a practice oriented research method. They contain three phases: an empirical analysis of the practices in the field, the development of innovative ICT artifacts with continuous participation of end-users related to the empirical findings and the evaluation of their appropriation (Pipek, 2005) in practice. In the case reported here, the empirical study on emergent collaboration by police and fire services, aid agencies, energy network operators and citizens in emergencies in two counties in Germany outlined the importance of improvisation work in situation assessment as well as mobile collaboration and reporting practices. The ICT design aimed towards the support of these emergent practices, illustrated by various concepts and prototypes. They comprise (1) an inter-organizational social network for emergency management (SiRena), (2) an inter-organizational situation assessment client (ISAC) as well as mobile applications for (3) the ad hoc participation in mobile collaboration (MoCo) and (4) the articulation of information needs in mobile reporting (MoRep).

Based on the empirical, technical and practical findings, the subsequent analysis uses the concept of *infrastructuring* (Pipek & Wulf, 2009), the integrated perspective on the design and use of information systems, and derives implications for emergent collaboration infrastructures, which contribute overall to the academic fields CSCW, *Human Computer Interaction* (HCI) and *Information Systems* (IS).

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Publications of the Author

Some parts of this thesis have already been pre-published as articles. In sum, 42 publications[*] (journal articles, conference papers, workshop papers, edited volumes and special issues) emerged in the context of my work.

The following seven publications are included as chapters within this thesis:

Reuter, C., Marx, A., & Pipek, V. (2012). Crisis Management 2.0: Towards a Systematization of Social Software Use in Crisis Situations. *International Journal of Information Systems for Crisis Response and Management (IJISCRAM)*, *4*(1), 1–16. **[Chapter 4]**

Ley, B., Pipek, V., **Reuter, C.**, & Wiedenhoefer, T. (2012a). Supporting Improvisation Work in Inter-Organizational Crisis Management. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI)* (pp. 1529–1538). Austin, USA: ACM Press. [GI-CSCW-A, WKWI-A, Acc. 23%] **[Chapter 5]**

Christofzik, D., & **Reuter, C.** (2013). The Aggregation of Information Qualities in Collaborative Software. *International Journal of Entrepreneurial Venturing (IJEV)*, *5*(3), 257–271. [VHB–C] **[Chapter 6]**

Ley, B., Ludwig, T., Pipek, V., Randall, D., **Reuter, C.**, & Wiedenhoefer, T. (2014). Information and Expertise Sharing in Inter-Organizational Crisis Management. *Computer Supported Cooperative Work: The Journal of Collaborative Computing (JCSCW)*, *23*(4-6), 347–387. [IF 1.1, GI-CSCW-A, WKWI-B] **[Chapter 7]**

Reuter, C., Ludwig, T., & Pipek, V. (2014). Ad Hoc Participation in Situation Assessment: Supporting Mobile Collaboration in Emergencies. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *21*(5). [IF 1.2, GI-CSCW-A, WKWI-A] **[Chapter 8]**

Ludwig, T., **Reuter, C.**, & Pipek, V. (2013b). What You See Is What I Need: Mobile Reporting Practices in Emergencies. In O. W. Bertelsen, L. Ciolfi, A. Grasso, & G. A. Papadopoulos (Eds.), *Proceedings of the European Conference on Computer Supported Cooperative Work (ECSCW)* (pp. 181–206). Paphos, Cyrus: Springer. [GI-CSCW-A, WKWI-C, Acc. 18%] **[Chapter 9]**

Reuter, C., Heger, O., & Pipek, V. (2013). Combining Real and Virtual Volunteers through Social Media. In T. Comes, F. Fiedrich, S. Fortier, J. Geldermann, & T. Müller (Eds.), *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)*. (pp. 780-790). Baden-Baden, Germany. **[Chapter 10]**

[*] The publications are rated according to the following lists: *GI-CSCW*: CSCW journal and conference list (Leitungsgruppe der GI-Fachgruppe CSCW, 2009), *WKWI*: Wirtschaftsinformatik journal and conference list (Wissenschaftlichen Kommission Wirtschaftsinformatik, 2008), *VHB*: business administration journal list (Verband der Hochschullehrer für Betriebswirtschaft e.V., 2008), *IF:* impact factor (Thomson Reuters, 2010) and the acceptance rate. In some publications, the authors have been listed in an alphabetical order.

The following publications contain related findings, but are not explicitly included chapters:

Balduin, N., Becker, G., Brand, J., Görgen, M., Hannappel, M., Hasenfuß, P., Ley, B., Pipek, V., Probst, F., **Reuter, C.**, Rose, T., Rusch, G., Wiedenhoefer, T., Zinnen, A. (2010). InfoStrom: Learning information infrastructures for crisis management in case of medium to large electrical power breakdowns. In *Future Security - Proceedings of the Security Research Conference*. Berlin, Germany: Fraunhofer VVS.

Christofzik, D., & **Reuter, C.** (2012). Einfluss der Qualitätsermittlung kollaborativ erstellter Informationen auf die Gestaltung interorganisationaler Krisenmanagementsysteme. In D. C. Mattfeld & S. Robra-Bissantz (Eds.), *Multikonferenz Wirtschaftsinformatik (MKWI)* (pp. 2049–2060). Braunschweig, Germany: GITO-Verlag. [GI-CSCW-C; WKWI-C]

Heger, O., & **Reuter, C.** (2013). IT-basierte Unterstützung virtueller und realer Selbsthilfegemeinschaften in Katastrophenlagen. In R. Alt & B. Franczyk (Eds.), *Proceedings of the International Conference on Wirtschaftsinformatik* (pp. 1861–1875). Leipzig, Germany. [WKWI-A, GI-CSCW-A, Acc. 25%]

Hess, J., **Reuter, C.**, Pipek, V., & Wulf, V. (2012). Supporting End-User Articulations in Evolving Business Processes: A Case Study to explore Intuitive Notations and Interaction Designs. *International Journal of Cooperative Information Systems (IJCIS)*, *21*(4), 263–296. [GI-CSCW-B, WKWI-B, IF 1.4]

Kaufhold, M.-A., & **Reuter, C.** (2014). Vernetzte Selbsthilfe in Sozialen Medien beim Hochwasser 2013 in Deutschland. *i-com - Zeitschrift für interaktive und kooperative Medien*, *13*(1), 20–28. [GI-CSCW-B]

Ley, B., Pipek, V., **Reuter, C.**, & Wiedenhoefer, T. (2012b). Supporting Inter-organizational Situation Assessment in Crisis Management. In L. Rothkrantz, J. Ristvey, & Z. Franco (Eds.), *Proceedings of the Information Systems for Crisis Response and Management (ISCRAM)*. Vancouver, Canada.

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Abbreviations

Apps	Mobile phone applications
BOS	Organizations and public authorities with security responsibilities *(German: Behörden und Organisationen mit Sicherheitsaufgaben)*
CSCW	Computer-Supported Cooperative Work
ENO	Energy Network Operator
EXIF	Exchangeable Image File Format, a standard that specifies the formats for images, sound, and ancillary tags used by digital cameras
GIS	Geographical Information System
HCI	Human-Computer Interaction
ICT	Information and Communication Technology
IOIS	Inter-Organizational Information Systems
IS	Information Systems
ISAC	Inter-Organizational Situation Assessment Client (ICT artifact)
KML	Keyhole Markup Language, a XML notation for expressing geographic annotation and visualization within Internet-based maps
MoCo	Mobile Collaboration Application (ICT artifact)
MoRep	Mobile Reporting Application (ICT artifact)
OGC	Open Geospatial Consortium, an international industry association for developing publicly available interface standards
REST	Representational state transfer, a style of software architecture for distributed systems such as the World Wide Web.
SiRena	Inter-Organizational Social Network (ICT artifact), abbreviation of Security Arena
THW	Federal Agency for Technical Relief *(German: Technisches Hilfswerk)*
WMS	Web Map Service, standard protocol for serving geo-referenced map images using web services
WFS	Web Feature Service, standard protocol for serving geo-referenced map features using web services
XML	Extensible Markup Language, a markup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable

Part I:
Foundations

The first part of this dissertation presents the conceptual foundations: Chapter 1 (Introduction) contains the motivation, aims, objectives and the structure of this work. Chapter 2 (Related Work) describes the theoretical foundations and relevant concepts and further discusses related work. Based on these foundations, chapter 3 (Research Design) outlines the research approach, the research setting and the methodology used within this work.

1 Introduction

1.1 Motivation

Advances in ICT and collaborative software over the last decades have made it possible to technically support collaboration beyond spatial, temporal and organizational boundaries. This kind of work will become more and more important for organizations, businesses and individuals in an increasingly networked world (Grudin, 2010; Moog & Werner, 2013). *Cooperation,* Latin *cooperatio* (*co* = together; *operatio* = operate) can be thought of as the practice of operating together. It is often necessary in order to arrange tasks among the actors involved. Even more intense is the expression *collaboration*, Latin *collaboratio* (*col* = together, *laboratio* = work). It "consists of those activities through which multiple actors work together on a given task" (Michelis, 1990), going beyond the sheer coordination of their sub-tasks. In both cases, best practices emerge with time. Processes, descriptions and instructions represent these practices on a formal level for decision, execution and analysis purposes (Shipman & Marshall, 1999). ICT, as well as the overall work infrastructure, are typically used to support these formal structures rather than the emergent practices, which are our concern. The term *work infrastructure* refers to the "entirety of devices, tools, technologies, standards, conventions, and protocols on which the individual worker or the collective relies to carry out the tasks and achieve the goals assigned" (Pipek & Wulf, 2009). However, many tasks and processes depend on contextual conditions. As soon as the actual situation differs significantly from the original process descriptions, it may not be possible to execute them as previously defined. These situations may be caused by the phenomena of *emergence*, as the "arising of novel and coherent structures, patterns, and properties […] in complex systems", that cannot be anticipated in their full extent before they actually emerge (J. Goldstein, 1999). At this point, processes have to adapt to new and possibly unfamiliar situations. Adaptation becomes a challenge when work infrastructures, partly composed of ICT, are no longer capable of fully supporting the necessary tasks. ICT therefore has to reflect this dynamic and emergent nature of cooperation and collaboration, in order to satisfy the need for *emergent collaboration*: spontaneous collaboration in novel and rapidly evolving situations.

The purpose of this work is to contribute to *infrastructures for emergent collaboration*. This is instantiated here by research into ICT support for collaborative practices by actors affected by crises and emergencies, including natural disasters (tsunamis, floods, earthquakes, wildfires) or technical accidents (oil leaks, energy breakdowns), but also smaller incidents, due to unforeseeable events. To make coping and recovery work more calculable and predictable, many plans and processes already define these collaborations. However, crisis management is a practical field that needs to be prepared for the unforeseeable. The number of dynamically changing factors which may influence events is potentially very large (weather conditions, number of affected people, etc.), and they have to be managed along with structural dependencies (electricity, roads and railways, fuel resources, communication infrastructures, etc.) in a context where a high number of heterogeneous organizations may be involved (police and fire services, aid agencies, administrations, infrastructure providers, etc.). This makes it impossible to plan all activities ahead (Mendonça, 2007). Therefore the necessity for *improvisa-*

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tion, Latin *improvisus* (*im* = not; *provisus* = foresee) increases and typically also occurs in collaboration beyond local or organizational boundaries. Improvisation work faces many challenges, such as different organizational cultures, individual work practices and the limitations placed on actors by encapsulated information systems. All organizations rely on solid ICT infrastructures especially tailored to their individual needs. Hence, when it comes to (inter-organizational) emergence, the existing infrastructure may not be adequate and collaboration breakdowns, or at least complications, may occur.

1.2 Aims and Objectives

This work explores novel ICT-based approaches to support inter-organizational emergent collaboration practices. Based on theoretical considerations associated with these issues and related work, it presents empirical studies on collaboration in crisis management, the design and implementation of innovative ICT artifacts as well as evaluations of their appropriation in the application field. The research was accomplished in the project *InfoStrom*, which aims to develop collaborative tools to improve cooperation in coping and recovery work in medium and large power outages (Balduin et al., 2010; Wiedenhoefer et al., 2011, 2013). The purpose of my work is to contribute to *infrastructures for emergent collaboration*, in which respect it addresses the following questions, using the example of inter-organizational crisis management:

1. Where do emergent collaboration practices reveal work infrastructure limitations?
2. What kind of novel concepts and artifacts are appropriate for improving work infrastructures towards enabling emergent collaboration?
3. What are the potential organizational effects of such collaboration infrastructures on the ability to deal with emergence?
4. What are the methodological implications for technology design towards emergent collaboration infrastructures in inter-organizational settings?

In order to research this topic, *design case studies* (Wulf et al., 2011) serve as a methodological approach. They consist of three phases: an empirical analysis of the given practices, the innovative design of an ICT artifact related to the findings of the first phase and an evaluation of the appropriation of the artifacts with continuous participation of end-users. *Appropriation* is the "process by which people adopt and adapt technologies, fitting them into their working practices" (Dourish, 2003). In this thesis, cooperation practices between actors dealing with medium and large power outages in Germany have been researched. The aim is not to implement ICT tools, but to attempt the improvement of work infrastructures, seen as sociotechnical systems. The concept of *infrastructuring* (Pipek & Wulf, 2009), an integrated perspective on the design and use of information systems, will therefore act as the theoretical perspective which guides the analysis and interpretation of results.

1.3 Structure of the Work

This thesis is organized in three parts: *foundations*, *findings and analysis*.

Part I – Foundations

The first part presents the conceptual foundations.

Chapter 1 (Introduction) contains the motivation, aims, objectives and the structure of the work.

Chapter 2 (Related Work) describes the theoretical foundations, defines relevant terms and discusses related work on emergence, CSCW, social software, crisis and emergency management and infrastructuring.

Chapter 3 (Research Design) outlines the research approach, the research setting and the methodology used within this work: design case studies consisting of empirical study, conception of ICT artifacts and evaluation.

Part II – Selected Findings

The second part presents sub-findings related to the questions outlined above. The chapters in this part have already been published and resemble the accepted versions of reviewed journal articles or conference papers with minor changes. Chapters 4 to 6 present conceptual considerations and empirical results. Chapters 7 to 10 contain concepts, implementations of ICT artifacts and their evaluations in practice.

Chapter 4 (Crisis 2.0: Towards a Systematization of Social Software Use) presents a classification matrix for cooperative work in crisis management. It considers the different actors and helps to distinguish collaboration scenarios. It has been published in the *Journal of Information Systems for Crisis Response and Management (IJISCRAM)* (Reuter, Marx, et al., 2012).

Chapter 5 (Empirical Perspective on Inter-Organizational Improvisation Work) offers the results of an empirical study on improvisation practices during coping and recovery work by emergency response agencies (especially police and fire department, energy network operator) in Germany. It has been published in the *Proceedings of the International Conference on Human Factors in Computing Systems (CHI)* (Ley et al., 2012a).

Chapter 6 (Composing Collaborative Information Quality) builds on the empirical results, analyzes the interconnections in collaborative information generating and sharing over geographic distances and outlines approaches that foster information quality related to collaboration scenarios. It has been published in the *International Journal of Entrepreneurial Venturing (IJEV)* (Christofzik & Reuter, 2013).

Chapter 7 (Scenario A: Information and Expertise Sharing in Situation Assessment) derives the concept, implementation and evaluations of ISAC, a web-based system to support information aggregation and visualization using geographical information systems. It has been published in *Computer Supported Cooperative Work – The Journal of Collaborative Computing (JCSCW)* (Ley et al., 2014).

Chapter 8 (Scenario B: Ad Hoc Participation in Mobile Collaboration) presents the concept, implementation and evaluation of MoCo, a mobile application to share ISAC information ad hoc beyond local and organizational boundaries and to expand the group of people participating in situation assessment. It has been published in the *Transactions on Computer-Human Interaction (TOCHI)* (Reuter et al., 2014).

Chapter 9 (Scenario C: Articulation Work in Mobile Reporting) presents the concept, implementation and evaluation of MoRep, a mobile semi-structured request-and-report application. It has been published in the *Proceedings of the European Conference on Computer Supported Collaborative Work (ECSCW)* (Ludwig et al., 2013a).

Chapter 10 (Perspective: Integrating Real and Virtual Volunteers) presents a survey of further possibilities to support emergent collaboration among citizens and volunteers. It has been published in the *Proceedings of the International Conference on Information Systems for Crisis Response and Management (ISCRAM)* (Reuter et al., 2013). Further results related to emergent volunteers have been published in the *Proceedings of the Conference on Wirtschaftsinformatik (WI)* (Heger & Reuter, 2013).

Part III – Analysis

The third part combines the different perspectives and already published papers and analyzes them in relation to their theoretical and practical implications.

Chapter 11 (Empirical Results) summarizes the main empirical findings of the given practices and describes detected infrastructural phenomena that have an effect on possible ICT support in emergent collaboration practices.

Chapter 12 (Concepts and Artifacts) contains challenges, concepts and implementations of innovative ICT artifacts (SiRena, ISAC, MoCo and MoRep) to support emergent collaboration practices related to the empirical findings of the previous chapter.

Chapter 13 (Evaluation) presents the results of the evaluations of these concepts in the application field using three scenarios: information aggregation and visualization in situation assessment (scenario A), ad hoc participation in mobile collaboration (scenario B) and articulation work in mobile reporting (scenario C).

Chapter 14 (Towards Emergent Collaboration Infrastructures) builds on the results of the previous chapters and discusses them in order to answer the initial research questions. It outlines the *collaboration sphere* and the concept of *distance* and presents methodological implications for infrastructuring in emergent collaboration.

Chapter 15 (Summary) outlines the contribution, states the overall conclusion and presents perspectives for future work.

2 Related Work

2.1 Emergence, CSCW and Social Software

Collaboration infrastructures dealing with the concept of *emergence* face many challenges. The latter term was introduced by the philosopher George Henry Lewes (1875), who wrote:

> *"Every resultant is either a sum or a difference of the co-operant forces […]. It is otherwise with emergent. […] The emergent is unlike its components insofar as these are incommensurable, and it cannot be reduced to their sum or their difference."*

This definition emphasizes the nature of emergent structures which, in their nature, not allow for accurate or even adequate calculation or prediction. The whole, to use a commonplace expression, is more than the sum of its parts. A newer version defines emergence as follows: "[it] refers to the arising of novel and coherent structures, patterns, and properties during the process of self-organization in complex systems" (J. Goldstein, 1999). According to this perspective, emergent phenomena share certain characteristics: (1) they cannot be anticipated in their full richness before they actually manifest themselves, (2) they tend to maintain some sense of identity over time, (3) the locus of emergent phenomena occurs on a global level, (4) they arise as a complex system over time and (5) they can be perceived.

Informal organization can be viewed as an example for emergence, i.e. spontaneously occurring organizational events, structures, processes, groups, and leadership (J. Goldstein, 1999). In respect of the design of self-organizing applications, a combination with emergence is common "which makes it infeasible to impose a structure a priori: the system needs to self-organize" (De Wolf & Holvoet, 2005). Working in emergent structures can be challenging due to unpredictability, incalculability and therefore uncertainty. Goldstein (1999) distinguishes between the source of an organizational structure in an organization (self-organized or imposed) and its type (hierarchical or participative). His two-by-two grid (Table 1) highlights *emergent networks* as participative and self-organized networks that "can include both intra- and intergroup dynamics and also pertain to the spontaneously arising organizational structures and practices".

Source of Structure	Hierarchical	Participative
Self-Organized	Informal Leadership	Emergent Networks
Imposed	Command and Control	Imposed Teams

Type of Structure

Table 1: Emergence and organizational dynamics (J. Goldstein, 1999)

Some environments and structures may allow precise prediction and full automation but, the academic field of CSCW has a broadly skeptical view of this prospect and aims at "supporting self-organization of cooperative ensembles as opposed to disrupting cooperative work by

C. Reuter, *Emergent Collaboration Infrastructures,*
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computerizing formal procedures" (Schmidt & Bannon, 1992). The field is therefore appropriate for understanding how to deal with emergences. The intent of CSCW is to:

> *"understand the nature and characteristics of cooperative work with the objective of designing adequate computer-based technologies"* (Bannon & Schmidt, 1989).

The term was first used by Irena Greif and Paul Cashman in 1984 to describe an interdisciplinary workshop they were organizing on how to support people in their work arrangements with computers (Grudin, 1994). A few years later Greif (1988) defined CSCW as "an identifiable research field focused on the role of the computer in group work". Cooperative work has been identified as a "phenomenon we can study systematically, as a category of work practice, distinct from its organizational and socio-economic form" (K. Schmidt, 2010). Besides the exclusive focus on the tasks, a distinction between (mainly distributed) cooperative work, that is concerned with the tasks itself, and articulation work, that includes all activities required to coordinate the tasks among individuals, is common (Schmidt & Bannon, 1992). *Articulation work* can be seen as "a kind of supra-type of work in any division of labor, done by the various actors" (Strauss, 1985):

> *"Who is doing what, where, when, how, by means of which, under which requirements? Articulation work arises as an integral part of cooperative work as a set of activities required to manage the distributed nature of cooperative work"* (K. Schmidt, 1994).

Awareness is further crucial factor for collaborative work and provides a "context for individual activities and thus facilitates group progress" (Dourish & Bellotti, 1992). In order to support emergent collaborative work, supporting articulation and considering awareness is essential.

When considering *emergence* in collaborative systems, with new structures, actors and/or environments in play, evolving concepts like *social software* as opposed to *groupware* have also to be taken into consideration. Groupware is defined as "intentional group processes plus software to support them" (Johnson-Lenz & Johnson-Lenz, 1991) or "computer-based systems that support groups of people engaged in a common task (or goal) and that provide an interface to a shared environment" (Ellis et al., 1995). Social software, in contrast, cannot be so narrowly defined. Social software will commonly be found, along with collaborative systems, in work-related contexts, but the former is also common in the private arena. Richter (2010, p. 108) points out, that one characteristic of social software is not to focus on the creation of communities to specific tasks, but to focus on the usefulness of the individual user. The term social software came into more common usage, when Clay Shirky in 2002 organized a "Social Software Summit" (Allen, 2004). He did not use the term groupware in order to gather all uses of software that support interaction in groups, even offline; he also did not use the term *collaborative software* because to him that seemed as a sub-set of groupware which just focuses on work (Allen, 2004). An early and very simple definition of *social software* is "software that supports group interaction" (Allen, 2004). It is more used in private contexts and is perceived as being a significant part of Web 2.0, which describes the innovations of the Internet after the crash of the new economy in 2000 (Alby, 2007). *Social media* is defined almost synonymously as:

> *"Group of Internet-based applications that build on the ideological and technological foundations of Web 2.0, and that allow the creation and exchange of user generated content"* (Kaplan & Haenlein, 2010)

User generated content can be seen as "the sum of all ways in which people make use of Social Media" (Kaplan & Haenlein, 2010). *Web 2.0* was first coined in 1999:

> *"The first glimmerings of Web 2.0 are beginning to appear […] through which interactivity happens. It will […] appear on your computer screen […], your TV set […] your car dashboard, […], your cell phone […] hand-held game machines […] and maybe even your microwave."* (DiNucci, 1999, p. 32)

At the "Media Web 2.0 conference" held by Tim O'Reilly, the competences of the surviving companies of the new economy were summarized under the term *Web 2.0*, which was then used more frequently. O'Reilly (2005) defined them as having seven characteristics including (1) the usage of the Internet as a platform to provide different services, (2) the participation of users and a collective intelligence, (3) the consideration of the user-generated data as the capital of an application, (4) the inclusion of the user in the development, (5) using new software development models, (6) the use of services on different terminals, and (7) rich user experience. For him Web 2.0 is the "business revolution in the computer industry caused by the move to the Internet as platform, and an attempt to understand the rules for success on that new platform" (T. O'Reilly, 2006). From his perspective, the term social software describes web-based applications that support the user's interaction and communication process. In addition to this definition, there are various other considerations. Hippner (2006) defined social software as the possibility to exchange information, manage relationships and communicate in social contexts. Besides the exchange of information, Ebersbach et al. (2008) defined user generated content as an essential element. The existence of a community therefore is an important pre-condition. In summary, social software and social media encompass a range of applications from the Internet that enable different people to contact and interact with each other. A community providing the data is the basis of these applications and they support different activities: the allocation of information, the generation of information, relationship management, communication and self-expression. Different activities are often combined. Allen (2004) points out that the "core ideas of social software itself enjoy a much longer history, running back to Vannevar Bush's ideas about *Memex*[*] in 1945 through terms such as *augmentation*, *groupware*, and *CSCW* in the 1960s, 70s, 80s, and 90s". Koch (2008) also argues that "most of what currently is advertised as a revolution on the web has been there as CSCW applications years (or even decades) ago – however, not as nice and as usable as today in the Web 2.0 with social software". The use of social software and the use of groupware may therefore not necessarily be entirely different.

A common important characteristic of both, CSCW applications and social software, is that they do not focus on automation but on the support of social activities or work practices, which may be neither organized nor coordinated formally. Kieser and Walgenbach (2010, pp. 93ff) distinguish seven types of coordination: coordination by (1) programs, (2) planning, (3) intra-organizational markets, (4) organizational culture, (5) standardized roles, (6) hierarchical decision-making and (7) self-coordination by non-hierarchical communication. The mechanisms of "self-coordination and hierarchical decision-making allow ad hoc coordination"

[*] A device in which individuals would compress and store all of their books, records, and communications.

(Wulf, 1999) make it possible to "use the potential of emergent changes". The introduction of ICT therefore should be participatory and evolutionary and applications should be technically flexible (Wulf, 1999).

The characteristics of emergence, as described, mean that it may not be possible to carry predefined processes into execution – (cooperative) work in such settings therefore needs ad hoc coordination and *improvisation* which can be defined as a "situated performance where thinking and action seem to occur simultaneously and on the spur of the moment" (Ciborra, 1996). While some authors define it from a management perspective as "to be composed while performed" (Perry, 1991), others describe it in the case of fire service management as "thinking and doing unfold simultaneously" and "retrospective sensemaking" (Weick, 1996). Improvisation becomes necessary when planned decision-making does not, for a variety of reasons, work. This is for example the case in a crisis situation, which often leads to unexpected events. The necessity to judge highly novel problems and to act quickly reduces the possibility of extensive planning: "Decision makers in emergencies must be prepared to improvise" (Mendonça & Wallace, 2007). Antecedent conditions, such as unexpected problems, changes in the structure of the problem areas or environmental and knowledge limitations, lead to the need for improvisation (Stein, 2011). Even in highly structured organizations, improvisation is a well-grounded process that can be leveraged to face those situations where rules and methods fail (Ciborra, 1999). Improvisation can be performed on different hierarchical levels and can be treated as an individual or as a team phenomenon (Moorman & Miner, 1998). Instead of trying to eradicate it through automation, the need for an appreciation of requirements for flexibility and effectiveness seems to be clear.

2.2 Field of Application: Crisis Informatics and Emergency Management

In order to develop software for social settings, especially to support group interaction, it is important to take the specifics of the field into account (Wulf et al., 2011). Depending on the work domain and the exact nature of work, the use of coordination mechanisms varies and consequently the (technical) artifacts in use may differ. The concept *coordination mechanism* describes "the use of artifacts for the purpose of coordinating cooperative activities in different work domains" (K. Schmidt & Simonee, 1996). Considering the case of crisis and emergency management, it is obvious that one unit cannot manage the situation alone; coordination mechanisms, such as ICT artifacts, are therefore needed. A definition of the application field is not trivial:

> *"Disaster, crisis, catastrophe, and emergency management are sometimes used synonymously and sometimes with slight differences, by scholars and practitioners."* (Hiltz, van de Walle, et al., 2011)

However, according to the *internationally agreed glossary of basic terms related to disaster management* (United Nations Department of Humanitarian Affairs, 2000), an *emergency* can be seen as a "sudden and usually unforeseen event that calls for immediate measures to minimize its adverse consequences". According to the same document, a *disaster* is a "serious disruption of the functioning of a society, causing widespread human, material, or environmental losses which exceed the ability of affected society to cope using only its own resources". The term, 'crisis', has not been defined in that document. Yet, *crises* are situations

that the normal structural and process organization cannot overcome (BSI, 2008). The Greek root word *krisis* (judgment, decision) shows the ambivalent possibilities and leads to a very important task in such situations: decision-making.

The *emergency management process* deals with such decision-making and can be separated into four to eight phases (Turoff et al., 2009), where all classifications at least include the main four phases: (1) *Mitigation* - "pre-disaster actions taken to identify risks, reduce them, and thus reduce the negative effects of the identified type of disaster event". (2) *Preparedness* – "actions taken prior to a possible disaster that enables the emergency managers and the public to be able to respond adequately when a disaster actually occurs". (3) *Response* (also called emergency management) – "actions taken immediately prior to a foretold event, as well as during and after the disaster event, that help to reduce human and property losses". (4) *Recovery* – "enable the population affected to return to their normal social and economic activities" (Hiltz et al., 2011, p. 5-6). Quarantelli (1995) suggests separating different types of work in crisis management. He distinguishes between old and new structures as well as between old and new tasks (Table 2). He argues that crises differ from routine situations and actors have to face new and unstructured tasks. Contexts are often unforeseeable or *emergent* and cannot result from a small set of rules or events. Based on structural or functional emergence he defines *emergent behavior* as new structures with new tasks.

New Tasks	Type III: Expanding	Type IV: Emergent
Old Tasks	Type I: Established	Type II: Extending
	Old Structures	New Structures

Table 2: Types of emergent behavior (Quarantelli, 1995)

In emergencies, collaboration and, consequently, articulation between many involved actors in different phases is required in order to be able to make informed decisions. Emergency management is faced by an "unlimited variety of incidents that require interpretation, decision and coordination" (Normark & Randall, 2005). Articulation work includes reports from on-site units to the control center, information provided by the control center or even the communication between different units or organizations and public authorities with security responsibilities (German: *Behörden und Organisationen mit Sicherheitsaufgaben*, BOS) such as the police, fire departments, aid agencies, the THW and public administration. It can also include communication with actors who are not necessarily part of the official BOS, such as citizens and companies. Quarantelli (1988) derives five different categories to characterize the flow of information in a crisis: (a) intra-organizational, (b) inter-organizational, (c) from organizations to the public, (d) from the public to the organizations and (e) communication within systems of organizations. Collaboration between the "private and public sectors could improve the ability of a community to prepare for, respond to, and recover from disasters" (Board on Earth Sciences and Resources, 2011). This ability is sometimes called *collaborative resilience* (B. E. Goldstein, 2011, p. 370) and:

> *"examines a variety of ways to build resilience to violence, hazards, and resource decline. These collaborative methods range from consensus-based*

> *stakeholder agreements to collective mobilization of change in durable institutions that are dysfunctional and inequitable."*

Emergencies also fulfill other characteristics of emergent situations by Goldstein (1999): (1) they are not anticipated in their full richness before they actually arise, (2) they tend to maintain some sense of identity over time, (3) the locus of emergent phenomena takes place on a global level, (4) they arise as a complex system over time and (5) they can be perceived. In crisis and emergency management "improvisation and preparedness go hand in hand" (Mendonça, 2007): without improvisation, emergency management loses flexibility and without preparedness, emergency management loses efficiency. Based on an analysis of the responses to the 2001 World Trade Center attack, Mendonca (2007) suggests that some specifics of emergency management can be considered as characteristic. First, (a) the rarity of incidents limits opportunities for training and learning. Furthermore, (b) time pressure forces a convergence of planning and execution. (c) Uncertainty is present because the development of an extreme incident is rarely predictable. Extreme events also have (d) high and broad consequences; therefore, there is a need to manage interdependencies within a wide range of physical and social systems. The (e) complexity of the event arises, which is partly due to the high and broad consequences. Finally, (f) multiple decision-makers and responding organizations may need to negotiate with each other while responding to the event. Based on interviews with emergency responders, Chen et al. (2008) also derived characteristics of the field, which are often similar to those mentioned above and do not provide new aspects unless the "disruption of infrastructure support" occurs: (a) high uncertainty with sudden and unexpected events, (b) risk and possible mass casualty, (c) increased time pressure and urgency, (d) serve resource shortage, (e) large-scale impact and damage, (f) disruption of infrastructure support, (g) multi-authority and massive people involvement, (h) conflict of interest and (i) high demand for timely information.

Information systems are increasingly important to support the actors involved (Hiltz, van de Walle, et al., 2011). The term *crisis informatics* was coined by Hagar (2007) and later elaborated (Palen et al., 2009):

> *"Crisis informatics views emergency response as an expanded social system where information is disseminated within and between official and public channels and entities. Crisis informatics wrestles with methodological concerns as it strives to develop new theory and support sociologically informed development of both ICT and policy."*

The dynamics and specifics of crises and emergencies make it extremely difficult to find appropriate approaches to articulate information needs amongst all actors (Heath & Luff, 1992). Obviously, one single ICT-system cannot support the specific activities of all actors; cooperation and communication between different information systems is therefore necessary as a part of the collaboration infrastructure for crisis management. Based on empirical work in the field, Denef (2011) presents patterns of firefighter's activities in order to transform the existing practices into a design space. The pattern "handy multi tools" describes important characteristics of BOS working practices, relative to physical and time constraints (Denef, 2011, p. 193):

> *"Firefighters bring tools that can be used for different purposes and invent new ways of using the tools. Tools are designed open for new uses and can be combined with the environment."*

In his intention to design navigation support for firefighters Ramirez (2012, p. 160) also mentions that rigid regulations and tool definitions are adapted if the (emergent) situation requires it. Computer-based systems can allow such practices, if the system design is informed by an understanding of the cognitive processes involved in responding to unanticipated contingencies (Mendonça, 2007). Systems must support the actors in reworking their knowledge, in order to fit the requirements of the current situation. ICT which supports improvisation needs to handle ad hoc coordination, unique problem solving strategies and new or changed information needs (Waugh & Streib, 2006). Computer based comparisons of the current decision situation with past ones have been identified as appropriate in this context (Mendonça, 2007). Case-based reasoning systems, which catalogue the set of planned-for situations or decision alternatives, can be used for this purpose, too. Ad hoc re-planning and the ability to share material were identified as design challenges for large-scale events (Lindström & Pettersson, 2010). Furthermore, the following ICT-supported mechanisms for improvisation in emergency management are suggested: graphical representations of data during crisis response, intelligent systems that select and help contact experts, centralization of data to enable actors to find information and virtually supported coordination to create shared information (Adrot & Robey, 2008). Additionally, verbal communication should be made persistent, visible and accessible in order to support accountability (Landgren, 2006). Current crisis management systems cover only parts of these requirements. Based on an analysis of over 170 systems (Neuhaus et al., 2012), they can be divided into *information systems*, *alerting systems*, *command and control systems* and *communication systems*, while a shift from single solutions to hybrid systems and towards the provision of web- or mobile solutions was observed. However, "although there is a common body of knowledge, [multi-agency] disaster management is still an under-developed area" (Janssen et al., 2009).

2.3 CSCW Applications for Inter-Organizational Collaboration

Besides the consideration of the field of application, the aspect of *inter-organizational* needs to be studied. While *inter-organizational systems* (IOS) or *inter-organizational information systems* (IOIS) are automated information systems shared by two or more organizations (Cash & Konsynski, 1985), CSCW applications normally provide "capabilities beyond simple information access to facilitate communication and collaboration among partners" – and IOIS are therefore a subset of CSCW systems (Drury & Scholtz, 2005). Literature on IOIS has grown in many directions motivated by the efficiency account of cooperation or social and behavioral bases of firm relationships (Chatterjee & Ravichandran, 2004). Coordination among the organizations involved, as well as the sharing of information and expertise, is of high importance, especially in unforeseeable and emergent situations. In CSCW, *information sharing* (or *knowledge sharing*[*]) is used for artifact-centered studies, while the communication-centered *expertise sharing* focuses on the actor (Ackerman et al., 2013). Expertise sharing focuses on the "self-organized activities of the organization's members and emphasizes the human aspects" (Ackerman et al., 2003), in addition to information storage and retrieval. IOS can provide a basis for planned and automated collaboration among organizations; however they usually do not cover emergent and ad hoc collaboration as CSCW applications do.

[*] Ackerman et al. (2013) mention to "not differentiate between knowledge and information" in their overview article about the "CSCW View of Knowledge Management".

Many papers address coordination, information and expertise sharing practices across different organizations: A study on coordination mechanisms in software development discovered a large variety of informal communication and ad hoc coordination mechanisms (Doherty et al., 2012). The authors suggest introducing technologies that support the establishment of "less formal communication channels" instead of structured information management systems. An empirical study on municipal governments, trying to understand information sharing needs and practices, confirms this finding: due to the different information needs, *flexibility* was identified as the main requirement. They also point out that employees "rely heavily on manual methods for data sharing" (Hobson et al., 2011). A study on the challenges of sharing and coordinating information during multi-agency disaster response highlights that the "actual level of information sharing across different organizations is often limited, although it is being promoted". A reason is that agencies "are mainly concerned with obtaining information from others, rather than providing others with information at their disposal" (Bharosa et al., 2010). A possible approach could be, as White et al. (2009) discovered in a survey study that social networks for emergency management should be considered as a viable solution to the problems plaguing information dissemination and communication.

In addition to work on flexibility, improvisation and communication, studies focusing on visualization and collaboration, especially using *geographic information systems* (GIS) – sometimes as a part of IOIS, are of interest. The study of Li and O'Hara (2009) focuses on the decision-making of geographically distributed committees and found that difficulties arose from not having shared visual access to the information being discussed. The ethnographic study of Paul and Reddy (2010) on collaborative information seeking shows that in addition to the ambiguous nature of information, the different roles and expertise of group members make sensemaking more challenging; they propose to visualize sensemaking trajectories in order to foster awareness among BOS. Kraut et al. (2002) confirm that "collaborative pairs can perform more quickly and accurately when they have a shared view of a common work area". In terms of group work, "most spatial decisions using geographical information are done by teams, but existing geospatial information technologies […] have been designed for use by individuals", according to Cai (2005). His approach extends distributed GIS with collaborative functionalities and proposes a system architecture that integrates web service-based distributed computing paradigms. The geocollaborative software architecture for emergency management planning of Schafer et al. (2007) combines Java-based collaborative infrastructures with GIS tools to be able to support awareness and collaboration with annotations and selections that can be shared, as well as to provide the possibility to lead or follow another user's map or to link georeferential data to other content. These functionalities have also been used in the study of Convertino et al. (2011) that focuses on knowledge sharing and activity awareness in distributed emergency management planning with a collaborative geospatial prototype. With a series of paper and software prototypes, they show that using collaboration technology can reduce coordination efforts among spatially distributed teams. Web-based geocollaborative tools have also been examined: the approach of Chang and Li (2007) integrates collaborative tools to support participants' awareness and their collaboration. Many of these web-based crisis mashups are described by Liu & Palen (2010), who focus particularly on "merging the professional GIS culture with the participatory neo-geographic culture to address the mapping challenges which are likely to arise in this increasingly networked world".

2.4 Social Software for Emergent Civic Participation

This increasingly networked world and the aforementioned appearance of social software also led to its use by the public. For more than one decade, social software has been used by the public in crisis situations: after the terrorist attacks of September 11th, 2001, wikis, created by citizens, were used to collect information on missing people (Palen & Liu, 2007). In a study on the information search behavior during the forest fires in Southern California in 2007, it was found that affected people communicated via mobile phones and used the Internet to search for information and to trigger communication, to read blogs, news sites and forums (Sutton et al., 2008). During the last few years this behavior has even increased: Social software is widely used by citizens collaboratively coping with a crisis. Many published papers deal with crises in the USA and many of them focus on the use of Twitter. Its use was analyzed in the context of various crises, such as technological failures, floods, attacks, hurricanes and earthquakes (Reuter, Marx, et al., 2012), but also during political activities, such as the 2011 Egyptian uprising, during the 2011 Tunisian revolution (Wulf, Misaki, Atam, Randall, & Rohde, 2013), and while fighting against the wall in Palestine (Wulf, Aal, et al., 2013).

Other studies show that *Wikis* are used for supporting people affected by a crisis (White, Plotnick, Addams-Moring, Turoff, & Hiltz, 2008). They are useful to collaboratively collect information and knowledge and to then create collective intelligence, but there are deficits in communication. Scipionus is an example of such a crisis-related wiki, which arose during the struggle against the effects of Hurricane Katrina. It uses a visual interface that allows its users to publish and edit information on the Google Map Interface (Palen, Hiltz, et al., 2007). Other examples are Emergency Wiki or Quake Help Wiki (White et al., 2008).

Micro blogging is used to collect and distribute information, to communicate and answer help requests. However, for intensive coordination work, Twitter-users switch to other software, such as Skype (Starbird & Palen, 2011). Twitter serves as resource for situation updates (Vieweg et al., 2008) and as a platform for coordinating activities, exchanging opinions and coping emotionally with a crisis (Qu et al., 2011). As for Twitter messages, it had been found out that tweeters assume the role of the classical media if the actual news coverage by the media and organizations is not satisfactory (Sutton, 2010). The observers tried to show what distinguishes the Twitter experience in a crisis from everyday Twitter usage (Hughes & Palen, 2009). Within the first hour of an emergency, using Twitter for information retrieval is almost a default and mainstream media, it is argued, catch up to the average level of information quality on the Twitter network after about 24 hours (Mills et al., 2009). Twitter can raise awareness of a crisis because it is able to reach a large number of people at once. Therefore, the service is often used as a broadcast medium (Hughes & Palen, 2009). False information is prevented from being spread by the collective intelligence of the users, who ensure that faulty tweets are corrected: retweets serve as an evaluation mechanism for important information (Starbird et al., 2010). In order to improve the use of tweets by BOS, Starbird and Stamberger (2010) proposed the use of a particular hashtag-syntax during a crisis, which would be machine-readable and could help collect more relevant information. Starbird et al. (2012) also showed how to identify on-the-ground tweeters during mass disruptions. A study on the geographical distribution of Twitter users has shown that people who are not or who are only slightly affected by the crisis, use Twitter more often than citizens and organizations more significantly affected. However, the information generated by those who are not involved is

of great help to those affected by the crisis or disaster (Sutton, 2010). As opposed to everyday Twitter activities, more *information brokers* (Hughes & Palen, 2009) were identified, who collect information from various validated sources and pass it on to help the victims of the crisis (Sutton et al., 2008; Vieweg et al., 2008). Also without specific analytic tools, Twitter is used by BOS such as fire departments, to obtain citizen-generated content and to publish their own information (Latonero & Shklovski, 2011). In the Twitter-use of the police, different strategies were observed, as an instrumental approach - where the police aimed at remaining in a controlling position and to keep a distance from the general public - or taking on an expressive approach - where they actively decreased the distance from citizens (Denef et al., 2013).

Besides micro blogging, *social networks* are an important kind of social media. Social networks enable its users - who are represented by profiles - to connect with each other and offer various interaction tools, such as sending messages, sharing photos and videos, providing information within a user or group profile, publishing notifications, reporting current status, announcing events and discussions in forums (White et al., 2009). Existing networks, like Facebook, have the advantage that users already possess a net of social relationships from everyday use before the actual crisis takes place and its functionalities do not have to be learned during a crisis. They are intensively used to create collective intelligence, serve as a source of information and contain quality control (Palen & Vieweg, 2008). Activities, tasks and domains can be identified as mechanisms of self-organization for *digital volunteers*, described as people with "new behaviors of mass interaction that ICT enables" (Starbird & Palen, 2011). During a rampage, the decentralized problem-solving behavior of students was observed: a short time after the beginning of the attack, they used Facebook to identify the victims together and used the social network's group function for that purpose (Vieweg et al., 2008). The authors show that the collective intelligence of citizens helped to correctly identify the victims, because users were concerned about reliable sources in this particular situation.

Besides classical categories of social software, crisis-related platforms specifically customized for crises are another type of relevant social software. Sahana, Ushahidi and Google Crisis Map integrate several web-based applications (van de Walle & Turoff, 2008). These and other types of social software are used by people who are physically present on-site as well as by off-site users and digital volunteers (Starbird & Palen, 2011). The ubiquitous availability of collaboration technologies leads to situated (civic) engagement (e.g. collaborative and social software use related to the current situation via smartphones), where each participant is embedded in a socio-spatio-temporal context (Korn, 2013), which needs to be allowed by the respective infrastructure.

2.5 Infrastructures and Infrastructuring

In order to research emergent collaboration infrastructures, the term, 'infrastructure' needs to be defined. *Infrastructure* comes from the Latin *infra* (below) and comprises all basic structures needed for the operation of a society. According to van Laak (1999), the term has originally been used for assets for mobility, e.g. the train stations and bridges of the French railroad since 1875, or barracks and radar stations of the North Atlantic Treaty Organization since 1950. At that time, NATO developed a program to coordinate the expansion of airports, pipelines and fuel reservoirs, and communications and air defense systems. The term was then

used for those strategically important facilities and later for other non-military areas as a sign of the *superiority* of the West (van Laak, 1999). The first systematic approach (Jochimsen, 1966, p. 100) defined an infrastructure as:

> *"The sum of material, institutional and personal facilities and data which are available to the economic agents and which contribute to realizing the equalization of the remuneration of comparable inputs in the case of a suitable allocation of resources, that is complete integration and maximum level of economic activities".*

This definition distinguishes between material (e.g. plant and equipment of energy supply and transportation), institutional (e.g. all of the legal norms, institutions and procedures) and personal infrastructure (e.g. the number of people and their skills) (Jochimsen, 1966, pp. 31-39). Buhr (2003, p. 22) describes "whatever category of infrastructure is considered to be dominant, an essential task of infrastructure policy will be to maintain and improve the complementarities, the integration and cooperation, of institutional, personal and material infrastructure". He differentiates between the technical (e.g. facilities of transport or communication) and social infrastructure (e.g. education, cultural facilities). The overall objective of infrastructure is to satisfy basic physical and social needs (Jochimsen, 1966).

In CSCW and IS the term *IT-infrastructure* is used and can be considered both from a technical view and from the information management's point of view. For infrastructures in IS the material infrastructure of buildings and hardware equipment exists in different fields (telephone services, telecommunication, computer services), and the complementary personal infrastructure contains knowledgeable personnel of IT in diverse categories, as does the institutional infrastructure, which covers laws and norms concerning security of IS and data protection and international procedures of standardization (Buhr, 2003, p. 22). *Critical infrastructures* describe assets essential for the functioning of a society and economy, which become important during crises (Schulze, 2006). *Critical information infrastructures* are ICT systems that are critical infrastructures themselves or essential for the operation of other critical infrastructures (telecommunications, computers/software, Internet, satellites) (Commission of the European Communities, 2005). The breakdown of part of an infrastructure also affects the scope of the use of other infrastructures. Those cyber interdependencies occur if an infrastructure depends on information that is provided through information infrastructures (Rinaldi et al., 2001). This is the case in recovery work for electricity breakdowns using IT as an infrastructure for communication and collaboration (Mueller et al., 2010). Starting with Engeström's definition (1990) of a *tool* as "not just a thing with pre-given attributes frozen in time – but a thing becomes a tool in practice, for someone, when connected to some particular activity", Star and Ruhleder (1996) describe infrastructure as "something that emerges for people in practice, connected to activities and structures". Taking this perspective, infrastructure becomes whatever its users perceive as infrastructure. *Infrastructure* is:

> *"something that is built and maintained, and which then sinks into an invisible background. It is something that is just there, ready-to-hand, completely transparent"* (Star & Ruhleder, 1996).

Answering the question "when is infrastructure" – not what – they defined its salient characteristics, emphasizing the ongoing design process as directed towards the perception of something as an infrastructure (Table 3). In infrastructures, the nature of *design* needs to accommodate non-local constraints (Monteiro et al., 2013) is vital. However, the techno-centric un-

derstanding of IT infrastructure (Dourish, 1999), it is argued, does not always focus on infrastructure activities. Opposed to such more traditional considerations, and building on Star and Ruhleder (1995) as well as Star and Bowker (2002), Pipek and Wulf (2009) established a perspective on organizational IT as work infrastructure focusing on the infrastructural nature of organizational IS and describing challenges for designing within, and for, this type of infrastructure. Instead of focusing on isolated technical artifacts, infrastructuring aims to improve work infrastructures with all efforts "that contribute to the successful establishment of an information system usage" (Pipek & Wulf, 2009) and the progress of collaboration practices.

Dimension	Description
Embeddedness	*"Infrastructure is 'sunk' into, inside of, other structures, social arrangements and technologies.*
Transparency	*"Infrastructure is transparent to use, in the sense that it does not have to be reinvented each time or assembled for each task, but invisibly supports those tasks."*
Reach or scope	*"This may be either spatial or temporal - infrastructure has reach beyond a single event or one-site practice."*
Learned as part of membership	*"The taken-for-grantedness of artifacts and organizational arrangements is a 'sine qua non' of membership in a community of practice [..]. Strangers and outsiders encounter infrastructure as a target object to be learned about. New participants acquire a naturalized familiarity with its objects as they become members."*
Links with conventions of practice	*"Infrastructure both shapes and is shaped by the conventions of a community of practice, e.g. the ways that cycles of day- night work are affected by and affect electrical power rates and needs. Generations of typists have learned the QWERTY keyboard; its limitations are inherited by the computer keyboard and thence by the design of today's computer furniture."*
Embodiment of standards	*"Modified by scope and often by conflicting conventions, infrastructure takes on transparency by plugging into other infrastructures and tools in a standardized fashion."*
Built on an installed base	*"Infrastructure does not grow de novo; it wrestles with the "inertia of the installed base" and inherits strengths and limitations from that base. Optical fibers run along old railroad lines; new systems are designed for backward-compatibility; and failing to account for these constraints may be fatal or distorting to new development processes."*
Becomes visible upon breakdown	*"The normally invisible quality of working infrastructure becomes visible when it breaks: the server is down, the bridge washes out, there is a power blackout. Even when there are back-up mechanisms or procedures, their existence further highlights the now-visible infrastructure."*

Table 3: Dimensions of infrastructure (Star & Ruhleder, 1996, p. 113)

Infrastructuring is therefore defined as:

> *"re-conceptualizing one's own work in the context of existing, potential, or envisioned IT tools"* (Pipek & Wulf, 2009, p. 469).

The concept investigates "how results from the ongoing discussion about e-infrastructures can be used to improve the design of IT infrastructures in organizations". It therefore establishes a perspective on organizational IT as work infrastructure, elaborates on possible use of concepts from the e-infrastructure discussion, and describes "the methodological approach of infrastructuring to develop methodological and tool support for all stakeholders' activities that contribute to the successful establishment of an information system usage". The perspective is motivated by the increasing number of IT devices as well as the dependency of the users on a certain quality of service (Pipek & Wulf, 2009).

The related (and less technical) concept *work infrastructure* (Pipek & Wulf, 2009) corresponds to the full set of systems and practices employed by any given work group. The work

infrastructure only includes what users actually use and how they use it, and not necessarily the full range of facilities available to them, which "they have either chosen or to adopt or failed to become aware of" (Edwards et al., 2009). It also includes locally developed workarounds, shortcuts and combinations of systems and practices not intended by system designers. Therefore, user innovations are also explicitly part of the *work infrastructure*, defined as:

> *"entirety of devices, tools, technologies, standards, conventions, and protocols on which the individual worker or the collective rely to carry out the tasks and achieve the goals assigned"* (Pipek & Wulf, 2009, p. 455).

Accordingly, *collaboration infrastructures* are work infrastructures supporting collaborative work. In order to distinguish the "whens of design", Pipek and Wulf (2009) describe layers of infrastructuring: *Infrastructural background work* corresponds to basic technology and work developments, *preparatory design work* and *preparatory work development* includes activities that indicate an intention of use and engage technology to support a certain work. *In-situ design work* includes tailoring, configuration, appropriation and negotiating the actual work (Figure 1).

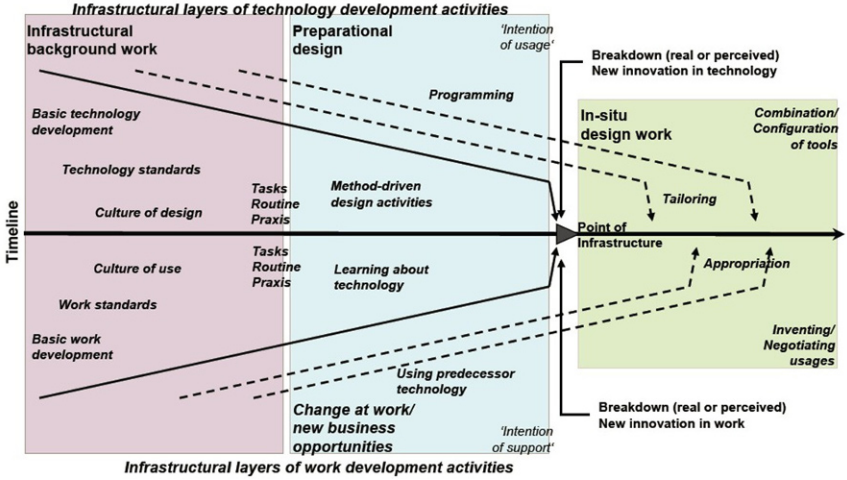

Figure 1: Infrastructural layers of technology development activities (Pipek & Wulf, 2009)

In-situ design work usually occurs after a *point of infrastructure*, the "moment when an infrastructure becomes visible" (Pipek & Wulf, 2009). Temporary infrastructure breakdowns, where the users experience an "insurmountable incongruence between the expected infrastructure service and its actual or perceived behavior" are an example for that point. There, the normally invisible elements of the work infrastructure become visible and "users successfully appropriate a new infrastructure for a local context". Concerning the design of IS, internal (things to modify/design) and external (issues to consider) aspects can be distinguished. Regardless, IS are a special type of infrastructure due to their unique versatility (IS may be used for many purposes), and their reflexivity (designers and users are part of the same infrastructure). The infrastructure therefore can be processed reflexively within the infrastructure, allowing design-before-use and design-in-use and in turn allowing its emergence. Ciborra and

Hanseth (2000) even postulate that, "infrastructures tend to *drift*, i.e. they deviate from their planned purpose for a variety of reasons often outside anyone's influence" which leads towards and "understanding of infrastructure as an embedded and drifting institution".

2.6 Research Potentials

Emergent collaboration occurs in many scenarios if the supporting infrastructures allow it. Infrastructuring aims to also support uses of the infrastructure, which have not been intended by the designer. According to its characteristics, the chosen application field of crisis and emergency management is probably one of the most suitable examples of the need for and occurrence of, emergent collaboration. It includes "uncertainty […] because the development of an extreme incident is rarely predictable" (Mendonça, 2007), "disruption of infrastructure support" (Chen et al., 2008) and users "rely heavily on manual methods for data sharing" (Hobson et al., 2011), which are exemplars of points of infrastructure (Pipek & Wulf, 2009). Furthermore crises require (collaborative) improvisation (Adrot & Robey, 2008; Ciborra, 1996; Mendonça & Wallace, 2007; Stein, 2011; Weick, 1993).

The exemplary application field of crisis and emergency management therefore offers enormous potential for further research on infrastructures for emergent collaboration. Related work on CSCW, groupware, social software, emergence, improvisation (chapter 2.1), crisis management (chapter 2.2), inter-organizational collaboration, information and expertise sharing (chapter 2.3), public participation (chapter 2.4) and infrastructuring (chapter 2.5) presented in this chapter illustrate many insights for emergent collaboration infrastructures. Furthermore, related work illustrates many possible approaches for future work: Turoff et al. (2004), for instance, describe research opportunities in the area of "collaborative knowledge bases". Cunha et al. (1999) identify an "unresolved issue [which] is the need for close relationships between those improvising", suggesting an application field for CSCW. Cai (2005) mentions a potential for collaboration in GIS, which have only partly been addressed, e.g. by Convertino et al. (2011) in terms of activity awareness, and Wu et al. (2013) in terms of geospatial planning tasks. Approaches to supporting improvisation typically do not have the ability to consider ad hoc tasks (Wu et al., 2013) or to consider an integration of new actors from outside one's own organization to situation assessment in an ad hoc manner (Monares et al., 2011). Furthermore, in most approaches officers-in-charge are information providers and consumers, whereas units on-site are primarily information providers (Nilsson & Stølen, 2010).

Insufficient studies focus on research into methodologies to design emergent collaboration infrastructures using empirical studies in inter-organizational crisis management. In consequence, considering actual collaboration practices in order to design ICT artifacts is unusual. There is, therefore, an evident need for research, which considers actual collaboration practices and the real – not just intended – use of technologies to support them and the impact on collaborative practices on information technology design and use.

3 Research Design

3.1 Conceptual Background

My dissertation researches emergent collaboration infrastructures. Therefore, the aim is to provide a detailed perspective on collaboration practices and work infrastructures as well as to design ICT for (inter-)organizational crisis management. This work follows, as stated above, the *infrastructuring* approach (Pipek & Wulf, 2009) to IT development, a perspective on organizational ICT as work infrastructure (chapter 2.5). The concept is used to distinguish it from notions of design that only refer to professionalized design activities, and aims to improve work infrastructures with all efforts "that contribute to the successful establishment of an information system usage" (Pipek & Wulf, 2009). The work infrastructure therefore also includes workarounds. It describes all designer and user activities that contribute to the successful establishment of an ICT usage (intended or emerged), which is equivalent to a work infrastructure improvement. According to that concept, improvements in work infrastructures usually occur at the *point of infrastructure*. This happens during an innovation in work, use or technology, and during a real or perceived breakdown of work infrastructures, because at that point designers and user think about possibilities to handle the actual situation. New patterns of usage, even so, sometimes go beyond those intended by the designers. IT systems therefore must allow for those spontaneous improvised actions.

As the electricity infrastructure is an important basis for many activities of everyday private and professional life, I treat breakdowns in that infrastructure as illuminating the themes elaborated above. All stakeholders involved in scenarios of medium and large power outages already have and use ICT in coping and recovery work. ICT infrastructures here are the main basis for communication, coordination and collaboration in crisis management situations. The failures and shortcomings of ICT in this context, I suggest, can motivate and inform the development of IT for crisis management. Furthermore, power outages and related crises are scenarios where the actors responsible for crisis response have to collaborate, especially police and fire departments, public administration and power suppliers. The application field of crisis management therefore looks appropriate.

One prerequisite to support this move to designing innovative ICT to improve work infrastructures is a deep understanding of the practice in the field. Therefore, in this case, an understanding of the cooperation practices is also necessary. In order to overcome these challenges *design case studies* (Wulf et al., 2011; Wulf, 2009) serve as a methodological approach. As mentioned in the introduction they consist of three phases: (1) an empirical analysis of the given practices, (2) the innovative design for an ICT artifact related to the findings of the first phase, and (3) an evaluation of the appropriation of the artifact. The empirical analysis of the given practices contains detailed descriptions of social practices and used tools. IS is not a purely descriptive discipline but deals with the design of ICT and their effect on social practices. Design case studies should therefore document in-depth description of existing practices to inform the second phase of a context-oriented design process, methods used and developed design concepts. It should describe how anticipated changes in social

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practices were involved in the design process and how these considerations have been incorporated into the design of ICT artifacts. A third phase is the introduction, appropriation and redesign of ICT artifacts in their respective organizational fields of application for an extended period, in order to research their effect on social practices. The different phases were conducted in a cyclic way related to the respective working practices and designed IT artifacts (Rohde, 2007).

This research is inspired by Lewin's *action research* as "comparative research on the conditions and effects of various forms of social action and research leading to social action" that uses "a spiral of steps, each of which is composed of a circle of planning, action, and fact-finding about the result of the action" (Lewin, 1958). In our case "planning" is the empirical analysis of the given practices, "action" is the design and use of suggested ICT artifacts, and the evaluation leads towards "fact-finding about the results of the action". This interpretation follows Hevner and Chatterjee's suggestion (2010) to integrate action research with design research. A *design science* approach, consisting of the design of an artifact for a relevant problem combined with rigorous evaluation methods for the design, is used to create the artifacts (Hevner et al., 2004). The analysis of the empirical data material was based on the *grounded theory* method according to Strauss (1987), an inductive approach which does not entail any hypothesis testing but which instead is data-driven. That is, data is collected before any theory is developed and the processes of constant comparison and theoretical sampling drive the organization of data into categories. *Open coding* (Strauss, 1987) was used to analyze the material and to uncover interesting phenomena. The focus that emerged was on the breakdowns of practices or practice innovations (Pipek & Wulf, 2009) that depend on inter-organizational collaboration, and the methods that participants used to deal with them. The knowledge previously acquired in the literature study was used to heighten the *theoretical sensitivity* (Strauss, 2004). A part of the grounded theory method is *theoretical sampling*, which means that the selection of the studied units is led by the theory, which emerges in the analysis.

3.2 Research Setting

The empirical parts of this study involved mainly actors of BOS such as police and fire departments, public administration, energy network operators (ENO), partially aid agencies, THW and citizens. Most empirical work took place at the observants'/interviewees' workplaces. In order to improve the relevance this study was conducted in two regions, both in the German federal state of North Rhine Westphalia: the districts Siegen-Wittgenstein (A) and Rhein-Erft (B).

District A (Siegen-Wittgenstein) is densely wooded and hilly and located in the middle of Germany. Much of its industry is based on metalwork (e.g. mechanical engineering). The center of the region is the city of Siegen. The county lies on the border of three federal states – and different structures in emergency management may therefore interfere. It has an area of 1,131.47 km^2, a population of 281,585 and a density of 250/km^2. The county has four companies that require external emergency planning. The firefighters are mostly members of voluntary fire departments. Only members of the control center have salaried positions. It is a more rural district. Conversely, the more urban district B (Rhein-Erft) consists of ten growing communes in the west of Cologne with a huge number of large chemical and power plants.

Some of Germany's most important transportation infrastructures, which involve specific risks, like highways, airports, railroads and the river Rhine, are located here. It has an area of 704.54 km^2, a population of 465,578 and a density of 660/km^2. The county has 24 companies that require external emergency planning. The district provides many professional fire departments.

3.3 Methods

According to the chosen research framework (Wulf et al., 2011), the first phase is a strong ethnography to capture existing practices. One aim is the identification of information and collaboration needs that cannot be covered by the stakeholders themselves, but requires inter-organizational exchange of information. The view of the field was sensitized by the design intention. A *grounded theory* oriented approach (as mentioned above) was therefore conducted (Strauss, 1987), where the field was not analyzed with predefined categories, but categories were derived from empirical data. To reconstruct the practices, different qualitative methods were used (Randall et al., 2007) such as document analysis (D), observations (O), group discussions (W), and interviews (I, IM) including the development of crisis scenario, and regular user workshops (U) (Table 4). The second phase is the design of ICT, followed by the third phase comprised of empirical evaluations (E, EM). The collected empirical material eventually consisted of 114 pages* of observation, group discussion and user workshop notes, 1108 pages of interview transcripts and 289 pages of evaluation notes and transcripts.

No.	Method	Phase of design case study	n
D	Document analysis	1	-
O	Observations	1	3
W	Group discussions	1	5
S	Development of a scenario framework	1	2
I	Interviews focusing on working practices and IT support	1	23
IM	Interviews focusing on mobile collaboration	2	4
S	Social media analyses	1-2	3
E	Empirical evaluations on situation assessment (ICT artifact: ISAC)	2	12
E	Empirical evaluations on information and expertise sharing (ICT artifacts: ISAC and MoCo)	3	16
EM	Empirical evaluations on mobile reporting and collaboration (ICT artifacts: MoCo and MoRep)	3	12
U	Regular user workshops	1-3	8
PS	IT artifact use in practice: SiRena	2-3	~350
PI	IT artifact use in practice: ISAC, MoCo, MoRep	2-3	25

Table 4: Empirical study at a glance

* Norm-pages of 1,500 signs per page according to *VG Wort* (http://www.vgwort.de), the organization that administrates the rights on literary works in Germany.

3.3.1 Empirical Pre-Study

The primary goal of the document analysis was to obtain an overview of the organizations in crisis situations and their official work practices. Therefore, the aim was to analyze documents that regulate and describe the work in crisis management (laws, regulations, directives and course materials).

The observations (Table 5) were used to acquire knowledge about practical work in inter-organizational crisis management. These were conducted in a control center during a normal working day (observation time: 9 hours), in the crisis management group and in the operations management during a crisis communication training (4 hours) as well as on a major annual cultural event, the NRW-day, reminding at the founding of the federal state of North Rhine-Westphalia, which was hosted 2010 in Siegen, with about 400,000 visitors (9 hours).

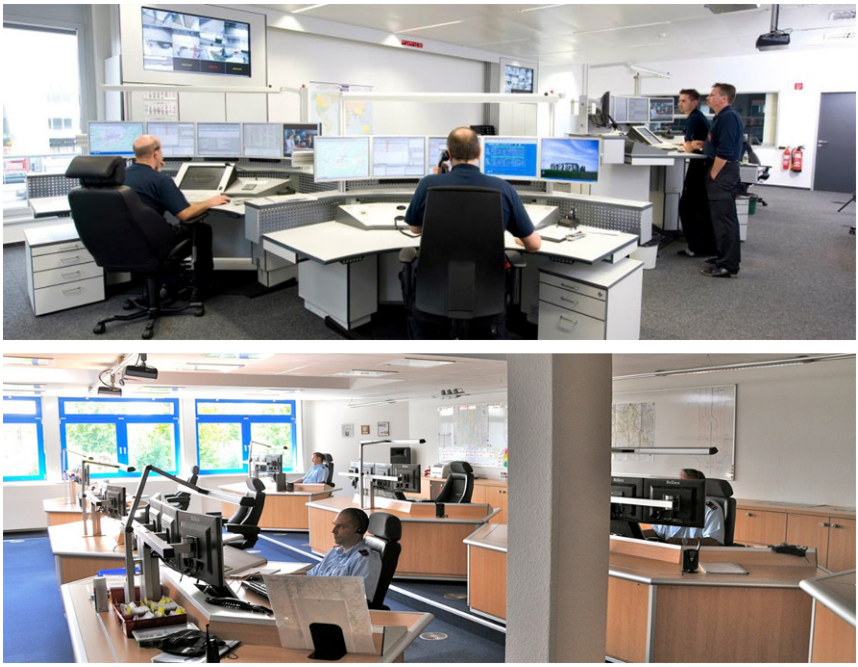

Figure 2: Work in the control center A and B

No.	County	Topic	Participants	Date
O1	A	Normal working day in control center	Control Center Dispatcher	18.11.2010 (9 hours)
O2	A	Crisis communication training	Crisis Management Group and Operations Management	09.09.2010 (4 hours)
O3	A	Major event NRW-day	Crisis Management Group and Operations Management	19.09.-20.09.2010 (9 hours)

Table 5: Observations (2010)

Furthermore, inter-organizational group discussions (Table 6) were conducted to understand the communicative practices in inter-organizational crisis management. We did five inter-organizational group discussions, each lasting about four hours, including the participation of leading BOS.

Figure 3: Group discussions (here: W4)

No.	County	Topic	Participants	Date
W1	both	Challenges in practice, visit of control center	Energy Network Operator (ENO)	17.05.2010
W2	B	Challenges in practice, visit of control center	County Administration, Police, Fire Department	28.06.2010
W3	A	Challenges in practice, visit of control center	Department Head: Public Safety, Head of Civil Protection, Head of Police Control Center, Deputy Head of Control Center, District Fire Chief	20.07.2010
W4	A	Analysis of user interactions and communication flows	Head of Police Control Center, Head of Staff Coordination, Deputy Head of Control Center, Local Head of THW, Local Head German Red Cross	27.10.2010
W5	B	Analysis of user interactions and communication flows	Head Regulatory Authority, District Fire Chief, Red Cross: Disaster Management, Red Cross: Communications, Members of other aid agencies	30.01.2011

Table 6: Group discussions (2010)

One challenge of empirically researching crises is that they mostly happen in unforeseen circumstances. It is therefore difficult to observe practices within an actual crisis, especially on an inter-organizational level with spatially distributed actors. To overcome these circumstances, we and members of ENO, police and fire department developed a scenario framework consisting of a windstorm with many incidents and energy breakdowns for each participating county (see appendix A and B). The purpose of our scenario was to be able to quickly create a common understanding of a crisis situation and context in our interviews and to recapitulate breakdowns. It helped to increase their validity and comparability and to develop ideas regarding improvements of tools to support improvisational practices.

Based on these scenarios, interviews (Table 7) were conducted in 2010 and 2011 with actors from different positions in the participating organizations. They lasted between one and two hours and followed an interview guide (see appendix C). They allowed us to analyze the work context and the use of information and communication systems of relevant actors. The first part of the interview focused on the participants' role, qualification, activities and work steps in normal conditions. The second part covered their tasks in crisis situations and was based on the developed scenario framework. The third part covered information and communication systems as well as perceived problems with these tools.

No.	County	Organization	Role	Date
I01	A	Administration	Regulatory Authority	21.02.2011
I02	A	Police Department	Head of Control Center	18.01.2011
I03	A	Police Department	Head of Section	03.02.2011
I04	A	Police Department	Patrol Duty	28.02.2011
I05	A	Fire Department	District Fire Chief	22.02.2011
I06	A	Fire Department	Deputy Head of Control Center	17.01.2011
I07	A	Fire Department	Workmanship	28.02.2011
I24	A	Fire Department	Head of Control Center	26.08.2010
I08	B	Administration	Office Civil Protection	10.12.2010
I09	B	Fire Department	Chief Officer / Chief of Fire Department	06.04.2011
I10	B	Fire Department	Operation Controllers	06.04.2011
I11	B	Fire Department	Clerical Grade Watch Department	06.04.2011
I12	B	Fire Department	Control Center Dispatcher	27.04.2011
I13	B	Fire Department	Head of Control Center	27.04.2011
I14	Both	Police Department	Member of the Permanent Staff	08.04.2011
I15	B	Police Department	Head of Control Center	06.04.2011
I16	B	Police Department	Head of Group	21.04.2011
I18	Both	Energy Network Operator	Higher Area, High Voltage	28.01.2011
I19	Both	Energy Network Operator	Operation Engineer, High Voltage	28.01.2011
I20	Both	Energy Network Operator	Operation Technician, Low Voltage	02.02.2011
I21	Both	Energy Network Operator	Dispatcher, Low Voltage	02.02.2011
I22	Both	Energy Network Operator	Workmanship Technical Incidents	01.03.2011

Table 7: Interviews on working practices and IT support (2010-2011)

To study the mobile collaboration practices more closely five additional, partially structured, interviews were conducted in 2012 (Table 8), in which the current practices were studied, also in regards to the creation, exchange and use of information by the response teams and the work in the control center (see appendix D). They lasted on average 60 minutes.

No.	County	Organization	Role	Date
IM01	A	Police Department	Head of Control Center (=I2)	20.05.2012
IM02	A	Fire Department	Control Center Data Support / Digital Radio (=I24)	30.05.2012
IM03	A	Fire Department	Administrator Control Center	30.05.2012
IM04	A	Police Department	Department Chief Control Center	05.06.2012
IM05	B	Fire Department	Head of Control Center (=I13)	18.06.2012

Table 8: Interviews on mobile collaboration and reporting (2012)

In addition, to study the collaboration work of citizens, the use of social media during three crises has been analyzed (Table 9).

No.	Topic	Date
S1	Flight cancellations in the course of the volcanic eruptions of Eyjafjallajökull in Iceland (see chapter 4)	15.-21.04.2010
S2	Love Parade disaster in Germany (see chapter 4)	24.07.2010
S3	Super Outbreak in the USA (see chapter 10)	19.-20.04.2011

Table 9: Social media analyses

3.3.2 Conception and Design of ICT Artifacts

Based on the empirical pre-study and its analysis, we designed and developed ICT to support the challenges in the field that we had identified. The aim of the first IT artifact, SiRena, was to act as a basic infrastructure for both technical infrastructure and for long-term end-user involvement in participatory design processes (Ogonowski et al., 2013) in order to create and validate prototypes that takes real use into account (Eriksson et al., 2006). The IT artifacts were implemented in order to evaluate the suitability of the empirically determined approaches and help in answering the research questions. Details about the artifacts are presented in chapter 12.

#	Role	Limited Roll-Out	"Full" Roll-Out
1	Basic Infrastructure: Inter-Organizational Social Network (SiRena)	10.11.2011	28.01.2012
2	Inter-Organizational Situation Assessment Client (ISAC)	11.02.2013	29.08.2013
3	Mobile Collaboration Application (MoCo)	11.02.2013	29.08.2013
4	Mobile Reporting Application (MoRep)	11.02.2013	29.08.2013

Table 10: Main technical artifacts within this thesis (2011-2013)

3.3.3 Evaluation

The evaluations aimed to answer the research questions and to improve the artifacts in question. The aim of the interim evaluation of the *Inter-Organizational Situation Assessment Client* (ISAC) in 2011 was to get user feedback on the general system design, possible use cases

and associated design limitations, which formed an early basis for an improved design of the second IT artifact. The functionality of the first prototype was still limited and not suitable for real-use testing, so we chose a scenario-based user testing under controlled conditions. The tests were conducted at the users' workplaces and lasted between 1 and 1.5 hours. Twelve users participated in the study (Table 11).

No.	County	Organization	Role	Date
E01	A	Police Department	Head of Control Center (=I02)	05.08.2011
E02	A	Police Department	Head of Section	05.08.2011
E03	A	Fire Department	Deputy Head of Control Center (=I24)	14.08.2011
E04	A	Fire Department	Head of Control Center (=I06)	04.08.2011
E05	both	Energy Network Operator	Operation Engineer, High Voltage	14.07.2011
E06	both	Energy Network Operator	Dispatcher, Low Voltage	29.06.2011
E07	both	Energy Network Operator	Higher Area, High Voltage	14.07.2011
E08	B	Police Department	Head of Control Center	24.08.2011
E09	B	Police Department	Head of Group	19.08.2011
E10	B	Fire Department	Head of Control Center	13.07.2011
E11	B	Fire Department	Operation Controllers	13.07.2011
E12	B	Fire Department	Head of Control Center	13.07.2011

Table 11: First evaluation of the Inter-Organizational Situation Assessment Client (2011)

At the beginning of the test, the IT artifact and its basic functionality were briefly introduced to the participants. In the next step they had to use the system independently and solve predefined tasks. Participants were asked to think aloud (Nielsen, 1993) and comment on their actions to be able to track and understand possible design and usability issues. In a follow-up interview they were asked about their personal experience and assessment concerning their first impression, individual system description, system handling, conceivable use cases in personal work context, requirements to make the system usable, collaborative situation assessment and missing information needs (see appendix E).

In 2012 we rolled out the *Inter-Organizational Social Network* (SiRena) as the basic infrastructure for our IT artifacts. Based on the interim-evaluation, the redesigned and improved ISAC was implemented as a plugin system for SiRena. Most of the participants of the second ISAC evaluation in 2013 were already members of SiRena and familiar with it. To keep the number of test persons manageable, only a predefined selection of 16 of the 350 registered SiRena users were invited to participate in the field-test (Table 12). We organized a roll-out workshop for each organization, where we gave participants a brief introduction into the system and its use. ISAC was then unlocked for the participating users for unrestricted use. After a three to five week evaluation period, we conducted interviews with the participating users to find out if the system was usable under real-use conditions and what the conceivable use cases were (see appendix G). Most of the interviews were conducted individually and lasted between 30-45 minutes. Two interviews were group interviews (police and fire department in county A) because of organizational and work shift scheduling reasons. Each group interview lasted about 60 minutes. The sessions were audio-recorded and transcribed for subsequent analysis.

No.	County	Organization	Role	Date
E13	A	Red Cross	County Head	11.02.2013
E14	A	Fire Department	Fire Chief, Administrator Control Center (=IM03)	11.03.2013
E15	A	Fire Department	Deputy Head of Control Center (=I24)	11.03.2013
E16	A	Fire Department	Head of Fire Department	11.03.2013
E17	A	Police Department	Head of Section	12.03.2013
E18	A	Police Department	Staff of Control Center	12.03.2013
E19	A	Police Department	Staff of Control Center	12.03.2013
E20	A	Police Department	Staff of Control Center	12.03.2013
E21	A	Police Department	Head of Control Center	12.03.2013
E22	both	Energy Network Operator	Operation Engineer, High Voltage	05.03.2013
E23	both	Energy Network Operator	Operation Engineer, High Voltage	05.03.2013
E24	B	Police Department	Staff of Control Center	08.03.2013
E25	B	Police Department	Data Administration, Control Center	08.03.2013
E26	B	Police Department	Staff of Control Center	08.03.2013
E27	B	Fire Department	Workmanship	18.03.2013
E28	B	Fire Department	Staff of Control Center	18.03.2013

Table 12: Second evaluation of the Inter-Organizational Situation Assessment Client (2013)

Figure 4: Evaluation of ISAC and MoCo in the control center (2011-2013)

We also evaluated the mobile applications *Mobile Collaboration* (MoCo) and *Mobile Reporter* (MoRep) (Table 13). Although our applications had been fully implemented, IT security regulations, privacy and documentation concerns of the BOS prevented us from having an in-use evaluation. We evaluated the applications with practitioners in police and fire stations in a scenario-based walkthrough and follow-up interviews (appendix F) and discussed with them how mobile collaboration systems (MoCo) and dynamic semi-structured requests (MoRep) might support current decision processes. The evaluation sessions lasted in average 45 minutes and eleven persons from police and (professional and volunteer) fire departments participated in different sessions. With this selection of interview partners the impressions and

experiences of communication partners on different levels within the chain of command could be gathered and evaluated. In each evaluation, the functionality of the application in different situations was introduced by referring to operations mentioned by the interviewees in the empirical study was demonstrated. The demonstration was an interactive session, where the users directly explored the application. The participants were again asked to make remarks using a *thinking aloud* protocol (Nielsen, 1993). After the demonstration, the participants were asked questions regarding practice-oriented use, e.g.: (a) What are possible implications of use? (b) Under what conditions can the concept and application support current working practices? (c) What are limitations concerning the usage? The workshops were audio-recorded and later transcribed. After the evaluations the users were able to continue using the applications.

No.	County	Organization	Role	Date
EM06	A	Police Department	Head of Agency Strategy (=I02)	14.07.2012
EM07	A	Police Department	Head of Section	14.07.2012
EM08	A	Police Department	Head of Section	14.07.2012
EM09	A	Police Department	Executive Staff	14.07.2012
EM10	A	Police Department	Executive Staff	14.07.2012
EM11	A	Fire Department	Fire Chief, Administrator Control Center (=E14)	27.07.2012
EM12	A	Fire Department	Municipal Fire Inspector	04.03.2013
EM13	A	Fire Department	Volunteer Fire Chief	04.03.2013
EM14	A	Fire Department	Volunteer Workmanship	04.03.2013
EM15	A	Fire Department	Volunteer Workmanship	04.03.2013
EM16	A	Fire Department	Volunteer Workmanship	04.03.2013

Table 13: Evaluation of the mobile collaboration and reporting application (2012-2013)

Figure 5: Evaluation of MoCo and MoRep in the control center (2012-2013)

Figure 6: Evaluation of ISAC, MoCo and and MoRep in the control center (2011-2013)

Besides the explicit methods, we conducted an informal, unstructured data collection in about 25 meetings and workshops during a 36-month research project. Mentionable are the regular user workshops (Table 14) with participants from the empirical study.

No.	County	Topics	Date
U-A1	A	Introduction of the overall concept	27.07.2011
U-A2	A	Presentation of SiRena and role models	21.09.2011
U-A3	A	Rollout of SiRena	10.11.2011
U-A4	A	Reflection on first impressions of SiRena	13.12.2011
U-A5	A	The role of skills in SiRena	31.01.2012
U-A6	A	Use cases for SiRena and ISAC	26.03.2012
U-A7	A	Introduction of ISAC	24.10.2012
U-B1	B	Introduction of the overall concept	19.09.2011
U-B2	B	Rollout of SiRena	08.11.2011
U-B3	B	Reflection on first impressions of SiRena	07.12.2011
U-B4	B	The role of skills in SiRena	14.02.2012
U-B5	B	Use cases for the SiRena and ISAC	23.04.2012

Table 14: Regular User Workshops (2011-2012)

3.4 Summary

This section has outlined the research approach, the research setting and the methods used within this work. This work follows the *infrastructuring* approach (Pipek & Wulf, 2009) to IT development, a perspective on organizational ICT as work infrastructure. *Design case studies* (Wulf et al., 2011; Wulf, 2009), consisting of empirical study, conception of ICT artifacts and evaluation, serve as a methodological approach. The analysis of the empirical data material was based on the *grounded theory* method according to Strauss (1987), an inductive approach which does not entail any hypothesis testing but which instead is data-driven. The empirical parts of this study involved mainly actors of BOS such as police and fire departments, public administration, energy network operators (ENO), partially aid agencies, THW and citizens in two regions, both in the German federal state of North Rhine Westphalia: the districts Siegen-Wittgenstein (A) and Rhein-Erft (B). To reconstruct the practices, different qualitative methods were used such as document analysis (D), observations (O) (Figure 7), group discussions (W), and interviews (I, IM) including the development of crisis scenario, and regular user workshops (U). The second phase is the design of ICT, followed by the third phase comprised of empirical evaluations (E, EM).

Figure 7: Inter-Organizational Collaboration in Crisis Management during a Crisis Training

Part II:
Selected Findings

The second part of this dissertation presents sub-findings related to the questions outlined in the first part. The chapters in this part have already been published and resemble the accepted or current versions of reviewed journal or conference papers with minor changes.

Chapters 4 to 6 present conceptual considerations and empirical results: Chapter 4 derives a classification matrix for cooperative work in crisis management, taking the different actors into account that helps to distinguish between different collaboration scenarios. Chapter 5 presents the results of an empirical study on improvisation practices during coping and recovery work by BOS. Based on the empirical study chapter 6 analyzes the interconnections in collaborative generating and sharing information over geographic distances and outlines approaches that foster information quality related to collaboration scenarios.

Chapters 7 to 10 contain concepts, implementations and their evaluations in practice: Chapter 7 focuses on scenario A: *information and expertise sharing* and derives the concept, implementation and evaluations of ISAC, a web-based system to support information aggregation and visualization using geographical information systems. Chapter 8 considers scenario B: *ad hoc participation in mobile collaboration* and presents the concept, implementation and evaluation of MoCo, a mobile application to ad hoc share ISAC information beyond local and organizational boundaries and to expand the group of people participating in situation assessment. Chapter 9 researches scenario C: *articulation work in mobile reporting* and presents the concept, implementation and evaluation of MoRep, a mobile semi-structured request-and-report application. Chapter 10 presents further possibilities to integrate emergent collaboration among citizens and volunteers.

4 Crisis 2.0: Towards a Systematization of Social Software Use (IJISCRAM)

In this paper, we propose a systematization of social software use in crisis situations, examining different types of cooperation and challenges. We discuss how the organizational actors involved in crisis management (police, fire-fighters, organizations, etc.) and the affected citizens are communicating and can communicate and collaborate through the use of social software. After defining the term *social software*, we outline its use in crisis management. We present two case studies where they have examined the use of social software in 2010: first during the disruption of air travel caused by the eruptions of the volcano Eyjafjallajökull in Iceland and second during the mass panic at the Love Parade music festival in Germany. Based on both previous work and case studies, we discuss potentials and weaknesses and propose a classification matrix for different types of cooperation as a step toward a systematization of social software use in crisis situations.*

4.1 Introduction

There have been crises and disasters at all times. Crises are situations that the normal structural and process organization cannot overcome (BSI, 2008). Disasters are large events that last for a considerable time, affect large areas and have widespread consequences on people, values and objects (BSI, 2008). In the last decades many crises came up, not only because of changes in climate. There are not just tsunamis, floods, earthquakes or wildfires: technical accidents such as oil leakages, energy breakdowns or crises caused by humans, e.g. spree killings and terror attacks, affect both, organizations and people. The pictures of those accidents can be seen always in old and new media: cities in exceptional circumstances, a large number of injured people and often no functioning infrastructure. Those responsible for crisis management may find it hard to obtain essential information to make reasonable decisions and to help the people affected by the crisis. This can be due to a lack of infrastructures for cooperation between people and organizations. Anyway, people are an authentic source of crisis-information and should be included in the information infrastructure. Palen and Liu (2007) point out that organizations of formal response may be shaped to "support the new information pathways that will arise". People often use mobile phones and the Internet to inform their families and friends. Using social software applications, such as social networks, blogs, micro-blogs, photo and video communities, a lot of information is published by everyone.

The aim of this paper is to suggest a systematization of the use of social software in crisis situations, which allows deriving different types of cooperation and developing related requirements. We therefore first describe major categories of social software and review the

* This chapter has been published as an article (Reuter, Marx, et al., 2012):

Reuter, C., Marx, A., & Pipek, V. (2012). Crisis Management 2.0: Towards a Systematization of Social Software Use in Crisis Situations. *International Journal of Information Systems for Crisis Response and Management (IJISCRAM)*, 4(1), 1–16, DOI: 10.4018/jiscrm.2012010101.

Earlier ideas have also been published (Reuter, Marx, et al., 2011a, 2011b).

C. Reuter, *Emergent Collaboration Infrastructures,*
DOI 10.1007/978-3-658-08586-5_4, © Springer Fachmedien Wiesbaden 2015

related state of the art. Furthermore we enhance it with data from our own case studies in Germany, where we observed the social software use at two major events, particular about the relationship of organization and citizen. Based on a discussion on both literature and case studies and the identification of both strengths and weaknesses we suggest a systemization of cooperation in social software use for crisis management.

4.2 Potential Social Software in Crisis Communication

Social software is a part of Web 2.0. The term *Web 2.0* is not well defined but describes the innovations of the Internet after the crash of the *new economy* in 2000 (Alby, 2007). At a conference held by O'Reilly, the competences of the surviving companies of the new economy were summarized under the term Web 2.0. O'Reilly (2005) defined them in seven characteristics which include the usage of the Internet as a platform to provide different services, the participation of users and a collective intelligence, the consideration of the user generated data as capital of an application, the inclusion of the user in the development using new software development models, the usage of services on different terminals and rich user experience. The term *social software* describes web-based applications, which support the user's interaction and communication process. In addition to this definition, there are various other considerations. Hippner (2006) defined social software as the possibility to exchange information, manage relationships and communicate in a social context. Besides the exchange of information, Ebersbach et al. (2008) have defined that user-generated content is an essential element of social software. Therefore, the existence of a community is an important precondition.

The following characteristics arise from the different definitions and will be used in this paper: Social software encompasses a range of applications from the Internet, which enable different people to contact and interact with each other. A community providing the data is the basis of these applications and they support different activities: the allocation of information, the generation of information, relationship management, communication and self-expression. Different activities are often combined. Based on the definition of these activities, various classes of social software applications can be distinguished (Ebersbach et al., 2008):

Wikis aim at a collaborative accumulation and creation of information and knowledge. They are useful to collect knowledge of a topic based on one's own research. In a crisis, this activity may be done by people who are not seriously affected by the crisis.

Blogs support the publishing of information and self-expression through an individually owned journal. They are not useful as a fast response as they often contain longer personal entries. *Micro-blogging* is an alternative. These applications use allow entries limited to 140 characters, similar to text messages. The most prominent application is *Twitter*. Users can publish messages (tweets) on their site and tag words (#hashtag) within a message. With the help of these tags, certain messages can be found. It is possible to address other users with the '@user' notation. It is also possible to publish tweets by sending text messages using a mobile phone. Due to the tweet's text message-like structure, tagging and easily finding tweets about specific topics, its huge dissemination with over a 100 million users worldwide and its mobile usability, Twitter is a significant social software for crises.

Social networks were originally used for relationship management, self-expression and communication, but now these applications are more and more incorporating by functionalities related to blogging and the exchange of information. An example for a social networking service that offers good opportunities for crisis communication is Facebook. In addition to networking with people, organizations, companies or celebrities are possible. Each profile includes a wall where people can leave messages or where the owner of the profile can post his/her own status messages. The entries can include text, links, photos, videos and other users can add comments. On the wall a dialogue between individuals and organizations is possible. Facebook provides a client for various mobile devices making it possible to upload profile information from almost everywhere. People with older devices can receive updates through text messages and in turn update their own pages by sending their own messages via SMS. Lastly, the wide acceptance of Facebook, there are about 800 million active users worldwide, makes it the largest online community – one of the most important reasons why we recommend its use in crisis management.

Social sharing enables the user to generate and categorize digital content. Photo and video communities are the most interesting for crisis communication. The most popular are Flickr for sharing photos and YouTube to share video clips. Both services allow the indexing of uploaded content using self-selected tags describing the content and making a targeted search possible. Flickr offers several ways to interact with the website; one option is a website optimized for mobile devices, another is uploading photos via e-mail. YouTube offers a mobile version of the page, which supports the recording and uploading of clips by using a mobile phone. Flickr also lets users geo-tag pictures that can then be placed on a map, or be displayed with additional image information using EXIF data.

When a crisis impends, quick reaction is necessary. Therefore, information about the incident is needed. For social software this means that the user has to provide his/her information in real time on the Internet. Not every type of social software is adequate for this. Regarding the potentials of different types of social software, in this paper we will focus on micro-blogs, social networks, social sharing and the provision of content with an eye on classifying social software use in crisis management.

4.3 Literature Review: Use of Social Software in Crisis Management

Social software has been used in crisis management for at least 10 years: Already after the terrorist attacks of September 11th (2001), wikis, created by citizens, were used to collect information on missing people (Palen & Liu, 2007). In a study on the information search behavior during the forest fires in southern California in 2007, it was noted that people affected by the fires communicated via mobile phones. Furthermore, they used the Internet to search for information and to trigger any kind of communication, to read blogs, news sites and forums. They made use of photo-sharing services like *Flickr* in order to obtain information (Sutton et al., 2008).

Many published research papers focus on crises in the USA, and many of them on the use of Twitter. The use of Twitter was analyzed scientifically in the context of various crises such as in the case of technological failures (Sutton, 2010), the flood of the Red River (Starbird et al., 2010), an attack on four police officers in Lakewood, Washington (Heverin & Zach, 2010), hurricanes (Hughes & Palen, 2009) and earthquakes (Qu et al., 2011). The focus of these in-

vestigations was on the general examination of all messages that had been twittered during the particular crisis. Objects of analysis included the geographical distribution of Twitter users around the trouble spot, their group membership (individual person, organization, journalist, activist, etc.), their daily Twitter activity, the number of tweets per user and the number of responding tweets, retweets and broadcasts. The observers tried to show what distinguishes the Twitter experience in a crisis from everyday Twitter usage (Hughes & Palen, 2009). As for Twitter messages it has been found that twitterers assume the role of the classical media if the news coverage by the media and other organizations is not satisfactory (Sutton, 2010). Within the first hour of an emergency, using Twitter to retrieve information is almost essential. It takes up to 24 hours for mainstream media to catch up to the average level of information quality on the Twitter network (Mills et al., 2009). Twitter can raise awareness of a crisis, as it is able to reach a large numbers of people all at once. Therefore, the service is often used as a broadcast medium (Hughes & Palen, 2009). False information is prevented from being spread by the collective intelligence of users, who ensure that faulty tweets are corrected. In this context, retweets serve as an evaluation mechanism for important information (Starbird et al., 2010). A study on the use of a Chinese microblogging platform very similar to Twitter during an earthquake in China in 2010, found that it cannot only be used to collect information, but also can be used to coordinate actions, exchange opinions and assist in emotionally processing the disaster (Qu et al., 2011). Twitter is also used by organizations, such as the fire department, to obtain citizen-generated content and also to publish their own information (Latonero & Shklovski, 2011).

A study of the geographical distribution of Twitter users has shown that people, who are not affected or only slightly affected, use Twitter more often than citizens and organizations that are affected much more seriously. However, the information generated by those who are not involved, is of great help to those affected by the crisis or disaster (Sutton, 2010). While looking into the habits of individual Twitter users, it was discovered, that there are so-called *information brokers* (Hughes & Palen, 2009), who collect information from various valid sources, and pass it on to help victims of the crisis (Sutton et al., 2008; Vieweg et al., 2008). In these exceptional situations, the broadcast and brokerage of information plays an important role. They occur much less often in everyday Twitter activities (Hughes & Palen, 2009). Activities, tasks and domains can be identified as mechanisms of self-organization for digital volunteers in times of crisis (Starbird & Palen, 2011). During a rampage, the decentralized problem-solving behavior of students was observed: a short time after the beginning of the attack, they used Facebook to attempt to identify the victims together and used Facebook's group function for that purpose (Vieweg et al., 2008). An important conclusion can be drawn from this study, which is that the assumption that rumors are spread via social software, is wrong. The authors show that the collective intelligence of citizens helped to correctly identify the victims, because users were concerned about reliable sources in this particular situation.

In addition to these studies on user behavior and the use of social software in crisis situations, other articles propose solutions for including citizen-generated information in crisis management. The program TED - Twitter Earthquake Detector - is based on tweets, and scans for (previously defined) crisis-relevant hashtags (Guy et al., 2010). Relevant tweets are filtered and archived. The application is used during earthquakes to close the gap of about 20 minutes between the first quake and the publication of scientific data. The idea of including citizen-generated information is very helpful but unfortunately it also bears some problems. By fo-

cusing specifically on Twitter, the range of opportunities for citizens to help by using social software is not entirely covered. The use of visual information, for example during floods, is also left out by TED.

Vieweg et al. (2010) analyzed the structures of twitter messages in order to detect information categories used in tweets to describe aspects of crisis situations. Based on these findings Starbird and Stamberger (2010) proposed the use of a particular hashtag-syntax for tweets during crises. A standardized hashtag-syntax would be machine-readable and could help to collect information that is more relevant. In another study, Latonero and Shklovski (2011) monitored the Twitter-use of a Fire Department to obtain citizen-generated information. Another proposal for the treatment of user-generated data is being provided by Bellucci et al. (2010): their project eStoryS is a social software mash up, that identifies crisis-related photos from the *Flickr* API, and arrange them on a map. A similar function is provided by the TED system, which can display tweets on a map. Goolsby (2010) considers the ad hoc crisis community Ushahidi, which uses social media as a crisis platform to generate community crisis maps.

Raman et al. (2010) suggests that wiki technology can be used to manage knowledge for emergency response. *Scipionus* is an example for a crisis-related wiki, which arose during the fight against the effects of Hurricane Katrina. It deploys a visual interface which allows its users to publish and edit information on the Google Map Interface (Palen, Vieweg, et al., 2007). Further examples are Emergency Wiki or Quake Help Wiki (White et al., 2008). Jennex (2010) warns against just adopting social media for crisis response without analyzing its impact on the organization; he suggests combining it with a knowledge management strategy.

To summarize, the following lessons can be learned from the present literature: during crises Twitter can take over the (1) *role of the mass media* if it does not fully cover the needs of the receivers. Twitter is then used as a (2) *broadcast medium* to pass on information to the public. Information is not only meant for the victims, but is addressed to all readers and thus can draw attention to the crisis. As a consequence groups of *digital volunteers* emerge during a crisis (Starbird & Palen, 2011). Another finding in relation to Twitter is the role of (3) *retweets*. They can be considered relevant information, and thus an evaluation mechanism. The importance of a tweet depends on the number of retweets (Starbird et al., 2010). In relation to the usage of any social software, (4) *brokerage* is more common in crisis situations: Users are identified as *information brokers*, when they gather relevant information, prepare them and make them available to other users (Hughes & Palen, 2009). One last very important conclusion that can be drawn from the literature is the fact that (5) *collective intelligence* prevents the spread of false information (Vieweg et al., 2008). Misleading information is detected and corrected because a large group of people receives the information. This important finding helps to judge the validity of user-generated information.

4.4 Case Studies: Volcanic Eruption in Iceland and Love Parade Disaster 2010

Many published research papers focus on crises in the USA. Hence, it is useful to observe the use of social software in Germany. Our focus is to observe the role of the organizations using social software to keep in touch with people affected and these people's perception. Therefore

we observed the use of social software in Germany during two crises in 2010, the volcano eruption in Iceland and the mass panic at the Love Parade in Germany.

4.4.1 Case 1: Use of Social Software during the Flight Cancellations in the Course of the Volcanic Eruption in Iceland in April 2010

In April 2010, the eruption of the volcano Eyjafjallajökull in Iceland caused a huge disruption of air travel across western and northern Europe for a period of six days. Haarhaus (2010) wrote, in a very short article, that some airlines attempted to manage the crisis by offering services to their customers through social software such as Twitter and Facebook, while others failed to inform their customers properly about the development of the crises.

Method: Inspired by this article, we have analyzed the activities of the airlines Lufthansa, EasyJet and AirBerlin on their Twitter and Facebook pages. The three airlines were mentioned in Haarhaus' article. For our study, the period between April 15th, 2010 (the eruption was first mentioned) and April 22nd, 2010 (air travel was resumed) was selected. We observed and analyzed the activities of Lufthansa, EasyJet and AirBerlin on their Twitter and Facebook pages. To obtain relevant information from Twitter and to search for tweets, we used the search engine Topsy (http://topsy.com), on Facebook we gathered information manually from the Facebook wall. Our explorative study aimed at understanding the field and the motives of the infrastructure providers and citizens. We analyzed the data with a focus on the connection between organizations and citizens.

Results: The observation of the Twitter pages showed that all three airlines provided news and constant updates about flight cancellations and the spread of volcanic ash. Most of the tweets provided a link to the news sections of their own websites. Thus, the subscribers were constantly being informed by the companies. Twitter was used very efficiently as a broadcast medium during the crisis by the airlines (Figure 8). Communication with customers was observed on all three channels. Tweets with questions that directly addressed the companies were answered individually. In the channel of EasyJet, questions were either answered immediately or the customers were redirected to EasyJetCare, a special service-channel of EasyJet on Twitter. Although all three companies used Twitter as a broadcast and contact medium for customers, the activities varied. While AirBerlin published 18 tweets in the period from April 15th to 22nd and answered only three personal questions, Lufthansa tweeted 69 times in the same period and replied to about 17 personal customer requests. EasyJet showed the largest activity on Twitter: in addition to the broadcasting of news, many personal tweets were answered, mainly because this airline was operating on two Twitter-channels to provide customers with quality service.

On Facebook, AirBerlin posted news on their wall, but comments posted by users were hardly taken into account. This shows that AirBerlin did not consider Facebook as a medium for communication with customers. The users of Facebook recognized this and they regularly answered questions that were left unanswered by AirBerlin on Facebook. EasyJet and Lufthansa also used Facebook as a broadcast medium. Unlike Air Berlin, these two companies used Facebook to actively communicate with their customers: the supervisors of the profiles answered almost all of the questions posted to their walls, although most were only referred to the service center.

In summary, taking Twitter and Facebook into consideration as a way of communication within this crisis, shows that many companies use social software as a broadcast medium. Some companies have recognized the potential of those applications and use them to support the communication with customers. From the perspective of their clients, Twitter and Facebook are accepted ways of contacting the companies, although many customers wrote that the first contact happened by phone or mail, afterwards they used social software to get help.

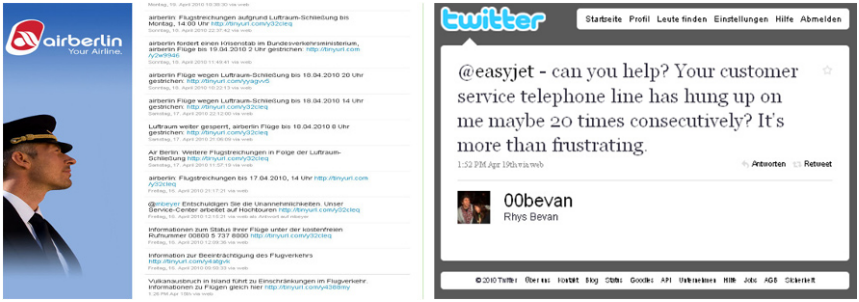

Figure 8: Examples of use of social software caused by the volcanic eruption in Iceland

4.4.2 Case 2: Communication via Social Software during the Love Parade Disaster in Germany on 24th July, 2010

A second case where we analyzed the use of social software was the mass panic that occurred at the Love Parade in July 2010, an electronic dance music festival in Duisburg, Germany, which led to the death of 21 people in the resulting stampede and at least 510 people were injured. Shortly after the incident, many TV reports mentioned that visitors had used social software to warn others about the huge crowd. Pictures and videos taken with mobile phones were offered as first sources, providing insight into the disaster.

Method: Due to these reports, we observed the activities on Twitter, Flickr and YouTube before and after the accident, in order to investigate if participants had been able to deliver information to participating organizations other visitors of the Love Parade in a timely manner via social software. To obtain relevant information and to search for tweets, we used the search engine Topsy (http://topsy.com), for Flickr we used its own search engine and YouTube videos were filtered with Google Video. We concentrated on Twitter messages exchanged from 9 a.m. to 10 p.m. on July 24th, 2010, videos uploaded on the same date and photos that were uploaded on July 24th, 2010 before 6 p.m.

Results: The search for tweets provided us 105 results containing the term "#loveparade". This list has to be regarded as incomplete, but our aim was to focus on the tweets, which were tagged with this well-known term. Most of the tweets were posted only in the wake of the disaster. However, some tweets had warned of overcrowding and chaos beforehand. For example, *sektorkind* tweeted: "*Police says: area is full. No chance of admission. #loveparade 3duisburg*" at 4:47 p.m., about an hour before the mass panic broke out (Figure 9, left). Helpful tweets were mainly distributed on the news portal *Der Westen*, belonging to the WAZ media group, the third largest newspaper and magazine publisher in Germany, where a news ticker about the Love Parade was created. The news was also reported on Twitter in short intervals, tagged with #loveparade. Before the actual disaster happened, the portal had given

information on train delays, the backlog of the crowd and the closure or congestion of the festival venue. The media published some of the tweets that followed the disaster. Entries such as "*visitors of the #loveparade make sure to keep calm. Do not go to the station. It's closed! Pass this info on!*" warned others, trying to avoid further chaos and panic (Figure 9, right). Information, especially about the number of deaths, the recommended ways to return home and about other security measures was also distributed. It is noticeable that even here some twitterers acted as information brokers and played a major role in providing information to stakeholders. They collected information about the event from different sources and made them available via Twitter.

The search on Flickr showed that only three photos, showing the conditions at the Love Parade, were uploaded before the incident. One photo shows the crowded stairway to the festival site, posted at 5:42 p.m., two pictures from another user, also taken with a mobile phone, show the tunnel to the festival site and people climbing over the embankment of the festival grounds. The images were posted at 2 p.m. and at 2:24 p.m. respectively. All other images, which were identified as photos uploaded by visitors, were taken with either digital cameras or mobile phones and had been uploaded later in the evening to Flickr, images on Flickr show the time of their posting. Many photos have EXIF (Exchangeable Image File Format, a standard that specifies the formats for images, sound, and ancillary tags used by digital cameras) data, which is displayed next to the photo on Flickr. This data shows both the camera model and the settings with which the photo was taken, and the exact time of the recording and upload.

On the video portal YouTube the upload date is provided, but the exact time of the upload cannot be determined. The Google-search on YouTube (http://www.youtube.com) with the exact phrase "Love Parade 2010", the tag "panic" and the date July 24th, 2010 found 73 results. Parts of the results show footage and coverage from television and interviews with eyewitnesses. Some videos are a compilation of images and text, as reminders of the disaster. Many of the results contain mobile phone videos, taken by visitors during the accident, also included are several videos that give an impression of the event before the accident. For example, the tunnel and the staircase are shown at various times before the panic, almost always full of people. Other videos show the huge crowd at the accident site, or paramedics caring for the injured after the panic. The videos are often tagged with the exact time of recording, which is added by the uploader as a comment. If the videos were not tagged, users asked for that meta-data in the comments field of the video, leading to the information to be added subsequently. Showing the recording time is now a common practice on YouTube that has evolved as a result of the accident. Users, who asked for such data, can be generally identified as information brokers that collected all relevant videos on YouTube and transferred them to a separate channel of information on the disaster. According to the description of the clips, some of the videos that show the locations before the accident were sent to the authorities responsible for criminal investigations of the disaster. Information brokers had the same intention, by tagging the clips and collecting the available recordings.

The investigations of the activities on Twitter, Flickr and YouTube following the Love Parade disaster, show that a significantly small amount of information was provided before the disaster. Only few images, tweets and videos warned others of the crowds in advance. The largest part of the information followed after the incident. Photos and videos showing the disaster were uploaded later in the evening or the following day. The information the majority of users

provided, was primarily used for the investigation of the incident, but could not act as a warning for other visitors. We observed that a flood of information was posted after the actual disaster. In the case of the Love Parade, the mobile phone network collapsed – therefore, visitors had few chances to even be warned beforehand. In our observation of Twitter and YouTube, we found that users tried to make out or commemorate the victims after the event.

Figure 9: Examples of use of social software during the Love Parade disaster in Germany

4.5 Discussion

4.5.1 Strengths

Based on our literature review and our observations we can conclude that services like Facebook, Twitter, Flickr and YouTube are appropriate tools for an exchange of information between citizens and organizations, also in Germany. All those applications can be used via mobile applications and not only via computer. The use of SMS is also very important particularly when no Internet is available. Tagging can help to find information. Geotagging can also help, especially when messages or pictures are sent with a mobile phone, because then the exact location of the described situation can be identified. This is important in case of fires, storms, floods or energy breakdowns. Especially when energy breakdowns occur, a mobile phone can provide important information. A hashtag-syntax can also help to sort information and link it to issues, groups or individuals (Guy et al., 2010). Retweets can confirm the importance of information (Starbird et al., 2010). Flickr has the opportunity to provide EXIF-data that help to determine date and time of when a picture was taken. Facebook has a large potential, as citizens can contact organizations without calling them, which usually takes a lot of time.

4.5.2 Weaknesses

Besides the potentials, we also observed some weaknesses in current social software applications. *YouTube* does not provide information on place or time; users have to add them in a comment, it has to be provided by the user in a comment, when uploading the content. *Flickr* supports the EXIF-data, but this depends on the device used, and it may provide wrong data. *Twitter* can use the location of a tweet, but only if the message was sent with a mobile phone with a location sensor. If the user twitters from his computer, the location of the user profile is used, but it might not be correct. *Facebook* is the most problematic service: many companies

use it for broadcasting, but not as a communication platform. A problem is that the users do use those systems, and then communicate only amongst themselves. While observing an interruption in air traffic, we saw that a large number of people affected, used this method of communication. A problem is often caused by the communication partner, as many organizations and companies use Facebook as medium for broadcasting – while many users interpret it as a communication platform. Another deficit, at this point, is that only few organizations and companies, that need to be contacted in a crisis situation, are registered there. This also indicates a more general problem within crisis communication. There is no official contact person whom citizens can address with their digital information; the only addressee is the general public of Internet users. There, the potential of the citizens as information providers is not fully utilized, because they do not have a central contact point. The opposite occurred in the following case: During the flood in Saxony in 2010, the regional television channel "MDR*" asked its viewers to act as reporters, and to upload images of flood on the television channel's website. People submitted over 1,000 images, which documented the flood in various cities. A search for relevant photos on Flickr brought only one page of results, consisting of pictures that users uploaded without being asked. From this observation, we have concluded that a specific motivation of the citizens and a central contact point generate more information than can be obtained through the people's own initiative.

Strengths	Weaknesses
Mobile use, use of SMS	YouTube: time
Tagging, GeoTagging	Flickr: EXIF-data base on cameras' settings
Twitter: Hashtag-Syntax	Twitter: location errors
Twitter: Retweets	Facebook: broadcasting vs. communication
Flickr: EXIF-data	No central contacting point
Facebook: contact point	Quantity of information

Table 15: Strengths and Weaknesses of detected social software use

4.6 Towards a Systematization of Social Software Use

In order to develop software for crisis management it is important to take the specifics of the field into account. Due to the large number of people involved systems should be "highly flexible", but "also structured group communication systems" (Turoff, 2002). Furthermore systems should be easy to learn, they should be concise and self-evident and contain a high degree of tailoring and filtering (Turoff et al., 2004). Most of the research in that field was done before the emergence of Twitter, Facebook et al., which actually do address many of the requirements described. In addition, social software services defined a new public articulation space that is particular helpful for establishing communication channels between organization actors and the general public as well as publics of citizens. Along these lines, the establishment of social software services in crisis communication concepts is not so much a question of the availability of new technologies, but of the configuration of existing technologies and services. With regard to software aspects of technology use Jennex (2004) called for organiza-

* Sachsenspiegel-Zuschauerreporter: Hochwasser in Sachsen, August 2010. *MDR*. Retrieved from http://www.mdr.de/galerie/sachsen/thumbnails.php?album=224

tion-wide templates and terminologies, the use multiple communication methods and recommended not to trust in the availability of the Internet.

In the discussion we saw that the potentials of social software are not yet exhausted. On the one hand, we observed that the integration of citizen into crisis management has some potential; on the other hand, social software can also be used for communication among the professionals involved. Based on a distinction between the organizations of crisis management and the public as two groups we suggest a classification matrix for cooperation in crisis situations, depending on the sender or creator of digital content (X-axis) and the recipient or user (Y-axis) (Figure 10)*. White and Plotnick (2010) created a more complex matrix to identify best practices also taking event size and event phase into consideration. The aim of this matrix is to take a step towards a systematization of social software use in crisis management and to clarify different types of cooperation in order to develop appropriate systems.

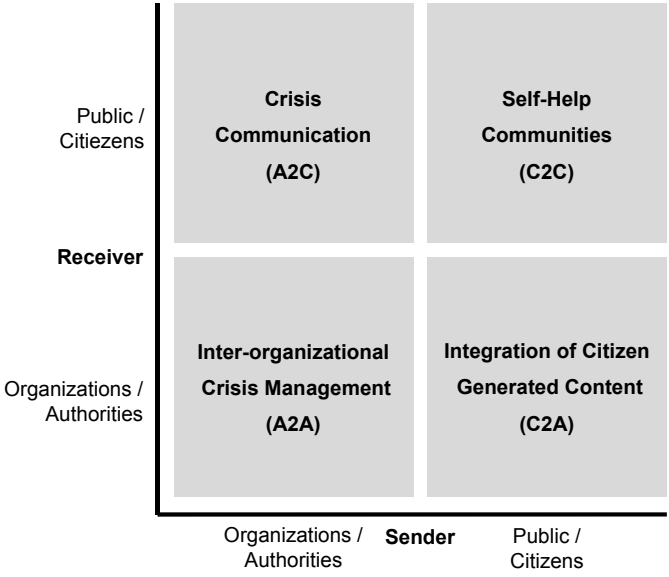

Figure 10: Classification matrix for social software use in crisis management†

4.6.1 Type 1: From Organizations to the Public: (Classical) Crisis Communication

Based on our results we think that it is important to research the information needs during different phases of a crisis and inform people in advance. With the publication of information

* The "categories of organizational behavior" of Quarantelli (1988) describe five different categories for the flow of information in a crisis: (a) intra-organizational, (b) inter-organizational, (c) from organizations to the public, (d) from the public to the organizations and (e) communication within systems of organizations, which have similarities to this categorization.

† Compared to the paper the acronyms (A2C, C2C, C2A, A2A) have been added.

to citizens (Vieweg et al., 2008), it is possible to reduce the load other channels have to carry. Furthermore the support of information brokers (Hughes & Palen, 2009) and the recommendation of crisis tags (Starbird & Stamberger, 2010) are possible. Incorporating social personal media, such as text messages or e-mail, allows to further refining communication strategies. Citizens may define certain triggers (e.g. "power outage will last > 4 hours") where they are automatically notified about critical escalations which may make it possible for them to start measures for their own crisis management (Ley et al., 2012a). This would also help remove pressure from the hotlines of infrastructure providers.

4.6.2 Type 2: From the Public to the Public: Self-Help Communities

Social software supports the creation of self-help communities and creates new opportunities for people to participate in such communities (Palen & Liu, 2007). Those emerging groups may act as virtual or neighborly help communities (Reuter, Heger, et al., 2012). The actual physical presence is no longer necessary in order to coordinate self-help locally. In a study on the use of ICTs in disasters, Shklovski et al. (2008) found a series of self-help activities being carried out with social software. These included the search for reliable information and thus also the confirmation or correction of different information spread by the media. The potential of the paradigmatic turn from perceiving the citizens affected as a passive force that needs to be managed and controlled towards acknowledging them as crisis managers in their own respect is visible in the usage patterns of social software. The articulation of questions, needs and fears meets the will to provide help, assistance and support. Self-help communities can be based on co-location (e.g. neighborhoods) or specific needs (e.g. baby caretaking, diabetes, treatments that require electric devices), but always require preparation e.g. by gathering resources (like locally available generators or independent fresh water wells) as well as determining specific needs (e.g. locations of dialysis patients).

4.6.3 Type 3: From the Public to Organizations: Integration of Citizen-Generated Content

There are different approaches to the analysis of citizen-generated content. Besides monitoring based on relevant crisis tags (Bellucci et al., 2010; Guy et al., 2010), which calls for the provision of relevant material, its aggregation (Starbird et al., 2010) and archiving for future analysis and training purposes (Reuter et al., 2009a) may also be helpful. Howe et al. (2011) describe the lessons learned from *Exercise 24*, which, with over 49,000 participants, tested how social media and crowdsourcing technologies can be implemented. Kavanaugh et al. (2011) analyzed the use of social media by government officials in Virginia and identified huge requirements concerning the overwhelming amount of data. Acknowledging the affected citizen as a responsible actor in crisis management raises the potential of benefitting from citizen-generated content e.g. to illustrate problematic situations through photographs taken with mobile phones. The perceived unreliability of such information is a significant obstacle in exploring such opportunities. This could be alleviated by crowdsourcing strategies to confirm the trustworthiness of information visible on a picture, but also by training *community scouts* as amateur *first informers*, just as there is training for medical first aid. The publicity of this information would help stimulate similar information postings. Also, according to the principle of the *wisdom of the crowd*, information may become more reliable if it comes from

different sources via different media. Tools to select and summarize as well as to access information quality can help improve the practice of professional actors in crisis situations.

4.6.4 Type 4: From Organizations to Organizations: Inter-Organizational Crisis Management

Social software can help to improve inter-organizational awareness and informal processes. White et al. (2009) examined the potentials of online social networks with emergency management students: Sharing information, communication and networking were the most requested features. They also show that possible concerns against those systems may be information integrity, user identification, privacy and technology reliability. With regard to the inter-organizational communication between the established organizations we discovered some potential of using social software for shared data maintenance about individuals, as social networks for professionals (e.g. LinkedIn, XING) offer it (Ley et al., 2012a). Valuable data types would be contact information, the role/responsibilities a person takes at different escalation states of a crisis, or specific experiences (prior crises) and expertise (additional qualifications or regional/domain knowledge). As with the professional social networks mentioned, these obvious benefits may also result in strengthening informal ties even beyond the organizational groups. This becomes visible in the everyday practice of the organizations. Complemented with representations of formal organizational structures and processes, this infrastructure may become an invaluable source for organizational learning (e.g. by exchanging experiences). Christofzik and Reuter (2013) show that the identification of information composition functions should be taken into consideration when designing those inter-organizational collaborative systems. Anyway any use of groupware – such as social software – might change interpersonal communication, both planned and unplanned (Mark & Wulf, 1999).

4.7 Summary and Conclusion

In this paper, the aim was to provide a systematization of social software use in crisis situations. The contribution of this paper is (a) to summarize the state-of-the-art in this field, (b) to define further requirements and (c) to create a classification matrix, which takes into consideration the actual use of social software in crises by citizens.

Based on a definition of the term social software and a first selection of these services due to their rapid reaction capability, we have defined four classes of social software suitable as tools in crisis communication. We have limited our study to these applications: *Facebook* as a representative of social networks, *Twitter* from the category of micro-blogging services, and *Flickr* and *YouTube* as photo and video sharing sites. A large part of the paper published so far deals with the general use of social software by the citizens in a crisis situation. All communication via the media was considered, but it was not explicitly stated how citizens can be involved to provide information to organization relevant in crisis management. Studies that address this point have tried to offer solutions in the form of programs tailored to these demands. In these texts only one social software service was included in the application design.

In our own descriptive study we investigated the use of social software by people in Germany during two crises. Regarding the case of flight cancellations the study focused more on the question of how citizens tried to communicate with companies and other organizations. Thus,

we analyzed the Twitter and Facebook pages of airlines during flight cancellations in April 2010, which were caused by the volcano outbreak in Iceland. The investigation yielded the finding that travelers used to contact airlines after the conventional communication channels, such as telephone and e-mail, failed. While the travelers regarded this method of communication as almost self-evident, the airlines used Twitter and Facebook more as a broadcast medium. In the investigation of the Love Parade music festival in Duisburg, Germany, the general provision of information by participants was analyzed. We considered information on Twitter, Flickr and YouTube, which referred to the disaster. As a result, we found that people did not provide information only because they had the possibility to do so, but because additional incentive existed: In the aftermath of this incident an information culture developed, available material was collected and conventions for a uniform database (date of the clip, collection of image sets and channels) were developed.

Based on the findings from literature and our own studies, we conclude that certain types of social software have the potential to combine citizens and organizations in crisis management, especially in combination with mobile phones or other location-based media. Our classification matrix for cooperation in crisis management is a first step and distinguishes between different types of cooperation: (1) *crisis communication* - to quickly inform citizens and to communicate with citizens with regard to individual needs, (2) *self-help communities* - to foster emergent groups and neighborhood aid, (3) *integration of citizen-generated content* - to gather citizen-generated information from various social software services and (4) *inter-organizational crisis management* – to support inter-organizational communities for professionals. Each of the quadrants we defined may require different technologies and technology configurations to reliably work in the event of a crisis, and the biggest challenges may be non-technological, but related to communication strategies and multilateral negotiations of information exchange. Our categorization helps to frame the arenas these interactions take place. It may also be helpful to structure research efforts: As (4) may well connect to IS or CSCW research in other organizational settings, and (2) may well connect to studies and design research with regard to communication and collaboration in communities, the sectors (1) and (3) identify fields of practice, where organizational work settings now interacts with not only a general public, but also the new ‘publics’ that manifest social network sites, and where new research methods may be needed that cover traditional crisis management work settings as well as the new online communication environments, and integrate analytical and design-oriented research methods. Design case studies (Wulf et al., 2011) could be an appropriate research framework to further work on this topic.

Particularly our empirical studies of the use of social software indicate, together with many others (Mark, Agdouri, Palen, & Martin, 2012; Starbird & Palen, 2012), that despite their vulnerability, social software services have already become an important societal infrastructure that is also used in coping and recovering work after a crisis. Citizens already have started their infrastructuring activities (Pipek & Wulf, 2009) by configuring and using social software to cope with and recover from crises, and it is high time to also look at and support, or motivate, infrastructuring activities in professional crisis management as well.

5 Empirical Perspective on Inter-Organizational Improvisation Work (CHI)

Improvisation is necessary when planned decision-making as the main managerial activity does not fit the conditions the practice provides. In these cases, information technology should not just automate planned and structured decisions, but support improvisational practice. In this contribution we present an empirical study about the improvisation work in scenarios of medium to large power outages in Germany. Our focus is on inter-organizational cooperation practices, thus we examined the cooperation of fire departments, police, public administration, electricity infrastructure operators and citizens. Our empirical material allows describing reasons and conditions for improvisation. Our resulting recommendations address the support of aggregation and visualization of information, a necessary individualization of information compositions, options for collaborative situation assessment, requirements for informal and formal communication, and accessibility of information resources.*

5.1 Introduction

Crisis management is a practice field that by its nature needs to prepare for the unforeseeable. The number of influencing factors (weather conditions, number of people affected, type of emergency, etc.) as well as structural dependencies (electricity, roads and railways, fuel resources, etc.) makes it impossible to plan all crisis management activities ahead. Nevertheless, all organizations that help guaranteeing civil security (police, fire department, red cross, etc.) have developed systematic approaches to deal with these uncertainties and to allow for planned, coordinated activities in crisis situations. Still, many situations require spontaneous, ad hoc decisions and short-term (re-)planning. The ability to improvise remains a valuable asset for individuals and organizations, and is usually cultivated in crisis trainings and grows with experience.

While all these organizations have their established responsibilities and practices, many larger incidents require collaboration with these stakeholders. In Germany (and many other countries), there are established processes and practices of coordination between police, firefighters, infrastructure maintainers and administrative staff, usually prescribed by laws and regulations. All organizations rely on strong individual IT infrastructures. These inform the organization's emergency management by maintaining an overview on the current situation in an area of the organizations responsibility and on available resources for the crisis response measures the organizations feels responsible to engage in, and by providing means to coordinate emergency response activities. There is anecdotal evidence that showed that despite all efforts taken to be prepared, misunderstandings happened while actors were forced to operate

* This chapter has been published as a full paper (Ley et al., 2012a):
Ley, B., Pipek, V., Reuter, C., & Wiedenhoefer, T. (2012). Supporting Improvisation Work in Inter-Organizational Crisis Management. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI)* (pp. 1529–1538). Austin, USA: ACM-Press, http://dl.acm.org/citation.cfm?doid=2207676.2208617.

C. Reuter, *Emergent Collaboration Infrastructures,*
DOI 10.1007/978-3-658-08586-5_5, © Springer Fachmedien Wiesbaden 2015

and interact outside the system of established practices. Some of them may have been avoided if the IT systems had not only supported routine processes but also deviations.

Several examples of large crises (e.g. Hurricane Katrina (Select Bipartisan Committee to Investigate the Preparation for and Response to Hurricane Katrina, 2006)) showed that improvisation abilities face a completely different level of challenge when the crisis at hand is of a magnitude that requires emergency response organizations to collaborate. When dealing with larger power outages (the scenario we are looking at in our research project InfoStrom (Wiedenhoefer et al., 2011), each of the organizations involved (police, fire department, infrastructure providers, etc.) sets up an own crisis management team. At county level a crisis management group tries to coordinate the efforts and also deals with the public. Nowadays, crisis managers as well as the crisis response teams, need to improvise at an inter-organizational level, and find their IT infrastructures not always prepared for that. As Mendonca (2007: 49) reveals it:

> *"Unfortunately, a focus on structure and doctrine obscures the need for technology that enhances improvisation and creativity. The specification and formalization of the planned-for structure has resulted in doctrine and technology to support it, ignoring the demonstrated, even inevitable, needs of the adhocracies that help manage the unanticipated contingencies presented by extreme events […] Improvisation and adhocracy have received considerable examination from social scientists, but have been far less frequently addressed by ICT designers."*

But what is the exact nature of improvisation work necessary in crisis response? Where do communication strategies fail? And how can we provide IT support for improvisation at an inter-organizational level? In this contribution we present an empirical study of the inter-organizational improvisation work of actors, which are involved in scenarios of medium to large power outages. We derive requirements for information systems that would be able to support these practices.

The paper is organized as follows: After defining relevant terms and discussing the literature we introduce the research filed and our research methods. Afterwards we focus on the improvisation practice we found in emergency management. Then we discuss our findings and focus on design issues with regard to IT support for improvisation, finally followed by a conclusion.

5.2 Related Work: Improvisation and Information Technology in Crisis Management

Improvisation can be defined as "situated performance where thinking and action seem to occur simultaneously and on the spur of the moment" (Ciborra, 1996). It can be interpreted as the unforeseen (Stein, 2011). While some authors define it from the management perspective as "to be composed while performed" (Perry, 1991) others describe it in the case of fire service management as "thinking and doing unfold simultaneously" and "retrospective sensemaking" (Weick, 1996).

5.2.1 Improvisation in Emergency Management

Antecedent conditions, such as unexpected problems, changes in the structure of the problem areas or environmental and knowledge limitations, lead to the need for improvisation (Stein, 2011). Even in highly structured organizations improvisation is a well-grounded process that can be leveraged to face those situations where rules and methods fail (Ciborra, 1999). Improvisation can be performed on different levels and can be treated as an individual or as a team phenomenon (Moorman & Miner, 1998). Improvisation becomes necessary when beforehand planned decision-making does not work for any reason. This is especially the case in crises. Crises and emergencies often contain unexpected events. The root word *krisis* means judgment and decision which leads to the most important task: decision-making. The necessities to judge highly novel problems and to act quickly reduce the chances of extensive planning: "Decision makers in emergencies must be prepared to improvise" (Mendonça & Wallace, 2007). Improvisation does not consist of more sophisticated methods or more structured systems (Ciborra, 1996). Instead of trying to eradicate it through automation, the appreciation of flexibility and effectiveness seems more adequate. There "improvisation and preparedness go hand in hand" (Mendonça, 2007): Without improvisation, emergency management loses flexibility, without preparedness, emergency management loses efficiency.

5.2.2 Characteristics of Emergency Management

To support improvisation in crisis management it is essential to know the characteristics of the field. Based on an analysis of the response to the 2001 World Trade Center attack, the following characteristics of emergency management can be considered as characterizing reasons for improvisation (Mendonça, 2007). Firstly, (a) *rarity* of incidences limits opportunities for training and learning. Furthermore, (b) *time pressure* forces a convergence of planning and execution. (c) *Uncertainty* is present because the development of an extreme incidence is hardly predictable. Furthermore, extreme events have (d) *high and broad consequences*, therefore there is a need to manage interdependencies among a wide range of physical and social systems. The (e) *complexity* of the event arises, partly due to the high and broad consequences. Finally (f) *multiple decision makers* and responding organizations may negotiate while responding to the event. When more than one actor is involved, decision-making is often a process of "muddling-through" rather than a "scientific" process (Lindblom, 1959). In emergency management this is not caused by a lack of planning, but is necessary because "in fact the major problem in emergency management is that the team often does not exist formally until the emergency occurs" (van de Walle et al., 2010), which is contrary to scientific communication processes. Crisis situations differ from routine situations and actors have to face new and unstructured tasks (Quarantelli, 1988).

5.2.3 Supporting Improvisation in Crisis Management

As stated above, decision-making is one of the main tasks where improvisation is needed. Organizations need to maintain flexibility in order to respond to unanticipated events. Computer-based systems can support these processes, if the system design is informed by an understanding of the cognitive processes involved in responding to unanticipated contingencies (Mendonça, 2007). These systems must support the actors to rework their knowledge in order to fit the requirements of the current situation. Information technology, supporting improvisa-

tion, needs to handle ad hoc coordination, unique problem solving strategies and new or changed information needs (Waugh & Streib, 2006). Computer based comparisons of the current decision situation with past ones were identified as appropriate in this context (Mendonça, 2007). Case-based reasoning systems, which catalogue the set for planned-for situations or decision alternatives, may be used for this purpose, too. Ad hoc re-planning and the ability to share material were identified as design challenges for large-scale events (Lindström & Pettersson, 2010). Furthermore, the following IT-supported mechanisms for improvisation in emergency management are suggested: graphical representations of data during crisis response, intelligent systems that select and help to contact experts, centralization of data to enable actors finding information and virtual supported coordination to create shared information consistent in time (Adrot & Robey, 2008). In addition, verbal communication should be made persistent, visible and accessible in order to support accountability (Landgren, 2006). Finally "ICT in disaster contexts will give further rise to improvised activities and temporary organizations with which formal response organizations need to align" (Palen & Liu, 2007).

Much prior research focused on improvisation within an organization. Our aim is to examine improvisation on an inter-organizational level in order to derive requirements for potential IT-support for improvisation work. Aside from some theory-led considerations and case studies above, we aimed to understand the local and collaborative practices of the agents. Therefore we conducted an empirical study in Germany focusing on improvisation work for actors involved in scenarios of medium to large power outages.

5.3 Research Field

This paper reports from a study focusing on improvisation practices during coping and recovery work at emergency response agencies in Germany. We conducted this study in two regions of North Rhine Westphalia in Germany (counties Rhein-Erft (B) and Siegen-Wittgenstein (A)). Siegen-Wittgenstein is a densely wooded, hilly county in the middle of Germany, whereas Rhein-Erft consists of 10 growing communes in the west of Cologne. In both regions we focus on several persons and organizations affected: Infrastructure suppliers (e.g. power supplier), public strategic administration (e.g. crisis management, county administration), public operative administration (e.g. police, fire department) and citizens.

Before we present findings from our empirical study, we will have a quick look on two interesting aspects in advance regarding police and firefighter forces at both counties. Firstly, related to the organization of fire and rescue forces, Rhein-Erft provides professional fire and rescue departments, whereas Siegen-Wittgenstein's firefighters are mostly members of voluntary fire departments. Here, just members of the control center have salaried positions. Secondly, another interesting aspect emerged, while we compared lead structures of both organizations. Despite the fact that firefighter forces process coordination from the field via incident commands, police forces in the field receive commands from members of the control centers.

5.4 Methodology

The aim of the empirical study was to understand the application field and improvisational practices in crisis management. The view on the field was sensitized by our design intention.

We conducted a grounded theory oriented approach (Strauss, 1987), where we did not explore the field with predefined categories, but derived categories from empirical data. To reconstruct the practices we used different qualitative methods (Randall et al., 2007) such as document analysis, 4 observations, 5 group discussions, and 22 interviews including the development of a crisis scenario. All empirical work took place at the observants'/interviewees' workplaces. All in all we talked to more than 50 different actors from district administration, police, fire department, Red Cross and energy network operator (ENO). We used open coding (Strauss, 1987) to analyze the material and to uncover interesting phenomena. We are neither focusing on similarities nor differences but on breakdowns of practices that depend on inter-organizational collaboration.

The primary goal of *document analysis* was to obtain an overview of the organizations in crisis situations. We analyzed documents that regulate and describe the work in crisis management (laws, regulations, directives, and course materials).

The *observations* were used to acquire knowledge about practical work in inter-organizational crisis management. These were conducted in a control center during a normal working day (observation time: 9 hours), in the crisis management group and the operations management during a crisis communication training (4 hours) as well as on a major cultural event with about 400,000 visitors (6 hours).

The *group discussions* (Table 16) allowed us to understand the communicative practice of inter-organizational crisis management. We conducted 4 inter-organizational group discussions, each lasting of about 4 hours, including the participation of leading actors.

No.	County	Topic	Participants
W1	both	Challenges in practice, visit of control center	Energy Network Operator (ENO)
W2	B	Challenges in practice, visit of control center	County Administration Police Fire Department
W3	A	Challenges in practice, visit of control center	Department Head: Public Safety Head of Civil Protection Head of Police Control Center Deputy Head of Control Center District Fire Chief
W4	A	Analysis of user interactions and communication flows	Head of Police Control Center Head of Staff Coordination Deputy Head of Control Center Local Head of Federal Agency for Technical Relief (THW) Local Head German Red Cross
W5	B	Analysis of user interactions and communication flows	Head Regulatory Authority District Fire Chief Red Cross: Disaster Management Red Cross: Communications Members of other aid agencies

Table 16: Group discussions

It is difficult to observe the practice of crisis management within an actual crisis situation, because crises mostly happen unforeseen. Furthermore, on an inter-organizational level, it is hard to observe spatial distributed actors at the same time during an actual crisis. To over-

come these circumstances, we and members of ENO, police and fire department cooperatively developed a *scenario framework* existing of a windstorm with many incidents and energy breakdowns. The purpose of our scenario was to be able to quickly create a common understanding of a crisis situation and context in our interviews. It helped to increase their validity and comparability and to develop ideas concerning improvements of tools to support improvisational practice.

No.	County	Organization	Role
I01	A	Administration	Regulatory Authority
I02	A	Police Department	Head of Control Center
I03	A	Police Department	Head of Section
I04	A	Police Department	Patrol Duty
I05	A	Fire Department	District Fire Chief
I06	A	Fire Department	Deputy Head of Control Center
I07	A	Fire Department	Workmanship
I24	A	Fire Department	Head of Control Center
I08	B	Administration	Office Civil Protection
I09	B	Fire Department	Chief Officer / Chief of Fire Dept.
I10	B	Fire Department	Operation Controllers
I11	B	Fire Department	Clerical Grade Watch Department
I12	B	Fire Department	Control Center Dispatcher
I13	B	Fire Department	Head of Control Center
I14	both	Police Department	Member of the Permanent Staff
I15	B	Police Department	Head of Control Center
I16	B	Police Department	Head of Group
I18	both	Energy Network Operator	Higher Area, High Voltage
I19	both	Energy Network Operator	Operation Engineer, High Voltage
I20	both	Energy Network Operator	Operation Technician, Low Voltage
I21	both	Energy Network Operator	Dispatcher, Low Voltage
I22	both	Energy Network Operator	Workmanship Technical Incidents

Table 17: Interviews

The *interviews* (Table 17) allowed us to analyze the work context and the use of ICT of relevant actors. The interviews lasted between 1 and 2 hours and followed an interview guide. The first part of the interview focused the participants' role, qualification, activities and work steps in normal conditions. The second part covered the tasks in crisis situations and was based on the developed scenario framework. The third part covered ICT as well as perceived problems with these tools.

5.5 Results: Improvisation in Practice

Facing novel problems and the need to act quickly, plays a significant role in handling crisis situations. Our study revealed that at both counties improvisation is a common procedure of decision makers responding to uncertain circumstances under risk and time constraint: "*Improvisation is essential, next to extensive planning. You can have the best predefined response*

plans, but there is always a situation, where you have to improvise" (I1) or "*We improvise as usual. We see to it that we make the best out of each situation*" (I11).

In this section we are going to point out existing improvisation practices of actors involved in crisis management (Table 17), which have been identified after analyzing existing coping and recovery practices. We have divided this section into aspects of improvisation in current management structures of emergency services, possible causes of improvisation and conditions of improvisation.

5.5.1 Improvisation in Current Management Structures

When we take a closer look at emergency response work, we can see that improvisation is a common practice in todays' emergency management processes, besides executing on one or more response plans. As we could see at police work practices, to be capable of facing uncertain events, flexibility is already part of their common working procedures: "*No, all workflows are flexible. This is necessary, because each situation is different*" (I2). One police officer explains, that "*once there is a problem, our command center gives us basically plenty of rope, to solve the problem*" (I4). When we focus on the degree of improvisation or situated actions, our study identified two factors: the audience and the scale of an incident. We have to distinguish between two cases: "*There are incidents, which are managed by incidents commanders and there are events, where a crisis management group is in charge*" (I1). Incident commanders are usually full responsible for coordination and decision-making at the incident scene, when response plans can be executed properly. This work is not so much shaped by improvisation actions as by executing predefined tasks: "*We get the tasks and we perform them*" (I7). However, when emergency services are faced with complex, unpredictable events and a bigger picture is needed to perform further actions, a crisis management group takes over decision-making on a higher level. Because these kinds of events are "*not static, they can develop in any direction*" (I5). At that point, response plans can rarely be executed, the procedures in this group and on decision-maker level "*are more flexible"* (I1) in order to be capable of generating and executing new orders or plans nearly simultaneously. An example of a typical order is: "*Look for schools or gymnasiums to accommodate 500 people. How you do it is your business*" (I1).

5.5.2 Reasons for Improvisation

Due to the uniqueness of each operation, the actors' procedures during coping and recovery work essentially depend on improvisation rather than on predefined workflows. *"This is necessary, because no situation is equal to any other. […] Our work is fundamentally different from other local authorities. There are no predefined processes we are working off – we would be helpless and lost. That's why we tactically work with frame orders"* (I2). Although these frame orders describe concrete tasks, the way how they are performed strongly depends on the current situation in the field: *"No one gets told by us: 'You have to enter the house via the left sidewalk'"* (I2).

Improvisation work requires making in-situ decisions based on the current condition. Hence, it is necessary to keep track of the occurrences. Information resources, which are considered for this purpose, often contain uncertainties and have to be evaluated cautiously. For instance, in case of severe weather alerts, preparations are made, e.g. putting staff on standby. Howev-

er, those warnings are published too frequently and in many cases no critical weather conditions occur (I2). For that reason, many actors individually collect supplementary information from various sources, for example, the current weather condition outside the building, other weather information systems or webcams that are focused against the wind direction, to obtain a better overview of the situation: *"You need as much information as possible"* (I24).

Besides the work in the control centers, on-scene actors also depend on an optimal overview of the situation. For this purpose, some of them use their private smartphones as an information medium, because the authorities do not provide such technology for their staff: *"Some of the colleagues have an Internet connection on their smartphone that is often useful, for example to get an aerial image from the locality via Google Maps to check other information. This can be helpful for mediation, when you need a phone number […]. Generally, we don't have navigation systems on board and there is often the problem: 'Go to house number 17' and when you have found number 5, the next three numbers are hard to read and then you suddenly find a house number 28 and then there is the question: 'Where are the others?'"*(I4).

Outside influences from an incident itself are not the only reason that requires an improvised acting. Also *organizational factors* and structures can bear unpredictable challenges. That is why each actor will have to be able to divert from given routines to be capable of acting even if the given structures and circumstances change: *"If a system is strongly rigid and structured, and then one component is missing, mostly the whole system will collapse. For this, informal acting can be helpful"* (I1). Reasons mentioned for such a collapse is that technology, especially communication tools, can fail (I3) or internal information resources (e.g. phone lists) required during an operation are unavailable (I2). Also *human factors* play an important role. Especially during major catastrophes staff members can also be affected personally: *"When an employee gets the call that his home is flooded, you are trying to relieve that staff member from his duties. It makes no sense to keep him here. You would arrange a replacement and say: 'Here, care about your home or about your family'"* (I2). In addition to organizational reasons, the collaboration with other agencies requires a more flexible and improvised acting in general due to different organizational structures and work practices (I1).

In this context, *terminological differences* play a decisive role. Depending on the individual structures and practices of the respective organizations, different terms are used which can cause several communicational issues: *"There is a person with a cut finger and an employee from THW [Federal Agency For Technical Relief] reports this injury – This nearly sounded like a fatality!"* Due to the different focuses of the organizations, it is difficult to expedite a terminological assimilation. *"Even if the police are talking to the fire department, there is a big deviation in the terminology and consequently terms are perceived differently"* (W2). Terminological differences with other organizations, especially in the private sector, can be even greater. An example describes a misunderstanding about the number of people injured after a fire in a factory where 19 casualties were reported: *"People injured in the perception of the factory management, consist of 19 people who were only triaged by doctors but weren't necessarily injured"*. Actually, in the understanding of the rescuers there were only *"two people whose health was affected"* (W2).

I5 and I4 mentioned that *personal biases* have a significant impact on the interpretation of given information. Mostly, members of the public with no professional expertise about the current situation tend to exaggerate or to understate their report about the current situation. For instance, one citizen reported about "*a major car accident*" which led to take actions by

the local emergency medical services for seriously injured or even dead passengers, while it was just a minor car accident only with material damages (I5). I4, I5 reported about contrary cases, as well.

Within one workshop (W2) a firefighter reported about the problem of *losing and changing information* during the transmission between organizations. "*We got the information about several seriously injured kids, during the world youth day in Cologne, 2005. After conducting appropriate actions, we figured out that these kids were hardly injured at all".* The information changed, while it was transferred from the first responder via skilled and non-skilled organization members to the responsible medical service.

Besides loosing available information, there is sometimes a lack of information provided by infrastructure operators (e.g. energy network operators or transport services). These organizations do not necessarily inform proactively about further development, but they have to be asked directly: "*The other actors have a different perception because they concentrate on their problems and not on providing information*" (I15). In case of infrastructure operations they sometimes provide information with missing details such as the amount of affected households (I10): "*What broke down, how much of the energy network is out of work and how many people are affected?*" Many organizations provide their information by email or phone, which is another source of information that needs to be handled.

Further *media disruptions* in the field of retrieving information occur in operations management where liaison officers of the police usually cannot access information provided by the police intranet. They always have to ask by phone. For actors working in the field additional information is usually obtained from the control center (I3). For instance, in case of a fire they ask the control center how many people are registered at a certain building (I4): *"How many people are registered at that address? For example, we now have to match five people standing here in front of the house who say that they left the house. Okay, now we must assume that others are still in the house. In such incidents the registration office is probably the most important source".*

5.5.3 Conditions for Improvisation

We found several conditions and ways for improvisation. Beginning with findings about the degree of improvisation, the use of official systems and non-digital maps, we also detected issues concerning privacy, trustworthiness, time pressure and cooperation which influence the improvisational practice.

Improvisation usually does not occur in the pure form: "*There is always a mishmash of formal structures and informal ways"* (I1). As said by the actors, structures are important to handle basic tasks and flexibility is necessary to react to very dynamic situations: "*We have standard measures and things, which we decide at the spur of the moment*" (I13). Besides the fact that they have "*a very clear communication structure*" (I2), they do not consider themselves as an civil servant, such as an administrative officer or a taxman: "*We [police] and the fire department work in a way which is different from all other authorities: We do not have a litany that we follow strictly, because then we would be lost*" (I2). This shows that they calculate with a certain degree of improvisation contrary to detailed planned processes that just need to be executed. The decisions on the field level do not just base on regulations, but on assessments of the situation and are done "*within the given clearances*" (I9).

To decide what to do and how to deal with a certain situation, much important information is necessary. Some of the information to fulfill the work tasks in operations management is provided by "official" information systems. In major catastrophic events or in case of weather alerts these internal information resources are enriched by many external, *informal information resources*, which are necessary in various situations. Therefore, actors sometimes use about "*40 windows which have to be observed*" for different applications and websites to have an overview of the current state and to handle the situation appropriately (I5). This external information includes webcams, water levels, weather forecasts, wind directions, storm warnings and traffic service. Much of that information is provided on different websites – but not in a compulsory "official" application – with the result that actors have to improvise and search by themselves.

Besides information from third party providers, internal information such as *digital and non-digital maps* is of central importance for all actors to plan and to deal with major catastrophic events. Emergencies always have a geographic reference, therefore the operations management and the crisis management group gathers related information on maps. Besides the utilization of technical supported maps, actors also use different non-digital maps: "*We always have to work redundantly to prevent chaos during technical breakdowns. We have to be able to proceed anytime*" (I9). In addition, the representation of the resources and their availability are only maintained on non-digital maps (I15). But this always depends on the given incident and how likely a breakdown is.

Apart from the fact that actors are interested in information of other organizations, *privacy* for their current state is required: "*Maps got nothing to do with anyone else but us, because we do not reproduce the current state but rather try to imagine what will happen next"* (I9). Due to the strategic and tactical operations, maps are kept locked up and cannot be passed to other agencies or organizations. Based on available information, the operations management does not just reproduce the current state but tries to foresee how the situation will develop. It considers what could happen next in order to derive actions and minimize the resulting damage: "*In the beginning we have to follow up the damage. […] Our aim is to be in advance of the incidents"* (I9).

Trustworthiness is directly connected to reliability and plays a significant role in sharing or retrieving information, especially for those kinds of information which have high impact on complex and lifesaving decisions: "*The safest information is the one I have seen by myself*". I2, I3 and I10 count on "*good human relations*" (I3) to members of other organizations in order to ensure reliability and to accelerate information verification processes. For example, I9 mentioned that "*good connections to police members*" help to trust on information accuracy and to better understand each other. However, "*people who put themselves in the limelight*" (I4), even from the same organization, can affect this relationships negatively. Because of the need for good relationships, a lot of informal contacts and relationships have been established alongside predefined communication lines, especially in Siegen-Wittgenstein. "*Police officers directly talk to members of the leading group via mobile phone and don't take the way via section officers as it should be*" (I2). This can lead to a significant problem: The loss of information. Furthermore, when receiving information from non-trusted information providers such as citizens (W3), each organization starts its individual verification process. "*If we receive a non-reliable emergency call, we will just wait for a second call*" (I3), "*we react on on-scene information from citizens but we will immediately verify this information by experts*"

(I1) or I12 and I22 stated that they use "*qualified interviews*" to get appropriate information from non-experts.

"*For security reasons we need up-to-date development schemes and building plans*" (I21). This shows that *timeliness* is another important dimension of information. All participants point out that, especially for handling crisis situations, up-to-date information, e.g. on situation maps or contact lists (I1), become more essential. However the following statement shows a conflict to guarantee accurate, complete and timeliness information: "*The more stressful a situation becomes, the less information can be provided to others*" (I3). Furthermore, particularly in stressful situations, informal communication lines do not work anymore because everyone has to do what they are supposed to do (I15).

A wide range of emergency response actions shows that improvisation is *often a collaborative task*. To deal with an uncertain and changing environment during crisis situations, usually a great number of people are involved in gathering and analyzing data, decision-making and monitoring of implementations and consequences. Two quotations explain these practices. The first one from a policeman on operational level: "*We all have to get the big picture of the scene at first. Than we have to coordinate ourselves: finding appropriate ways of solving the problem together and then running these actions*" (I4). In addition, a member of a command center of an ENO said: *"[…] but if it's critical anywhere, you will willingly ask a colleague: 'What do you think about it? Give it the once-over.' The big advantage we have is that there are at least two of us sitting here, even twenty-four-seven" (*I20). Focusing on crisis management group work, our study revealed that there are lots of improvisational actions. They especially occur during coordination processes between members of different agencies. To assess the potential impacts of present or future events, members of the group (usually police, fire department and county administration) share their knowledge within the group or – depending on the case – they have to consult external experts (e.g. members of the residents registration office to access numbers of occupants in case of a burning house). What we have seen is that gathering and analyzing situation information and decision-making is often performed cooperatively.

5.6 Discussion

As shown in the results, no situation is equal to the other. Highly novel problems require ad hoc decision-making based on available information on the situation. This information is not necessarily available in the own organization. Especially during unique emergency events, many external resources need to be consulted. Finding and retrieving relevant information are still huge challenges for several reasons:

1. *Information is mostly distributed*: Even routine situations require managers to retrieve various information, which is often not necessarily available at the own organization. Managers have to access several kinds of external information resources at different organizations (e.g. weather services, electricity providers, logistic companies, etc.) via different media channels (e.g. phone, Internet, face-to-face, etc.). During non-routine events this typically takes place in an ad hoc manner.
2. *Missing awareness about information available*: Our study revealed that current inter-organizational emergency management lacks instruments, which distribute meta-

information about suitable and available data or about resources at external organizations.

3. *Accessibility of information / policy issues*: Because of technical shortcomings (e.g. missing appropriate interfaces) and policy issues at the information providers, retrieving relevant information is either time-consuming or even not a possible task in many cases.
4. *Handling of information uncertainties*: In reality data is seldom absolutely reliable. Looking at current decision-making processes, it shows that shortcomings exist in providing accurate visual depictions of critical data sets from different domains.
5. *Terminology issues*: Different symbols on situation maps or different technical terms, for instance, make it difficult to share information and knowledge between organizations, especially when they originate from other domains.
6. *Perceiving interdependencies between information:* Certain Information resources are possibly only relevant in conjunction with others (e.g. formation of smoke and wind direction and strength). Those interdependencies have to be identified to obtain any necessary information.

Even if these challenges partially agree with earlier research findings on coordination practices in emergency response management (Chen et al., 2008) and previously identified challenges in designing interactive systems for emergency response (Kyng et al., 2006), our study underlines their relevance on an inter-organizational level. In the following sections we will respond to these issues with regards to existing practices that we identified in our study.

To overcome the shortcoming, that not every piece of information needed is officially available or accessible at current emergency management systems, actors have developed several strategies. For example, by using the WWW, actors have bookmarked websites with additional information resources such as webcams, to check weather conditions or the water level statuses of nearby rivers. Our study shows that technophile people, rather than people with less computer skills, have performed these strategies. Taking a closer look on these information compositions shows that they are arranged highly individual. Actors have retrieved only those information resources, which are suitable for their individual tasks.

Gathering and analyzing data, assessing the potential impacts of events and executing related actions are main activities of most of the actors we have described in the antecedent sections. What we have seen, when unanticipated events or unclear situation information emerge, actors often consult colleagues or other experts to collaboratively assess the information. Our study reveals that situation maps are essential artifacts to fulfill these tasks. Analyzing data with colleagues with the same knowledge background, in a same room (e.g. a control center) and therefore with a common situation map, usually works well. However, challenges arise when it comes to sharing situation information with geographical distributed participants or even with actors of different agencies. It can be explained with the aid of two examples: In early phases of emergency events members of emergency response organizations are not necessarily at the same location to consult about the latest events. For instance, members of crisis management groups call each other from different locations so that they are not able to use a joint situation map. Even situation maps at the control center differ from maps of on-scene commanders of the same organization, therefore synchronizing missing information shapes communication. This problem gets more significant when actors of different agencies with

different situation maps are involved. Typically, these maps only visualize agency-related information and use different terminologies and symbols. This circumstance makes collaborative assessment actions even more complicated.

Definitions about responsibilities and formal communication channels in organizations usually work well and are important for a smooth interaction within the agency. However, the results show that structures can collapse, e.g. due to the failure of technology, outdated phone lists or human reasons. In this circumstance as well as in urgent emergency situations it might be necessary to diverge from rigid standards and to use unofficial channels instead. The same applies to inter-organizational communication, for instance, when a responsible liaison officer is not available for any reason. Induced by the different structures of the two investigated counties, the significance of informal communication differs strongly. The rural structure of Siegen-Wittgenstein and the mainly voluntarily organized agencies entail that many of the members know each other. As a consequence, communication channels are much more informal than in the more urban county Rhein-Erft. These differences emphasize that both formal and informal communication channels are equally important for cooperative work. To support both there is a need for a better awareness about the structures of involved organizations as well as the availability of suitable contact persons including capabilities for contacting.

Accessibility to required information resources is a big challenge actors have to deal with. On the one hand users do not know what information is available and where to find it and on the other hand policy issues prevent the access to certain information. A reason that information cannot be found by the user is that they are mostly distributed and not listed in a central directory. However, the results of our study show that actors often consult the same or similar information services during a certain situation, no matter to which organization they belong to. Hence, the question arises whether it is helpful to have a central repository for information resources with access to actors from any organization. Accessibility restrictions due to policy issues are more complex to handle (e.g. non-public information, such as the degree of power supply for a certain area might be helpful for agencies during specific emergency situations). Obtaining such information through official channels can be extremely time-consuming. That is why there is a demand for negotiation processes to allow for a fast access to necessary information in crisis situations, but also sufficient protection to prevent malpractice.

5.7 Supporting Improvisation Work in Inter-Organizational Crisis Management

One of the fundamental design requirements for supporting improvisation work for the inter-organizational level is to create a complementing information infrastructure, not a tool to replace existing IT. Technologically, this can be implemented relying on a service-oriented architecture that allows to connect to the existing IT infrastructures in the participating organizations. But with regard to the functionality we need to support improvisation work at the inter-organizational level we can outline five specific implications for the design that focus on geographically visualized data on information and collaboration resources:

5.7.1 Aggregation and Visualization of External and Various Information

We have seen that, besides internal information, information from other organizations is needed to get an appropriate picture of ongoing and future events and activities. Most information is spatial (e.g. emergency plans for buildings or areas with electricity breakdowns). We suggest an enhanced map-based information repository that allows including different types of internal and external information (e.g. place marks, weather information, specific geo-referenced infrastructure maps, etc.). To avoid information overload, the user should be able to save specific map compositions. As confidence in information is crucial, it is also important to distinguish between information sources (particularly internal vs. external) and degrees of information reliability.

5.7.2 Individualization of Information Compositions

We have observed that actors of emergency response organizations adapt information compositions due to their personal needs. Users need instruments that enable them (technophile and technophobe) to customize information compositions in real-time. Users should have the opportunity to easily show and hide information resources on the map, to add additional and new information resources to the map (that may also be provided by external web services), and to add place marks with annotations at specific locations in the map.

5.7.3 Supporting Collaborative Situation Assessment

The common practice to perform situation assessments collaboratively needs an explicit inter-organizational support. Actors need be able to share map-based compositions of information resources with other actors in a very controlled way. Visualization and interaction should be possible in various environments and locations, e.g. from a notebook at home, via mobile phones at the incident location or on a large screen in the crisis management center. Additional communication channels need to support the collaborative analysis of the information on the map, e.g. instant messaging services or audio channels. Because current situations can change rapidly, all participants require the option to modify information compositions on the map approximately in real time. Issues of information rights may occur while sharing information and annotations; we address that below.

5.7.4 Supporting Informal and Formal Communication

Both, informal and formal (along official roles, usually recorded/documented) communication channels need to be supported. Actors should be able to spontaneously decide which ones to use. For a better support of formal communication the actor has to be aware of organizational structures of his own as well as of other involved organizations. In an ongoing incident, it is often not clear which organization is reacting how, who is on duty and how she can be contacted. Redundant and outdated information can be avoided by providing a central repository. For informal communication it is more important to know who is in reach and working on a subject I need information about. Organizational structures are less relevant, but personal relations are: It may be good to know who works ‘nearby’ (meaning spatial, but also social distance) the contact I am interested in. Offering a large variety of communication channels may be as important as offering options for an informed choice among them.

5.7.5 Accessibility of Information Resources

Each of the organizations involved are using or hosting information resources, or being an information resource by producing information (e.g. the police 'produces' road closures). All that may be relevant for other organizations as well. For improvisational work, it is necessary to provide mutual awareness of the information available: It requires a shared information repository where proper services can be registered, described and rated by the user. The information resources could be selected as required by the situation and could be integrated into the intermediate infrastructure. Some of this information is subject to (e.g. for copyright or security reasons) restricted organizational access policies. For supporting improvisational work, it is not only enough to map these policies to access rights at design time, but to provide interactive access rights to allow for unforeseen, but necessary information flows. Computer supported access control may support spontaneous information needs while enabling the user to attempt access and to legitimate it during use (Stevens & Wulf, 2009). We are experimenting with various access control mechanisms to simplify the access in crisis situations but without undermining necessary policies. In a first step three different types of access controls will be implemented:

1. *Role based access control*: The access rights for each information resource are predefined and based on the user's role. A user can either have access by definition or not.
2. *Gatekeeper access control*: This more flexible approach also predefines access rights. However, users without assigned access rights can request those from a so-called gatekeeper who has the right to allocate access to unauthorized users or a certain time period.
3. *Break-glass access control*: This concept enables a flexible and fast access to the required information. Even if a user has no access by definition, he is able to get access by breaking a symbolic glass. Thus, there is no need to request access privileges from an authority but every access is documented. That means that the user must be aware of possible consequences when "breaking the glass" unauthorized.

5.8 Conclusion

In medium to large crisis situations, the pressure on emergency response organizations (police, firefighters, administration, etc.) to collaborate with each other effectively increases. While some aspects of coping and recovery work are covered by negotiated procedures (sometimes prescribed by law) and trained routines, the variety of influencing factors and framing conditions always leads to a need for improvisation also at an inter-organizational level. Improvisation has been previously addressed as a topic (Adrot & Robey, 2008; Mendonça et al., 2007; Mendonça & Wallace, 2007; Mendonça, 2007; Moorman & Miner, 1998), but our study was able to show additional difficulties we encounter at the inter-organizational level. In our study of the improvisation practices during larger power outages between police, firefighters, public administration and an electricity provider in two counties, we showed that improvisation work suffers on the one hand from a lack of options for sharing information among the organizations, but also from a lack of awareness of information about the activities of others, and from a lack of collaboration in consolidating and interpreting the information available. If external organizations required explanations about established and successful inner-organizational practices for a successful crisis management (and thus opened

up for external critique), there would not only be a severe possibility for misunderstanding (even the organizational structures and strategies of frequent collaborators like police and firefighters are significantly diverse) but there would also be concerns about becoming vulnerable against legal or political claims.

Considering this aspect, it does not make sense to support inter-organizational improvisation work in crisis management with IT concepts that require centralized, aligned procedures dominating the practices of the individual organizations. It is more appropriate to offer a complementary infrastructure that allows maintaining informal information sources and manages informal collaboration opportunities (e.g. for situation assessment) that can as well be individualized/localized. The exchange of information regarding own status, resources and measures is also very valuable, but needs to be thoughtfully protected with interactive (gatekeeper model, break-glass model) access rights that allow easy information sharing when necessary.

As a next step, we are going to develop such a complementary infrastructure based on geographically visualized data on information and collaboration resources necessary for improvisation, and with additional support for ad hoc sharing of information. We also plan to integrate citizens as potential crisis managers on their own behalf to the scenario (as also requested by Palen & Liu, 2007). The most important experience resulting from our studies here was: No matter how much control and preparedness we wish for in the event of a crisis, we need to acknowledge, support and take pride in our abilities to improvise.

6 Composing Collaborative Information Quality (IJEV)

Collaborative software supports teams involved in a common task in generating and sharing information over geographic distances. Such software is used in the cooperation between organizations, companies or individuals. The overall quality of the resulting information product depends on the quality of the individual contributions as well as on an underlying consolidation process. We therefore present different *composition functions* indicating how the qualities of the contributions by single actors (q_i) influence the quality of the aggregated information product (Q). Based upon a qualitative empirical study of inter-organizational crisis management in Germany we match use cases with those composition functions and derive implications for the design of collaborative software.*

6.1 Introduction

In increasingly complex and decentralized environments cooperation between different partners and collaboration of enterprises and organizations are of growing importance. In small- and medium-sized enterprises, inter-firm collaboration is a common approach to foster competitiveness (Rosenfeld, 1996), as well as for business ventures dealing with the typical limitations of start-ups (Mainela & Puhakka, 2011). Empirical evidence suggests that the performance of a start-up is fostered by business networks and associations (Davidsson & Honig, 2003) as well as by well-connected venture capital networks (Hochberg et al., 2007) or co-investment networks of business angels (Böert & Werth, 2013). Web 2.0 technologies, such as collaborative software (Johansen, 1988), may act as a facilitator to encourage entrepreneurial opportunities (Le & Tarafdar, 2009; McAfee, 2006). In many cases, especially if information, resources or competences are distributed, collaboration is the only way to solve a problem.

In our paper we will consider such a case and illustrate that inter-organizational collaborative software can support different participants in merging decentralized information. Designing such a system requires a profound understanding of the underlying processes, especially of how the aggregate level of information is assembled and how individual contributions can be enhanced through the implementation of such an infrastructure. To identify appropriate scenarios we have conducted a qualitative empirical study using the example of inter-organizational collaboration in crisis management in Germany. We assume that it is possible to transfer our implications to other forms of collaborative systems as the essential processes are comparable whenever information is exchanged between organizations, companies as well as between individuals or interest groups.

* This chapter has been published as an article (Christofzik & Reuter, 2013):

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When organizations, enterprises or individuals work together, they combine individual contributions to create some form of collective good. This is connected with Mancur Olson's (1965) work on *collective action* or the economic literature on the private provision of public goods (Bergstrom et al., 1986). A matter of particular interest is the *production process* of such an aggregated commodity. In our example, this commodity is consolidated information, which is collected by means of an IT-based collaboration system. In the following sections, we will present different composition functions to give an understanding of the underlying consolidation process and to derive practical implications that are connected with the assumptions about the production process. We will show that this choice has a direct influence on the implementation process of such systems.

The paper is organized as follows: Chapter 6.2 characterizes inter-organizational collaborative software with special reference to our example, the crisis management collaboration system *SiRena* (Wiedenhoefer et al., 2011) and its module *ISAC*. Furthermore, possible composition functions based upon Hirshleifer (1983) and Cornes and Sandler (1996) are introduced. For these functions, optimization criteria are identified in chapter 6.3. Besides, qualitatively and empirically ascertained application scenarios are revealed to clarify these criteria and the implications of the composition functions. A transfer to other applications consummates this chapter. Chapter 6.4 is the conclusion.

6.2 Characterization of an Inter-Organizational Collaboration System

6.2.1 Principles

The electricity network is one of the most important infrastructures in modern industrialized societies. In everyday life, the population and the whole economy depend to a great extent on a solid infrastructure and especially in the case of breakdowns in power supply, they become aware of their dependence on electricity (Birkmann et al., 2010). Coping and recovery work has a high priority in order to regain electricity and decrease the consequences of the breakdown. As information and resources are distributed, inter-organizational collaboration between all stakeholders in these decentralized organizations – especially the fire brigade, the police, the county administration, the energy network operator, companies depending on power supply and affected citizens – are necessary to effectively handle the situation. One possible approach to support the essential cooperation, to foster collaboration and extend communication is an IT-based infrastructure for crisis management (Wiedenhoefer et al., 2011). By means of this system, important information can be shared, contact details can be identified or content generated by citizens can be utilized.

The regional network of crisis management is comparable to regional clusters, such as regional networks of companies. Technical approaches aiming at fostering awareness and collaboration among those companies are rare. Reichling et al. (2010) present an approach to foster interconnectedness and to strengthen existing network ties using software to help find expertise for specific tasks among the companies. Those are especially important for SME because they usually have limitations, e.g. in workforce. In this paper, we also focus on networks containing small entities such as SME, which could be supported by collaborative software.

Even though our empirical study allows us to study the case of crisis management in more detail, we will also discuss conclusions for other forms of collaborative work, for examples cooperation of nascent entrepreneurs or co-investors into start-ups. As empirical evidence shows that better connected investors show a higher performance (Böert & Werth, 2013; Hochberg et al., 2007), a possibility to foster the quality of such networks may be the implementation of collaborative software. The same applies to nascent entrepreneurs. Davidsson and Honig (2003) show empirically that nascent entrepreneurs who are member of a business network are more successful. They propose "to develop business centers that focus on the facilitation of community and networking activities" (Davidsson & Honig, 2003: 303). We will return to these examples in chapter 6.3.

As in company networks, the actors in crisis and disaster management are generally independent and decentralized organizations with shared responsibilities, so that they need to collaborate, especially in the case of disasters. Different access to information may impede the communication between the organizations and lead to a delayed solving of the problem (Kapucu, 2006; Lundberg & Asplund, 2011). The pooling of information using collaborative software is a possibility to facilitate acting in the case of a crisis. The contributions of the individual organizations are an investment in a collectively provided good, which allows coping with a crisis in a simplified and more rapid way because of the faster availability of the required information.

The information created jointly by all organizations within the cooperative system has characteristics of a *public* good, but non-members can be excluded from using the information. An active contribution of information in this context is largely voluntary.[*] If an organization contributes individual information, it privately provides a public good (Bergstrom et al., 1986).

In the following, we will focus on the provision of information and thus the *production process* of collectively produced information. Contributing information is associated on one hand with costs arising from the time spent on posting such contributions, which is especially relevant for organizations with limited resources and workforce. Also the implementation of such a technical innovation has to be taken into account. On the other hand, exposing information involves obstacles, especially if information is sensitive or confidential or potential competitors participate in the collaborative system. Moreover, the relevance and usefulness of the information provided can be uncertain for future events, in particular in case of specific information.

But moreover, the utility of the own investment depends significantly on the activities undertaken by other organizations. If only one partner participates actively, utility will be lower than in case of a broad participation of all relevant cooperation partners. Nevertheless, the quality will not necessarily be increased through an expansion of the activities of all organizations. Therefore, the traditional aggregation technology used in economic theory dealing with public goods – where the aggregated quality is achieved through the unweighted sum of the individual contributions (Samuelson, 1954) – is certainly not the only appropriate modeling. Especially for inter-organizational collaboration, alternative aggregation functions may be of practical importance. These functions help to formally describe the result of the collective

[*] Especially for state-owned organizations, an obligation would be imaginable. Yet, the specific contributions would have to be evaluated. This would involve the difficulty to measure and quantify the quality of the individual information provided. Particularly with regard to a possible crowding-out of intrinsic motivation, such a scheme not seems conducive (Frey & Jegen, 2001).

action. Thereby, the formulae clarify the underlying consolidation process and allow us to draw conclusions on the individual contributions and how they can be enhanced by adjusting the design of the collaborative software. Based upon Hirshleifer (1983) we refer to them as *(social) composition functions* or with reference to the similarities to production processes as *aggregation technologies*. In the following section, some extreme cases of these functions are described and illustrated using applications from crisis management.

6.2.2 Measuring Information Quality

In order to stimulate active contributions by the individual organizations, it is inevitable to identify a method to evaluate the aggregated information's quality. Only this allows us to analyze measures by which the collaborative software can be optimized. Therefore, it is crucial to determine how to evaluate the quality of a specific contribution, but also the benefit of collaboratively generated information to the network. The focus of this paper is on the second aspect.

According to Wang and Strong (1996) *data quality* is defined as "data that are fit for use by data consumers". According to DIN 55350-11 (2004), the term *information quality* is defined as "the entirety of quality attributes of information or as an information process which refers to its appropriateness and quality for the accomplishment of a given task". Different taxonomies exist for the determination of information quality, for example the *Extended ISO Model* (Zeist & Hendriks, 1996), which measures information quality on the basis of characteristics such as functionality, reliability, efficiency, usability, maintainability and transferability. The *Model of Information Quality* (P. Wolf, 1999) takes into account content, relevance for the decision, time, location, amount, form and profitability; the *Conceptual Framework of Data Quality* (Wang et al., 1996) is based on intrinsic, contextual, representational and accessibility concerned data quality. The quality of single contributions is influenced by various aspects; approaches to calculate a quality score, e.g. of Friberg et al. (2011), Bharosa et al. (2009) or Naumann and Rolker (2000), indicate the high complexity of consistently evaluating information quality. However, the quality of the specific pieces of information is only one part of the collaboratively generated information quality.

Such a specific piece of information becomes part of the aggregate information when it is published in collaborative software, no matter how its quality has been measured or determined. Therefore, it is crucial to identify the underlying production technology, which is the foundation of a collectively generated good and determines how the interdependencies between the contributors are depicted. Cornes and Sandler (1996) point out that the appropriate institutional structures depend on the properties of the aggregation function. Thus, their identification is a key factor when developing incentive schemes.

6.2.3 Composition Functions

Cornes and Sandler (1996) and Cornes and Hartley (2007) show that various composition functions can be illustrated using a generalized CES (constant elasticity of substitution) function and varying the exogenous parameters α (indicating if the average or the sum is decisive) and v (influencing the elasticity of substitution). Considering $i=1,\ldots,n$ single actors (e.g. organizations or individuals) contributing individual information with quality q_i, the quality of the aggregate information Q results from the following expression.

$$Q = \alpha \left[\frac{1}{n}\sum_{i=1}^{n} q_i^v\right]^{\frac{1}{v}} \quad (1)$$

The speed of availability is one important component of information quality. In crisis management, information often has to be disposable on short notice. A piece of information which is rapidly available, but with lower values in other components may be more relevant than high-quality information which is available at a later time. Though the speed of availability is not explicitly included in the formulae, the individual quality level q_i can be weighted with a time or discount factor in situations where this criterion is necessary.

6.2.3.1 Summation

Keeping this in mind, one possibility to calculate the aggregate information quality is to use the unweighted sum of the separate contributions q_i. In economics, this is the assumption of the standard public good framework (Samuelson, 1954). The contributions of the participants are thereby commutative. Hence, it is irrelevant by whom an individual contribution is made and how the sum is distributed across the contributors (Cornes & Sandler, 1996). This formula might be true for gathering general information for which the information of the individual organizations does not differ factually or when creating interfaces and processes for the exchange of organization-related data. Using the CES function mentioned above, the *summation* technology is derived if the exogenous parameter α is equal to n and v = 1 which implicates a maximal elasticity of substitution:

$$Q = \sum_{i=1}^{n} q_i \quad (2)$$

6.2.3.2 Weakest-Link

Especially in the context of crisis management, taking into account the necessity of cooperative work, an alternative composition function is conceivable which assumes that the least information of a specific organization is equal to the overall result. Collective information will only be useful if information of all partners is available. The expansion of one organization's activity will only increase the quality if the other organizations make their contributions, too. Vicary (1990) illustrates that such an aggregation technology is a suitable model for many aspects of teamwork. If the information of the organizations differs or is built upon one another and cooperation is necessary for a crisis' solution, this seems to be an appropriate assumption. For instance, if the collaboration of all participating organizations is necessary to restore an infrastructure and one participant's information is not available; all other contributions do not have any benefit at all in this extreme case. With reference to historical examples, Hirshleifer (1983) reveals that the conditions for modeling a *weakest-link* technology seem to be likely in the case of catastrophes. If so, the production process would be characterized by a formula, which is determined by the least of the contributed pieces of information. The *weakest-link* formula arises when the exogenous parameters of the CES function (1) are set to α = 1, v → -∞: [*]

$$Q = \min_i(q_1, \ldots, q_i, \ldots, q_n) \quad (3)$$

[*] This composition function is technically identical to the income function used by (Lazear, 2005) which captures the jack-of-all-trades entrepreneur. He assumes that the income depends on different skills as *input factors* and the weakest attribute limits his success as opposed to specialists who receive income associated with their best skill (*best-shot*).

Closely related to this composition function and less extreme is the assumption of a *weaker-link* function. This is a convex technology for transforming individual contributions into the aggregate information and emerges if $\alpha = 1$ and $-\infty < v < 1$.

6.2.3.3 Best-Shot

A further possibility of modeling the aggregation process is a *best-shot* formula, which assumes that the quality is solely derived by the best single contribution. This technology might especially be appropriate in the case of collective information which does not arise as a result of interaction between multiple participants, but which is referred to specific information that has the same relevance to all organizations. The *best-shot* technology can be expressed using expression (1) and setting the parameters $\alpha = 1$ and $v \rightarrow \infty$:

$$Q = \max_i(q_1, \dots, q_i, \dots, q_n) \quad (4)$$

Better-shot functions ($\alpha = 1$, $1 < v < \infty$) describe non-convex social composition functions and are less extreme than the assumption of a best-shot technology.

Compared to the standard formula of summation, Hirshleifer (1983) shows that the undersupply of a public good is decreasing in case of a weakest-link formula. It is increased if assuming a best-shot technology. This becomes obvious when considering the possibility of free-rider behavior and the influence of one's own action on the overall result. In case of a weakest-link technology, refusing to contribute has a substantial impact on the quality of the public good. In doing so, free-riding is not possible as the public good has no quality at all. In case of a best-shot technology, the individual utility arises from the best information of another organization if not contributing. Then, participants will only contribute information if they can expect a higher benefit from sharing their own information than from using the information, which is already available. However, established schemes of contribution do not arise as a result from identifying a technology, but it affects the requirements on institutional structures that can foster a more efficient contribution (Cornes & Sandler, 1996).

6.3 Implications of Different Composition Functions

Considering the different cases of social composition functions shown by Cornes and Hartley (2007), it becomes apparent that different implications for optimizing an inter-organizational communication system arise. In this chapter, therefore, we look at scenarios we have identified by conducting a qualitative empirical study using the example of inter-organizational collaboration in crisis management in Germany. Based on these scenarios, we have derived potential measures to optimize the quality level of the aggregate information and to identify specific requirements for information systems that are referred to as technical problem-solving approaches and concrete implications for the design of application systems. Even though rather mixed forms of the technologies presented exist in reality, an orientation towards these cases may foster the understanding of the meaning of the aggregation forms.

6.3.1 Empirical Basis for Identifying the Aggregation Form

The description of the application scenarios and their reference to the aggregation forms are based on qualitative-empirical studies in the field of inter-organizational crisis management. These studies were carried out in two counties of North Rhine-Westphalia, Germany, in the

years 2010 and 2011. Various actors of emergency response agencies, such as fire service, police, aid organizations, public administration and energy network operators, were involved. In crisis situations, they are organized in a crisis management group of the public administration, an incident command of the non-police agencies as well as in an incident command of the police's emergency response. Typically, these teams partly consist of representatives of other relevant organizations who are responsible for the transmission of information.

Document analyzes, observations, semi-structured interviews and group discussions were carried out as part of the data acquisition. The aim of the document analysis was to gain an overview of the organizations in crisis situations and their information exchange. Altogether 19 documents (laws, decrees, edicts, guidance, training documents) were analyzed which give a description of the activities in crisis management. The purpose of the observations was to obtain insights into the practical work in inter-organizational crisis management. They were conducted in a county's control center during a normal working day (observation period: nine hours), in a crisis committee and in an incident command during a training session of crisis communication (four hours) and an actual larger incident (six hours). The interviews' objective was to comprehend working practices and to identify inter-organizational demands for information as well as potential IT support in crisis management. 21 interviews, lasting an average of 1.5 hours, were accomplished with all relevant actors in crisis management. The group discussions were aimed to grasp the communication practices in cross-organizational crisis communication. Four group discussions were held with leading actors from the county administration, police, fire services and the German Red Cross, which took about four hours each. The goal of the empirical studies was to analyze information and communication processes in order to determine potentials for optimizing the exchange of information with the aid of a collaborative software (Ley et al., 2012a).

6.3.2 Initiating an Automated Exchange of Information and Target-Group-Specific Display

Scenario: A use case, which we observed, is the manual or automated provision of information in the control center during severe weather conditions. The activities of the incident command and the control center require a great amount of information. Some of this information is available via information systems; additional information can be searched and viewed online, other information has to be inquired manually of the providers or is transferred to the incident command via e-mail. The handling of severe weather conditions by the control center of the non-police emergency response agencies is a practical example. After having received consistent weather alerts from the German Meteorological Service and two private weather services, the situation is evaluated by the information service of the control center. For this purpose and besides 'official' information systems, additional information sources, e.g. webcams directed towards the weather front, online retrievable water levels or weather radars, are consulted, depending on the control center's dispatcher on duty. Generally, plenty of external online resources are utilized in the course of a situation that can lead to a major catastrophic event, with the result that the overview of the monitor is disturbed by the large number of open windows, which is perceived negatively.

Composition technology: When looking at the empirical data we see that the variety of sources makes it necessary to select the received information. However, additional sources of information can increase the quality of the aggregated information even in the case of redun-

dant information. They can increase the possibility of a correct evaluation of the situation. Furthermore, information from multiple sources is gathered to obtain additional data considering various aspects in order to achieve a correct assessment, such as webcams or water levels. The form of aggregation thus depends not only on the scenario, but also on the specific question. Summation seems to be a reasonable aggregation form, because the posts are commutative. However, weaker-link technologies also arise if specific data can only be provided by certain actors, for example, and then missing pieces of information can strongly affect the overall quality. In this case, the possibility of substituting information decreases.

Supportive approach: A possible approach to support the staff of the agencies would be a system that integrates information from different sources and providers (Ley et al., 2012a). An automated exchange of information on roadblocks delivered by police and fire service, on areas of power outages relayed by energy network operators, on weather data conveyed by the German Meteorological Service or on water levels passed on by the regional environment agency would be useful. Here, the aim is to pool and to integrate existing information once, instead of being forced to retrieve it manually. Because a reasonable use of the entire information is only possible if the amount of data is manageable for the user, mechanisms for the visual display must be created which meet the needs of the respective target groups, tasks and incidences. Customizable displays appear to be useful (Lieberman et al., 2006) which are configured on the basis of the user's work tasks. A further useful realization is a selection of user-specific services, which is realized by a flexible implementation as for instance a *Service-Orientated Architecture.* The users could select the appropriate services out of a repository and compose them on their personal display (Doerner et al., 2009). When presenting this information on a map, it should be possible to show or hide it depending on the respective role and the actual situation. Besides these manual setting options for the users, automatisms for the display of information on the basis of special incidents are conceivable, for example a visual display showing webcams, which are directed to where the severe weather is reported. Because of disjoint pieces of information, which frequently occur, and different areas of operations, the entire information's quality arises as a result of the summation of its components' quality. In other words, single pieces of information contribute to the evaluation of the situation based on different aspects.

6.3.3 Identifying Missing Information about Personal or Technical Resources in Inter-Organizational Situation Maps

Scenario: In crisis management there is a great amount of technical and personnel resources that are used in various scenarios. Especially during large operations, it is common to provide administrative assistance depending on one's own workload and to try compensating resource bottlenecks. Because of their lower number of staff, for instance, the police rely on the fire service to build up barriers. The management of free resources is inevitable. However, this is carried out manually and, to some extent, requires a significant amount of effort, because of juridical regulations, the non-existence of GPS transmission of the vehicles' locations as well as the lack of a cross-organizational, automated matching of the resources' availabilities.

Composition technology: In this case, it is important to gather the information of all relevant organizations and therefore, the active participation of all actors is crucial. The crisis management system is only useful if it includes reliable data. If a decision is made and information of some organizations is missing or if missing information has to be collected manual-

ly, the utility of the system declines. This scenario can be described by a weakest-link or weaker-link composition function.

Supportive approach: An approach to support this cooperation would be a central information system for the management of free resources in crisis management. A collaborative overview of the situation would be conceivable, too. The exchange of information, which is required at that point, should be conducted (semi) automatically by the individual organizations in order to reduce manual efforts. A central information system such as that would be useful if and only if really all resources were contemporarily recorded in it and if it was not necessary to obtain additional information from other organizations as and when required. If this was not the case, it would not reduce the efforts at all because the manual obtaining of information and the use of the information system would take place in parallel and the overview of the situation would not be complete. In this use case it is obvious that the information's quality is significantly affected by its weakest component. Here, it is of key importance to enable an *awareness* (Dourish & Bellotti, 1992) of the other actors' activities and to visualize information gaps. These gaps should not only be identified by chosen organizations but by all participants in order to fill them with additional information.

6.3.4 Selecting Relevant Information Generated by Citizens in Crisis Management

Scenario: Citizen-generated content in *social software* is a further possibility of getting important information. Social software comprises applications, which are attached to the Internet and enables contacting and exchange among various participants. During crises it is possible to supply family, friends and the public with information. Exemplary crises, in which social software was used, were the Love Parade disaster in Germany and the volcanic eruptions in Iceland which both happened in 2010 (Reuter, Marx, et al., 2012): Facebook (a digital social network), Twitter (a service for publishing short messages with a maximum length of 140 characters which can be shown by other Internet users on the basis of search tags), YouTube (a platform for videos) and Flickr (a service for photos) were used extensively. The information on these platforms was provided by the affected persons and accessed by a large number of people. Depending on the crisis' range, the amount of news and photos provided can hardly be overseen. Because the news is provided by citizens, different qualities and overlapping pieces of information exist. Today, this kind of information is being used and evaluated by the police, for example in the case of demonstrations. However, perceived flaws are the amount of news, which has to be examined, and the quality, i.e. the information content of the single news. Our empirical study made obvious that "*at best 5% of the news can contribute to a situation's evaluation*".

Composition technology: This example reveals that not the mass of the citizens' contributions generates additional value in crisis management, but that the best piece of information is crucial.[*] For instance, not a hundred pictures of a fire are needed, but only a few good ones from different perspectives. This is one example for a best-shot or better-shot composition function.

Supportive approach: A possible approach to technically support the control center's staff is the identification of the best-shots by evaluating the single pieces of information. This can be

[*] However, the quantity of contributions can give an indication of the crisis' intensity.

made automatically, for example on the basis of meta-data about the location and the time or on the basis of *retweets* (Starbird & Stamberger, 2010). Retweets are literally repeated news of other users that indicate a high importance of specific information. Manual evaluations by actors in crisis management or by citizens who correct faulty information by themselves on the basis of collective intelligence (e.g. Wikipedia) are useful, too (Vieweg et al., 2008). The system should highlight the qualitatively best pieces of information in order to enable their utilization. Besides these mechanisms for evaluations, the support of citizens when transmitting relevant information is another solution. For instance, photographing of relevant pictures could be supported by a special application for mobile phones, which on the one hand could render assistance when recording relevant information and on the other hand can ensure that all relevant meta-data are transmitted. In addition to that, users could see which incidences have already been reported in order to prevent repeated reports about the same incident and to enable confirmations. Frequently overlapping pieces of information and different qualities explain that only the best pieces are of relevance in such a use case. It shows that information quality can be especially influenced by the quality of single messages and not only by their amount. An evaluation and a selection of available contributions can foster the clarity and accessibility.

6.3.5 Discussion and Transferability to other Domains

The composition functions mentioned above are relevant in the evaluation of the aggregated information's quality in various fields of application. These formulae thereby only express the description of a state. Various combinations and mixed forms may be relevant in reality, but it can be approximated which function describes reality best in order to derive design requirements for technical solutions. Therefore, the issue has to be identified at first in order to match the single pieces of information. This can be accomplished by a simulation of possible crises (Reuter et al., 2009a), which can give clues about the character and the interdependencies of required information.

The composition function of *summation* is appropriate, if the sum of individual qualities determines the overall information's quality and the contributions are perfect substitutes. We used the example of automated provision of information from different sources to clarify this case (chapter 6.3.2). Requirements for collaborative software are to arrange information clearly, to enable a simple selection and target-group, task- and incident-specific display of information.

The composition function *weakest-link* is appropriate, if the least piece of (disjoint) information is the significant factor for the determination of the information's quality. In this context, we analyzed the example of administration of technical and personal resources (chapter 6.3.3). Requirements for collaborative software are to visualize gaps, claim missing information specifically and to create stimuli for providing entire information.

The composition function *best-shot* is appropriate, if and only if the usage of only the best piece of (overlapping) information comes into consideration and the second best piece hardly has any relevance at all. We used the example of the utilization of content generated by citizens in social software (chapter 6.3.4). Requirements for collaborative software are to classify and evaluate incoming information and to enable easy selection of the best pieces of information.

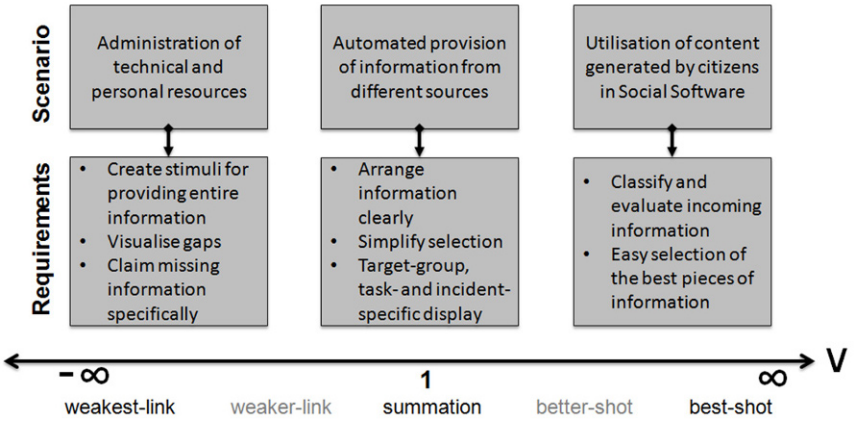

Figure 11: Scenarios, requirements and composition functions dependent on v (influencing the possibility of substitution)

Figure 11 illustrates our use cases, the requirements obtained and the composition functions dependent on the parameter v which influences the possibility of substitution.

When we look at other forms of collaborative systems, for example inter-firm collaborations (Davidsson & Honig, 2003) or co-investment networks (Böert & Werth, 2013), the requirements are identical. It does not matter whether the cooperation is supported by such collaborative software as presented in this paper or by other technical means. If we consider for example a venture capital network (Hochberg et al., 2007), which exchanges information how to improve the performance of start-ups using a bulletin board or other simple technical implementations, the requirements to foster the quality of the network depend on the mentioned mechanisms. The same applies to community and network activities of nascent entrepreneurs who "work in autonomous, distantly separated environments" (Davidsson & Honig, 2003, pp. 303) as business networks seem to be a main driver of success for emerging firms. Collaborative software can facilitate such exchange of information. Contingent upon the possibility of substitution, the incentives to provide information differ as shown above. In weakest-link situations, missing information of one investor or partner is the critical part and has to be highlighted, whereas in best-shot situations a selection and classification process of information reduces redundancies and search time. If a summation technology arises as appropriate description and the elasticity of substitution is maximal, it does not matter who provides the piece of information, but a simplified selection and a target-group, task- and incident-specific display enhances the quality of the system.

It has been shown that entirely different requirements for the design of collaborative software in crisis management, or other applications, arise as a result, depending on the aggregation technology. That is why a profound investigation of the context of single pieces of information seems to be a reasonable approach to extend the requirement analysis in every kind of information and cooperation system. We assume that it is possible to transfer our implications into other forms of collaborative software, as the essential processes are comparable whenever information is composed of information from different sources.

6.4 Conclusion

Our analysis has shown that the identification of information composition functions should be taken into consideration when designing inter-organizational collaborative software. These functions determine the impact of the specific pieces of information on the quality and usefulness of the aggregated information and affect the essential incentives to foster the quality of the collaborative system.

We have analyzed the relevance of identifying and investigating collective information qualities using qualitative empirical studies and the example of inter-organizational crisis management in Germany. Based upon the economic literature on the private provision of public goods we have illustrated different composition functions using a generalized CES function to show characteristics of specific pieces of information and their aggregations. On the basis of these use cases, implications for the design of collaborative systems have been derived to emphasize the importance of identifying characteristics of collectively provided information.

It has been shown that entirely different requirements for the design of collaborative software arise depending on the underlying consolidation processes. Therefore, a profound investigation of the application scenario is useful to extend the requirement analysis in every kind of information and cooperation system in order to implement appropriate measures. Our implications may be transferred to other forms of collaborative software, as the essential processes are comparable whenever information is composed of information from different sources and information is exchanged between organizations or companies as well as between interest groups or individuals.

7 Scenario A: Information and Expertise Sharing in Situation Assessment (JCSCW)

Emergency or crisis management, as is well-attested, is a complex management problem. A variety of agencies need to collaborate and coordinate in real-time and with an urgency that is not always present in other domains. It follows that accurate information of varying kinds (e.g. geographical and weather conditions; available skills and expertises; state-of-play; current dispositions and deployments) needs to be made available in a timely fashion to the organizations and individuals who need it. By definition, this information will come from a number of sources both within and across organizations. Large-scale events in particular necessitate collaboration with other organizations. Of course, plans and processes exist to deal with such events but the number of dynamically changing factors as well as the high number of heterogeneous organizations and the high degree of interdependency involved make it impossible to plan for all contingencies. A degree of ongoing improvisation, which typically occurs by means of information and expertise sharing practices, therefore becomes necessary. This, however, faces many challenges, such as different organizational cultures, distinct individual and coordinative work practices and discrete information systems. Our work entails an examination of the practices of information and expertise sharing, and the obstacles to it, in inter-organizational crisis management. We conceive of this as a design case study, such that we examine a problem area and its scope; conduct detailed enquiries into practice in that area and provide design recommendations for implementation and evaluation. First, we will present the results of an empirical study of collaboration practices between organizations and public authorities with security responsibilities such as the police, fire departments, public administration and electricity network operators, mainly in scenarios of medium to large power outages in Germany. Based on these results, we will describe a concept, which was designed, implemented and evaluated as a system prototype, in two iterations. While the first iteration focuses on situation assessment, the second iteration also includes inter-organizational collaboration functionalities. Based on the findings of our evaluations with practitioners, we will discuss how to support collaboration with particular focus on information and expertise sharing.*

7.1 Introduction

Sharing information and expertise is crucial in coping and recovery work in crisis management. Having the relevant information and expertise on time and with an acceptable degree of accuracy is a key task for all stakeholders. As Schraagen et al. (2010) put it, however:

> *"Current network structures are often characterized by their ad hoc nature. Large […] coalitions are assembled out of units that may never have worked together before, nor are they likely to see each other again […]. In the civilian*

* This chapter has been published as an article (Ley et al., 2014):

Ley, B., Ludwig, T., Pipek, V., Randall, D., Reuter, C., & Wiedenhoefer, T. (2014). Information and Expertise Sharing in Inter-Organizational Crisis Management. *Computer Supported Cooperative Work: The Journal of Collaborative Computing (JCSCW)*, 23(4-6), 347–387.

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> *crisis management area, units are assembled from the police, the fire brigades, and the paramedics to deal with unexpected situations that require coordinated effort for a limited time span. However, during the acute phase of a crisis, central controlled coordination cannot be achieved. This is because, in situations of time pressure, monodisciplinary organizations tend to fall back on well-established routines, each doing what it is they are best in doing. Although these ad hoc organizations are ideally characterized by collaborative working, unlimited communication across all levels and a broad sharing of situation information, in reality there are some bottlenecks that need to be overcome to fully realize their potential." (pp. 117-118)*

Organizations and public authorities with security responsibilities, such as the police or fire department, therefore put a lot of effort into making crisis management work as calculable and predictable as possible. However, large incidents (e.g. Hurricane Katrina (USA, 2005), thunderstorm Kyrill (Western Europe, 2007), Hurricane Sandy (US East Coast, 2012), European floods (Central Europe, 2013)) are hardly predictable. The number of influential factors (e.g. weather conditions, the number of people affected or the type of emergency), as well as structural dependencies (e.g. electricity, roads and railways or fuel resources), makes it almost impossible to plan all crisis management activities and calculate information demands well in advance. Hence, as Ley et al. (2012) suggest, many incident situations require the satisfying of ongoing situational information needs, spontaneous decision-making and ad hoc coordination between relevant organizations, different infrastructure providers and administrative staff. Due to this, improvisation work is at the same time both necessary and difficult to do. A completely different level of challenge is arguably seen when a crisis occurs that requires emergency response organizations to collaborate. For instance, when dealing with a medium to large power outage in Germany (the scenario we were looking at in our research project "InfoStrom"), each organization sets up its own crisis management team. Even at county level, a crisis committee has to coordinate efforts and also has to deal with the public. In these situations each organization has to leave its own area of organizational responsibility and is forced to operate and interact outside its system of established practices. However, there are established processes and practices of coordination and collaboration which are usually based on laws and regulations that make it difficult to improvise on an inter-organizational level. Additionally, since laws and regulations also restrict the design and information portfolio of emergency management systems in response to a pre-planned scenario, these systems cannot provide full support for improvisation work in these situations.

Our work will focus on inter-organizational collaboration in information and expertise sharing practices of stakeholders who are involved in a medium to large power outage in Germany. These are infrastructure suppliers (e.g. electricity network operators (ENO)), public strategic administration (e.g. crisis committee, operations management, county administration), public operative administration (e.g. police, fire department) and the citizens. We are interested in acquiring deeper understanding of the collaboration practices in information and expertise sharing in an inter-organizational crisis management setting, where improvisation plays an important role for coping and recovery work: What makes it necessary to collaborate with others? What factors influence improvised information and expertise retrieval and sharing activities? What communication lines exist and where do communication strategies fail? We also want to answer the question of how ICT support should be designed to be able to adequately support such practices under these or similar circumstances.

This article is structured as follows: after presenting and discussing relevant related work (section 7.2), we will introduce our research question and the research field for our three-year study (section 7.3). We will then describe the methodology of our empirical study and will present our findings with a focus on the aspects relevant for information and expertise sharing that we have found in emergency management (section 7.4). Afterwards, we will describe the concept behind, and implementation of, an inter-organizational situation assessment client and an inter-organizational information repository (section 7.5). We will finish by presenting the results of the evaluation (section 7.6) and then come to a conclusion (section 7.7).

7.2 Related Work

Our CSCW-related work stands as an exemplar of the problems entailed in inter-organizational crisis management, and of the nature of improvisation work in these situations. It further shows how information and expertise sharing occurs in practice and demonstrates the degree to which geographic information systems can provide potential solutions to problems experienced. In this section we review the related work in these areas and outline the research gap.

The "endeavor to understand the nature and characteristics of cooperative work with the objective of designing adequate computer-based technologies" (Bannon & Schmidt, 1989) has always been the aim of CSCW. In "disaster, crisis, catastrophe, and emergency management [which] are sometimes used synonymously and sometimes with slight differences, by scholars and practitioners" (Hiltz, van de Walle, et al., 2011) coordination, cooperation and collaboration are essential. Based on an analysis of the responses to the 2001 World Trade Center attack, Mendonça (2007) suggests that some specifics of emergency management can be considered as characteristic: Firstly, (a) *rarity* of incidences limits opportunities for training and learning. (b) *Time pressure* forces a convergence of planning and execution. (c) *Uncertainty* is present because the development of an extreme incident is rarely predictable. Furthermore, extreme events have (d) *high and broad consequences*, wherefore there is a need to manage interdependencies within a wide range of physical and social systems. The (e) *complexity* of the event arises, which is partly due to the high and broad consequences. Finally, (f) *multiple decision-makers* and responding organizations may negotiate with each other, while responding to the event. Based on interviews with emergency responders, Chen et al. (2008) describe similar characteristics but highlight the "disruption of infrastructure support" as an important occurrence.

7.2.1 Improvisation in Crisis Management

Emergency services face an "unlimited variety of incidents that require interpretation, decision and coordination" (Normark & Randall, 2005). The described characteristics of such situations (Chen et al., 2008; Mendonça, 2007) make it impossible to plan all these activities ahead. Therefore the necessity for *improvisation*, Latin *improvisus* (*im* = not; *provisus* = foresee), occurs, which can be defined as a "situated performance where thinking and action seem to occur simultaneously and on the spur of the moment" (Ciborra 1996). Cunha et al. (1999) present a list of more than 50 rather similar definitions of improvisation. Authors variously define it as "to be composed while performed" (Perry 1991), as "thinking and doing unfold

simultaneously" and "retrospective sensemaking" (Weick, 1996). In this article we will refer to the definition of Perry (1991).

Improvisation becomes necessary when planned decision-making does not work as anticipated. It further arises when "both a demand for speed and action, and an unexpected […] occurrence are perceived" (Pina e Cunha et al., 1999). The necessity to judge highly novel problems and to act quickly reduces the possibility of extensive planning: "Decision makers in emergencies must be prepared to improvise" (Mendonça & Wallace, 2007). Instead of trying to eradicate it through automation, the need to appreciate flexibility and effectiveness seems to be more realistic. In this case, "improvisation and preparedness go hand in hand" (Mendonça 2007): without improvisation, emergency management loses flexibility and without preparedness, emergency management loses efficiency. In his description of the Mann Gulch fire disaster in 1949, Weick (1993) outlines intergroup dynamics, such as dealing with the collapse of formal structures and role systems, besides the improvisation of individual firefighters. Accordingly improvisation can be treated as an individual phenomenon (independently solving a problem) or as a team phenomenon: "Collective improvisation" occurs in the interaction of at least two agents and manifests in different tasks: "planning or executing action" at "any level" (Moorman & Miner, 1998). The dynamics and specifics of emergencies make it extremely difficult to find appropriate approaches to articulating information needs amongst all actors (Heath & Luff, 1992). A perspicuous example of (collaborative) improvisation is therefore visible when we examine practical information and expertise sharing behavior among emergency services for situation assessment.

7.2.2 Information and Expertise Sharing in Situation Assessment

Conceptions of information need (and, indeed, what is meant by information) remain divided along roughly disciplinary lines. Endsley (1995), for instance, distinguishes between *situation awareness* as a "state of knowledge" and *situation assessment* as the "process of achieving, acquiring, or maintaining" that knowledge and sees information gathering as a selection process which leads to the construction of a mental model in accordance with individual goals. The terms largely associate with cognitive psychology and emphasize the role of environmental information acquisition and the various cognitive limits that constrain it. Such definitions are evidently quite different from conceptions of the 'situation' and 'situatedness' that are conventionally found in CSCW, and hence need some unpacking. While we do not share the goals- means assumptions behind the notion of situation awareness, the processes entailed in situation assessment are of some interest. We recognize the need to emphasize the external (environmental) information needs that are necessary for accurate and timely decision-making to unfold. Our concern is not with individual cognitive processes or internal models but with the processes by which (for the most part) factual information is acquired, disseminated, and interpreted across groups of people working in the same area. CSCW tends towards a more interpretive approach and emphasizes notions of 'expertise' or 'knowledge' sharing (Ackerman et al., 2013). *Information sharing* (or *knowledge sharing*[*]) is used for artifact-centered studies and "takes a perspective in which externalization of knowledge in the form of computational or information technology artifacts or repositories play an important role" (Ackerman et al., 2013). Communication-centered *expertise sharing* focuses on "self-

[*] Ackerman et al. (2013) mention to "not differentiate between knowledge and information" in their overview article about the "CSCW View of Knowledge Management".

organized activities of the organization's members and emphasizes the human aspects" (Ackerman et al., 2003) in addition to information storage and retrieval. It is used "when the capability to get the work done […] is instead based on discussions among knowledgeable actors and less significantly supported by a priori externalizations" (Ackerman et al., 2013). In line with Ackerman et al. (2013) we will use information sharing mainly to describe the externalization of knowledge and expertise sharing as socialization through shared experience (see also the SECI process of knowledge conversion by Nonaka et al. 2000).

Regardless, the need for up-to-date and accurate information in complex crisis scenarios cannot be completely covered by routine processes and predicted information demands (Ley et al., 2012a). Moreover, the necessary information is often not available in a centralized manner, but has to be specifically requested from the control center, from discrete relief forces in the network, or from a third party (Ludwig et al., 2013a) or even from citizen (Reuter et al. 2012a). Quarantelli (1988) has summarized research findings since 1963 and has identified a range of different challenges for the communication process and information flow in crisis: For communication inside the organization, he suggests that "during a disaster, the number of staff using the communication system will often increase greatly" (Quarantelli, 1988), and may exceed the communication systems' capability and result in *overload* (Hiltz & Turoff, 1985). Information flow between organizations is challenging since "formal contacts must often be established with previously unknown officials within organizations with whom there had been no pre-disaster relationships" (Quarantelli, 1988); likewise, "in fact the major problem in emergency management is that the team often does not exist formally until the emergency occurs" (Turoff et al., 2010). Other studies suggest that the "serious communication problems [with regard to] both police and fire departments […] stem less from lack of equipment or resources but primarily from the […] pre-disaster planning with respect to information flow" (Wenger et al., 1989). Turoff et al. (2004) draw requirements for emergency management systems which include, "establishing and supporting confidence in a decision by supplying the best possible up-to-date information". They therefore call for methods and techniques which act to maximize the free exchange of information: "Crises involve the necessity for many hundreds of individuals from different organizations to be able to exchange information freely, delegate authority and conduct oversight, without the side effect of information overload". They see prospective solutions in terms of "collaborative knowledge bases" such as "system directories with all the data and information that is available at the time [and the possibility] to add metadata, link data and to enable open and flat communication". Harrald (2006) similarly suggests that "the organizational systems that respond to extreme events must be open systems that allow information to be gathered from and transmitted to the public and nongovernmental organizations in addition to standard governmental sources". Rankin et al. (2011) look at the information and communication flow of persons acting in improvised roles and conclude that "making better use of technology for sharing information could be an important option for strengthening the teams' overall support system and information sharing during disturbances". Accordingly, "just as an artist may employ a new tool, new material or new strategies, so too do decision-makers […] to rebound when established methods fail or when unanticipated circumstances arise. In both cases, training and preparation remain fundamental, but creative thinking, flexibility and the ability to improvise in newly emergent situations are vital" (Kendra & Wachtendorf, 2003). How this is to be done, of course, is the problem. One solution is to spend more time looking at informal communication channels with a view to making them more effective.

Previous studies, for instance in software development, have discovered a large variety of informal communication and ad hoc coordination mechanisms in play (Doherty et al., 2012). These authors suggest introducing technologies that support the establishment of "less formal communication channels" instead of structured information management systems, a policy which may also be relevant in crisis management. Hobson et al. (2011), for instance, in an empirical study of the information needs of municipal governments argues that the heterogeneous nature of these needs meant that *flexibility* was identified as the main requirement. They also point out that employees "rely heavily on manual methods for data sharing" (Hobson et al., 2011). A related study on the challenges of sharing and coordinating information during multi-agency disaster response highlights that the "actual level of information sharing across different organizations is often limited, although it is being promoted". A reason is that agencies "are mainly concerned with obtaining information from others, rather than providing others with information at their disposal" (Bharosa et al., 2010).

7.2.3 Collaborative Geographic Information Systems

In emergencies, information is almost always related to specific locations, therefore *geographic information systems* (GIS) are of relevance for the presentation of information (Turoff et al., 2004). Li and O'Hara (2009) show that, in decision-making by geographically distributed committees, difficulties arise from not having shared visual access to the information being discussed. Paul and Reddy (2010) also consider the visual aspects: their ethnographic study of collaborative information seeking shows that in addition to the ambiguity of information, the different roles and expertise of group members make sensemaking (Weick, 1996) more challenging; they propose the visualization of sensemaking trajectories in order to foster awareness among emergency agencies. Kraut et al. (2002) confirm that "collaborative pairs can perform more quickly and accurately when they have a shared view of a common work area".

Other research has identified the need to locate and exchange information, or to quickly resolve ambiguities about location, in emergency services centers. Pettersson et al. (2004), for instance, highlight the relevance of maps, both paper and electronic. In terms of group work, "most spatial decisions using geographical information are done by teams, but existing geospatial information technologies […] have been designed for use by individuals", according to Cai (2005): his approach extends distributed GIS with collaborative functionalities and proposes a system architecture that integrates web service-based distributed computing paradigms. The related geo-collaborative software architecture for emergency management planning of Schafer et al. (2007) combines java-based collaborative infrastructures with GIS to support awareness and collaboration with annotations and selections that can be shared, along with the possibility to lead or follow another user's map or to link geo-referential data to other content. These functionalities are used in the study by Convertino et al. (2011) focusing on knowledge sharing and activity awareness in distributed emergency management planning with a collaborative geospatial prototype. With a series of paper and software prototypes, they show that using collaboration technology can reduce the coordination efforts among spatially distributed teams. Wu et al. (2013) contribute to the "design research on a new collaborative system [CIVIL] for teams doing complex geo-spatial planning tasks" and suggest to "provide both personal (role-specific) and shared (team) maps and support information transfer between them". Guidelines, based on an evaluation of CIVIL (Wu et al., 2013), include (a) inte-

grating map services that people are familiar with, (b) allowing users to add personal comments and drawings that overlay on maps, (c) providing both shared and private maps as well as supporting the transfer of information between them, (d) providing visualization tools to present information and help information analysis, (e) allowing platform-independent, distributed collaboration and (f) developing architectures that allow delegation of non-critical information management tasks to online public services. Another (mobile) collaborative application named MobileMap (Monares et al., 2011) was designed to help firefighters arrive faster to the emergency scene, to exchange digital information during emergency response processes and to reduce the need for radio communication. Web based geo-collaborative tools also have been examined: Chang and Li (2007) integrate collaborative tools such as chat and video to support participant's awareness and their collaboration. Many of these web-based crisis mashups among *Ushahidi* (Okolloh, 2009) are described by Liu and Palen (2010), who focus particularly on "merging the professional GIS culture with the participatory neogeographic culture to address the mapping challenges which are likely to arise in this increasingly networked world".

7.2.4 The State of Play

The demand for constant updating of information and the need to share expertise in a timely fashion in the crisis management arena - given the lack of workable plans - means that improvisation work is typical rather than abnormal. Improvisation, then, is a consequence of the demand for real-time, relevant, information. At the same time, as we will show, improvisation work suffers "from a lack of options for sharing information among the organizations, but also from a lack of awareness of information about the activities of others, and from a lack of collaboration in consolidating and interpreting the information available" (Ley et al., 2012a). Similarly Turoff et al. (2004) describes research opportunities in the area of "collaborative knowledge bases". Cunha et al. (1999) identified an "unresolved issue [which] is the need for close relationships between those improvising"; an application field for CSCW. Cai (2005) mentions a potential for collaboration in GIS, which have only partly been addressed, e.g. by Convertino et al. (2011) in terms of activity awareness and Wu et al. (2013) regarding geospatial planning tasks.

There is, therefore, an evident need for research which considers actual collaboration practices and the real – not just intended – use of technologies to support them and the impact on collaborative practices on information technology design and use. That is, existing research identifies a number of areas which, in principle, might improve and ameliorate communication channels in emergency-related work across organizational boundaries. How this might be done depends on better knowledge of exactly how, what, when and in what format, information is shared as events unfold. Therefore our study focuses on these improvisation practices (Perry, 1991) and the nature of the collaboration between those improvising (Pina e Cunha et al., 1999) when assessing situations. We show how this follows on from the need for real-time and relevant information and expertise sharing (Ackerman et al., 2013), with the aim of transferring our empirical findings to technology design for such settings. Specifically, we are interested in the design of a collaborative GIS.

7.3 Research Question and Approach

Our review of relevant literatures demonstrates that there is a common concern with certain issues, including situation assessment; sharing knowledge, information and expertise, and the use of collaborative channels to do so. That they are of concern is, then, a relatively high-level and commonly understood issue. In contrast, *how, in practice*, these things are managed is quite another issue, and relatively poorly understood. Our objective, therefore, in this paper is to examine *how* information and expertise sharing practices are conducted in an improvised manner on an inter-organizational level and to propose a socio-technical infrastructure to foster information and expertise sharing in inter-organizational crisis management. This, we felt, necessitated a close, 'on the ground' study of these practices. Ideally, of course, such studies should take place in situ. It is, however, known that ethnographic approaches *tout court* are difficult to conduct in our chosen context for a number of reasons. These include the difficulty of knowing when disaster will strike, of knowing how serious it might be, of avoiding obstructive behavior, and so on. Therefore, understanding local and inter-organizational collaboration requires us to employ satisficing techniques, as reported below. We chose a specific scenario, that of major power outages, because collaboration between crisis response organizations is particularly difficult when dealing with a crisis of this kind and magnitude. First, we set out to gain an understanding of information and expertise sharing practices within this inter-organizational crisis management setting, where improvisation and informal practices play a significant role when handling crisis situations. Secondly, we contribute knowledge of how to support these sharing activities. We therefore aimed at building a socio-technical artifact, which was then evaluated, and in turn, gave us the opportunity to extend our first contribution as well. To fulfill these contributions we followed an action research approach, specifically the methodology of the *design case study* introduced by Wulf et al. (2011). This method begins with an empirical analysis of the given practices. The data collected informs design by showing how improvisation influences information and expertise sharing in this setting. As technology builders, we can draw on a wealth of detail which is not typically available in more theoretical contributions. The design case study approach also, we should point out, draws attention to the long-term appropriation of new technology. Evaluation, however, of an in situ nature is difficult, not to say impossible, in crisis situations for the reasons we mention above. The circumstances of serious crisis response and rescue tasks are such that neither real-world 'on the ground' investigation nor evaluation are a practical proposition. We did, however, evaluate the artifacts in a work context with representative users. We will explain our methodology in the respective sections in detail.

The findings and concepts that will be discussed in the next sections are derived from a study in the years 2010-2013 focusing on collaboration, situation assessment and decision-making practices during coping and recovery work at emergency services. The study was conducted in two regions of North-Rhine Westphalia in Germany. Region A (Siegen-Wittgenstein) is a densely wooded, hilly county, whereas Region B (Rhein-Erft-Kreis) consists of 10 growing communes west of Cologne. In both regions we focused on several persons and organizations that were affected: infrastructure suppliers (e.g. ENO), public strategic administration (e.g. crisis committee, operations management, and county administration), public operative administration (e.g. police and fire department) and the citizens.

7.4 Empirical Study on Information and Expertise Sharing Practices

7.4.1 Methodology

The basis for our study, as intimated, was a perceived need for some more detailed understanding of information needs in the complex environment of crisis or emergency management. As we have suggested, traditional (sustained observational) ethnographic research is not practicable in this context. Having said that, if one accepts the views expressed by well-known anthropologists such as Clifford Geertz (1973) and Rabinow and Marcus (2008), as well as the views of CSCW researchers such as Randall et al. (2007) it is legitimate to speak of 'ethnography' as a form of analysis rather than as a specific method. Geertz, for instance, explicitly states:

> *"And it is in understanding what ethnography is, or more exactly what doing ethnography is, that a start can be made toward grasping what anthropological analysis amounts to as a form of knowledge. This, it must immediately be said, is not a matter of methods."*

We therefore characterize our work as ethnographic because, in the circumstances available to us, we adopted methods which gave us as realistic information as possible about information sharing practices in the application field. In fact, we adopted an informal group interview strategy, akin to what are sometimes called 'focus groups'. We conducted five inter-organizational group discussions (Table 18), each lasting about four hours. The goal of the group discussions was to understand the communication practices of inter-organizational crisis management in general.

No.	County	Topic	Participants
W1	both	Challenges in practice, visit of control center	Energy Network Operator (ENO)
W2	B	Challenges in practice, visit of control center	County Administration Police Fire Department
W3	A	Challenges in practice, visit of control center	Department Head: Public Safety Head of Civil Protection Head of Police Control Center Deputy Head of Control Center District Fire Chief
W4	A	Analysis of user interactions and communication flows	Head of Police Control Center Head of Staff Coordination Deputy Head of Control Center Local Head of Federal Agency for Technical Relief (THW) Local Head German Red Cross
W5	B	Analysis of user interactions and communication flows	Head Regulatory Authority District Fire Chief Red Cross: Disaster Management Red Cross: Communications Members of other aid agencies

Table 18: Group discussions

Furthermore, we conducted 22 individual interviews (Table 19) with representatives from organizations which normally would be involved in the scenario we envisaged. The scenario

itself was developed with participants from the organizations we were working with and consisted in outline of a windstorm with many incidents and energy breakdowns. The purpose of the scenario was to be able to quickly create a common understanding of a crisis situation. The interviews lasted between one and two hours each and were semi-structured, since they followed a guideline. They were separated into three parts. The first part focused on the participants' role, qualification, tasks and work steps under normal conditions. The second part covered the tasks of each participant during the crisis situation and was based on the developed scenario framework and the third part covered the applied information and communication systems and the problems perceived with these tools. Group discussions and interviews were recorded on audio and transcribed for data analysis. After conducting our empirical work, we derived the basic categories of: *technology usage*; *situation illustration and construction*; *information quality, quantity and trustworthiness*; *communication practices*; *cooperation and collaboration*; *debriefing and learning*; *citizen involvement*. After that, we identified the specific challenges in collaboration practices related to these categories.

No.	County	Organization	Role
I01	A	Administration	Regulatory Authority
I02	A	Police	Head of Control Center
I03	A	Police	Head of Section
I04	A	Police	Patrol Duty
I05	A	Fire Department	District Fire Chief
I06	A	Fire Department	Deputy Head of Control Center
I07	A	Fire Department	Workmanship
I24	A	Fire Department	Head of Control Center
I08	B	Administration	Office Civil Protection
I09	B	Fire Department	Chief Officer / Chief of Fire Dept.
I10	B	Fire Department	Operation Controllers
I11	B	Fire Department	Clerical Grade Watch Department
I12	B	Fire Department	Control Center Dispatcher
I13	B	Fire Department	Head of Control Center
I14	B	Police	Member of the Permanent Staff
I15	B	Police	Head of Control Center
I16	B	Police	Head of Group
I18	both	ENO	Higher Area, High Voltage
I19	both	ENO	Operation Engineer, High Voltage
I20	both	ENO	Operation Technician, Low Voltage
I21	both	ENO	Dispatcher, Low Voltage
I22	both	ENO	Workmanship Technical Incidents

Table 19: Interviews

7.4.2 Empirical Results

Before we describe our findings in the following sections, we will detail the organization of emergency management services in the regions we are concerned with, notably the structure of the police and firefighting services. Firstly we should note that, in the two regions we are concerned with, organizational structures are different. Region B provides professional fire and rescue services, whereas in region A, firefighters are mostly members of volunteer fire

departments. Here, in region A, the only professional positions are held by people working in the control center. Secondly, in both regions, firefighters receive their orders from the field via 'incident commands', while police forces in the field receive their commands from the operations management at the control center.

During major crisis situations, crisis management is organized as follows: Germany is separated in 16 federal states and each of these states in turn is separated into several counties. The administrative head of the county holds the overall political responsibility for crisis management action. Two types of crisis management groups exist in each county. There is one *crisis committee,* which is responsible for administration and organization tasks, and consists mainly of permanent staff from the administration office. The administration office includes, for instance, the general county administration, regulatory authority, office for civil protection and several other civil services. In addition, there are several *operations management groups,* which are responsible for operations during crisis situations and are located in each crisis response organization (e.g. police, fire fighters, etc.). To illustrate the general collaboration practices between crisis response organizations, we will present a short example. Two emergency phone numbers exist in Germany. In case of fire, flooding or medical emergencies, citizens have to call 112 in order to alert the fire department, in other cases 110 to call the police. After calling 112, the fire department will usually take action by executing predefined response plans. The fact that two different emergency numbers exist reveals that emergency response organizations act independently of each other in most normal circumstances. Both organizations are responsible for their own actions and have their own procedures. The only predefined collaboration that exists involves the police ensuring that fire fighters have enough room for e.g. fire trucks at an incident scene. When it comes to a larger incident or even to a crisis situation, however, the operation management groups will include liaison officers from the other involved emergency organizations to plan further actions cooperatively. Besides police and fire fighters, other crisis response organizations exist. However they for the most part just support coping and recovery work. The responsibility for their work remains with the operational management group or crisis committee. The Germany Federal Agency for Technical Relief is an example of such an organization. They can provide specific expertise and technologies to cope with special crisis situations, but they have no decision-making power.

Our empirical data revealed to us that improvisation does indeed play a significant role within intra- and inter-organizational collaboration practices, as the literature attests. It is, moreover*, is understood by participants to be a normal and routine feature of work of this kind*. It therefore has a major influence on information and expertise sharing practices as well. Hence, we describe below why *and how* improvisation is a key issue and what factors lead to improvisation activities. We will than have a closer look on information retrieval and expertise sharing practices.

7.4.2.1 Improvisation in Coping and Recovery Work

Constantly being faced with new problems and the need to act quickly play a significant role in handling a crisis situation. Our study revealed that in both counties coping with unexpected information needs, ad hoc decision-making and coordination is a regular and common practice among decision-makers when responding to uncertain circumstances under risk and with limited time available. Improvisation, in other words, is routinely done:

> *"Improvisation is essential, next to extensive planning. You can have the best predefined response plans, but there is always a situation, where you have to improvise" (I01)* or *"We improvise as usual. We see to it that we make the best out of each situation" (I11).*

So, besides executing one or more response plans, we could see that in today's emergency management processes straying from plans and predefined actions is common practice: "*All workflows are flexible. This is necessary, because each situation is different*" (I02). Hence, the uniqueness of each crisis situation and the resulting ad hoc information retrieving practices form the basis of the situation assessment work of each organization. A wide range of emergency response actions also demonstrates that improvisation is usually a collaborative task. To deal with an uncertain and changing environment during crisis situations, a great number of people are involved in gathering and analyzing data, decision-making and monitoring of implementations and consequences. The following extracts indicate the way in which these practices might be structured. The first shows why what we are calling 'improvisation' is so important:

> *"This is necessary, because no situation is equal to any other. […] Our work is fundamentally different from other local authorities. There are no predefined processes we are working off – we would be helpless and lost. That's why we tactically work with mission-type tactics" (I02).*

The point here is that no single situation can be assumed to be like others that have preceded it. This has some obvious ramifications, as is stated, for procedure. Responses, as is suggested here, need to be 'tactical' rather than strategic. Actions will be ordered specifically in the light of unfolding real-time events, rather than through assumptions about what such events typically entail.

What will follow from this is, again, evident. There is an urgent need for up-to-date and accurate information about what has occurred. Nevertheless, outdated information, e.g. phone numbers or contact persons, may exist. The picture of the situation – some kind of overall assessment – is necessary before any coordinative activities are possible. Put simply, coordination has to take place at a 'command' level before coordination can take place at an operational level. As a policeman on operational level said:

> *"We have to get a picture of the scene at first. Than we both have to coordinate ourselves: finding appropriate ways of solving the problem together and then running these actions" (I04).*

In addition, a member of a command center of an ENO said:

> *"But if it's critical anywhere, you will willingly ask a colleague: 'What do you think about it? Give it the once-over.' The big advantage we have is that there are at least two of us sitting here, twenty-four-seven" (I20).*

To assess the potential impacts of present or future events, members of the group (usually emergency services) share their knowledge within the group or – depending on the case – they have to consult external experts (e.g. members of the residents' registration office to access, for instance, numbers of occupants in case of a burning house).

7.4.2.2 Situation Assessment Practices

We have seen that no two situations are identical (or even similar) and, as a consequence, predefined response plans are not especially useful. These circumstances lead to further reasons for ad hoc decision-making and spontaneous information retrieving. We will explain this in detail, while having a closer look on organizational and inter-organizational situation assessment practices. Situation assessment, as we have suggested, is a necessary precursor to action in crisis management. The information needed will emanate from several sources and will be accessed through a number of different channels. This will include, for instance, information about staff positions, material resources, weather forecasts, emergency plans and will come from different organizations (e.g. weather services, ENO, etc.) via different media channels (e.g. phone, internet, face-to-face, etc.). During non-routine events this typically takes place in an ad hoc manner. However, current crisis management is such that information provision falls significantly short of what is needed. Not only is information sometimes missing but actors often do not even know what data other (or even the own) organizations are able to provide (it is important to bear in mind that the actors involved in a crisis situation may never have encountered a similar one before).

We were able to identify three factors that influence this. Firstly, as I15 pointed out, organizations usually concentrate on themselves and their work tasks, and not on providing information proactively. This is especially true during major events as a result of time constraints. Secondly, each individual organization may have little conception of what information other organizations might find useful. For example, actors from ENO highlighted the usefulness of information about roadblocks in specific situations to make alternative routing more efficient. This information is mainly provided by the police or the fire department, but it is apparent that they sometimes do not think to send such information through (I16). Thirdly, there is an issue relating to the granularity of information provided. Information, put simply, can be short on necessary detail. In the case of infrastructure operations, ENO sometimes provides information with previously missing details such as the number of households affected (I10):

> *"What has broken down, how much of the energy network is out of work and how many people are affected?"*

Information accessibility is also an issue. There are various reasons for this. These include the fact that appropriate interfaces for viewing information are not always available; access to important information is often restricted as a matter of policy (frequently the case with non-publically available databases) and the fact that there are terminological differences in the structuring of information in discrete organizations. It makes the sharing of information for situation assessment even more difficult (W2). "*Many terms are different*" (I02) and varying descriptions of incidents and situations can cause communication issues. This latter is significant in, for instance, trying to make an assessment of how serious a particular incident may be, as for instance:

> *"There is a person with a cut finger and an employee from the agency for technical relief reports this injury – This nearly sounded like a fatality!" (W2).*

More generally, one of the major challenges when retrieving information about a certain situation is assessing the quality of that information. This, we should recall, in situations where time can be of the essence. Information from the Internet needs to be evaluated carefully and it is often difficult to assess its correctness, truthfulness and relevance (I15). The same applies

to other citizen-generated content as there is no common *"level of consciousness"* (I15) and citizens cannot decide what information is needed by the authorities and other organizations (I02). Quality is equally compromised by the fact that, in times of crisis there can be floods of information that are difficult to manage – it can be duplicated, can be inaccurate and impressionistic, and can be misleading. Even information from official sources, such as alerts in the face of severe weather can contain uncertainties and has to be evaluated carefully. Such warnings are often published too frequently and in many cases no critical weather conditions occur:

> *"Most of the time, when we put extra staff on demand due to weather alerts, nothing happens. […] we have the problem, that these warnings are reported to frequently and I cannot put staff on demand for each weather warning." (I02)*

These ambiguities mean that direct viewing becomes especially valuable. Additional information resources (e.g. current weather conditions outside the building or webcams that are focused against the wind direction), and which give a more immediate 'picture', are used to obtain a better overview of the situation (I24). The point here is that more and more information does not necessarily lead to better information. Rather it can create ambiguity and uncertainty. The kind of 'direct view' we refer to here is a valuable means to reduce that ambiguity (I15). We substantiate these observations by giving an example (see below).

7.4.2.3 Information Retrieval and Exchange Processes

Information retrieval for situation assessment, unsurprisingly, usually begins with a trigger event such as an incoming emergency call or warning message (e.g. severe weather alert). To keep track of the events and to be adequately prepared for an incident, decision-makers have to collect supplementary information from various sources: *"You need as much information as possible"* (I24). Some of the information (like weather alerts) is provided by "official" information systems or files. In case of a major disaster or a weather alert, these internal information resources are enriched through external and informal information resources (like webcams, water level or traffic services). As we have indicated, emergency services need as much accurate and unambiguous information as possible, but are highly conscious of the fact that this will mean considerable filtering of data sources. Keeping track of several information resources to have an overview of the situation at this early stage is not unproblematic and is compounded by the fact that much of it is gathered individually from the Web. Nevertheless, the speed with which information is available to them seems to override other considerations:

> *"It turned out that the […] Internet [is] faster than our officers on-site. […] The information has admittedly to be evaluated but they were very, very useful concerning the quality. I was impressed by the mass, the speed and the usefulness" (I15).*

On-site actors are instructed to *"collect and communicate any information that is locally graspable and available"* (I07). At the same time, they also depend on an optimal overview of the situation as it develops. Above all, they always need be kept informed by the control center, where all information in theory comes together, is accumulated and then redistributed, either by radio or phone. In addition to that, they often make use of their private smartphones to obtain additional information:

> *"Some of the colleagues have an Internet connection on their smartphone that is often useful, for example to pull up an aerial image of the locality via Google Maps to check other information" (I04).*

Having said that, retrieving information from other organizations is a major challenge in the control center. As we have said, organizations do not necessarily proactively inform other organizations about further development. They have to be asked directly:

> *"The other actors have a different perception because they concentrate on their problems and not on providing information" (I15).*

Each organization uses their own emergency management and communication systems, developed for their specific organizational needs and which are not directly accessible by other organizations or by the public (W2). Moreover, the different control center systems of e.g. the police and fire department cannot communicate directly one with the other. The control center of the police, for instance, uses a different system for crisis response than the operations management. Furthermore, even at this point it is difficult to share information between these internal units:

> *"There is no interface between our software system and the control center system. We need to export a PDF-file and send via e-mail to the control center" (I15).*

We should also point out that there is a distinct distribution of expertise on the part of users. Some users are technically adept, and will, for instance, bookmark websites with additional information resources, such as webcams, to check weather conditions or the water level status of nearby rivers (because their official system does not provide this information). Others are less so. This means that available information is differentially acquired and, sometimes at least, is available to certain individuals but not to others.

7.5 Supporting Information and Expertise Sharing

The empirical study shows abundantly clearly that certain kinds of information need to be shared quickly, accurately and unambiguously to all relevant operators. At the same time, the flow of information has to be carefully managed so that the 'flood' does not produce the exact opposite. The current organizational and technical structures of each organization involved do not provide suitable interfaces to effect this efficient flow during major incidents, due to the large number of heterogeneous systems. The exchange of information is currently limited to e-mail, phone calls or special liaison officers, who are the on-site contacts of the operations management of the other organizations. The exchange of expertise tends to be dependent on the experience and contacts of long-standing employees. Our findings can be divided in two main areas: (1) inter-organizational information sharing and (2) inter-organizational expertise sharing. Table 20 shows the challenges for inter-organizational information and expertise sharing, from which we derived the design implications for the conceptual and technical architecture of our approach.

No.	Empirical Findings (related to section 7.4)	Inter-Organizational Challenges	Design Implications
Inter-organizational Information Sharing			
1	Besides fixed organizational processes, improvisation is very important (section 7.4.2.1)	Complement fixed processes and capability for improvisation practices	Functionality for ad hoc communication and information retrieval
2	Heterogonous, specialized communication systems at each organization (7.4.2.3)	System-independent additional inter-organizational communication options	Web-based architecture to facilitate system independent access
3	Lack of knowledge about available data at the own or other organizations (7.4.2.2)	Capability to structure available data	Meta-information about suitable and available data
4	Large amount of required information (7.4.2.2)	Capability to aggregate and structure information	Additional meta-attributes
5	Required information is mostly organizational distributed (7.4.2.2)	Capability to access information centrally	Shared inter-organizational information repository
6	Out-of-date information, e.g. phone numbers, contact persons (7.4.2.1)	Capability to keep information as up-to-date as possible	Decentralized, shared information maintenance
Inter-organizational Expertise Sharing			
7	Accessibility and policy issues between organizations (7.4.2.2)	Capability to provide tactical and operational accessibility	Authentication and individual sharing
8	Terminological differences between organizations 7.4.2.2)	Overcoming verbal terminology differences	Verbal communication with visualizations functionality
9	Difficult inter-organizational situation assessment (7.4.2.2)	Enable inter-organizational situation assessment	Shared inter-organizational situation map
10	Information overloaded situation maps (7.4.2.3)	Reducing overload on situation maps	Individual map layers
11	Spatially distributed teams and organizations during response work (7.4.2.1)	Enable location-independent inter-organizational collaboration	Location- and time-independent collaboration functionalities

Table 20: Empirical study-based design implications

7.5.1 Enhancing Inter-Organizational Information Sharing

The literature and empirical study show that due to the highly uncertain and dynamic nature of large-scale incidents, organizationally predefined structures and processes are often not sufficient and ad hoc information retrieval or spontaneous communication becomes much more important. Coping with unexpected information and ad-hoc decision-making require improvisation, which in this sense, means for example that units of one organization will call members of other involved organizations informally and spontaneously. On the one hand, (1) such improvisation work is indispensable while responding to highly dynamic emergencies; on the other hand, it does not guarantee that information will be shared by all those who need it, and it means that the flow of information depends on an adequate distribution of expertise which, again, cannot be guaranteed under the current arrangements. The fact that improvisation work in emergencies often prevail the fixed organizational work structures implicates the need for ad hoc communication and spontaneous information retrieval.

At the same time, each of these respective organizations needs to be able to fulfill its respective tasks and routine procedures under normal circumstances, and therefore needs its own individual, specialized systems and organizational structures. Besides phone calls or e-mails, which are fallbacks due to the dynamics of a situation, (2) the landscape of heterogeneous systems and organizational structures offer only inadequate possibilities for accurate, consistent and up-to-date inter-organizational communication. The design challenge would not be to replace existing systems through a comprehensive "integrated" solution or as mentioned above to break up the current organizational structures, but to create interfaces between the different systems and to provide additional opportunities for inter-organizational communication and information exchange to design the systems more flexible. To connect the diverse individual systems, a web-based, service-oriented architecture is needed since it offers platform-independent access that can act as a light-weight intermediary between the different interfaces.

Beside the aforementioned challenge of providing a more flexible technical (software) level, challenges also exist on an organizational information level. In information retrieval and exchange, the organizations are aware that their information is not only relevant for their own individual work, but also - in principle - for other organizations. For example, police road barriers have an enormous impact on the driving routes of aid agencies or fire departments to the location of the incident. However, due to the fact that emergencies evolve unpredictably and that organizational members often miss detailed insight into other work practices and structures, (3) the knowledge of what information is available within one's own organization, as well as the knowledge of *which* piece of information is relevant at *what* time for *which* organization, is very hard to predict and is often dependent on many years of individual experience. The current systems lack instruments to distribute meta-information about the overall process and suitable and available information as well as to articulate information demands in order to share information with other organizations. The dynamics of an emergency make it hard to predict all the information needs of other organizations in advance. Instead of trying to anticipate these information demands, we argue that organizations should proactively provide information with supplementary meta-information automatically added, even if they are not aware of how this information could be used of other organizations. In this way, even inexperienced actors from other organizations would be able to search through the available information and would be able to access it easily.

Associated with this, we suggest that, in order to deal with the problem of the (4) large amount of (5) external information and its distribution to individual organizations, *centralized* access to *decentralized* information sources should be provided. A central access point with standardized interfaces enable organizations to know where and how they can access information from other organizations. Technically, the central access point as well as the offer of meta-attributes can be realized by a shared, web-based information repository. The decentralized maintenance of the individual information and its meta-attributes in the repository could prevent the necessity of having to deal with (6) outdated information, since each organization is responsible for the timeliness of the provided information.

7.5.2 Enhancing Inter-Organizational Expertise Sharing

Due to the spatial distribution of organizations involved in response work, the current practice lacks options for inter-organizational collaboration or expertise sharing. Apart from one-to-

one phone calls, which mainly depend on knowing who to contact when from which organization, it is hard to collaborate among spatially distributed actors from different organizations. Even inside one organization the collaboration between on-site units and the staff at the control center is limited to speech and radio. It is not always obvious which person is the right one to contact or how to contact him. The challenge is to provide location-independent functionalities that simplify the current needs for inter-organizational collaboration. Further, accessibility, (7) legal regulations and policy issues limit cooperation between the various organizations. Coordination at present takes place on a political and strategic level, regulated through the legal agreements. In order to manage incidents successfully, especially large-scale emergencies, organizations are challenged to come together on several organizational levels. To pave the way for collaboration not only on a strategic level that is mandated by law, but also spontaneous on a tactical as well as operational level, authentication mechanisms are required across all organizations, which foster individual fine-granular expertise sharing. The information needs of other organizations are rarely trivial – especially, as is often the case, for inexperienced forces. Equally, their operational processes are opaque for the outsider. Regular sharing on a tactical and operational level, then, should help units to dovetail with the work practices of other forces.

As we have suggested, inter-organizational (and even intra-organizational, such as between control center, operations management and crisis committee) communication is bedeviled by (8) inconsistent technical terminology. For example police and fire services do not share a common understanding of the term “large-scale emergency”, which implicates different measures for each organization. Such terminological differences make it difficult to collaborate and share expertise among the various domains (Reuter et al. 2012b). Legislating vocabulary, however, comes with problems of its own (see e.g. Martin et al. 2007) as operators can be sometimes forced into artificial and ambiguous categories when confronted with unusual circumstances. Our proposed solution involves visualization techniques that operate with icons and images instead of exact descriptions or terms. At the time of writing, (9) no inter-organizational situation assessment takes place. During a large-scale incident each organization operates in its own control room as well as (10) on-site with a situation map, a “map showing the tactical or the administrative situation at a particular time” (US Department of Defense, 2010). Based on such a situation map, operation goals and concrete measures are derived by the respective organization. The challenge of establishing a common assessment of the situation must therefore include the possibility of a shared situation map (closely connected to the terminology issue) or a means to integrate information on the different maps, so the situation can be visualized and discussed as it unfolds.

One of the difficulties is that (11) each situation map in the respective organizations is often already overloaded. It already contains all tactical aspects and resources like units, the strength of unit groups, situationally important buildings as well as search radii or collecting points. It is apparent that simply adding more information in will create an additional load on ‘readability’. Map layering is a well-known solution to this kind of problem in GIS and is commonly used to examine scenarios in planning environments (see for instance Klosterman 1999). In this manner, all relevant information is preserved but maps can be tailored at any given moment to meet specific organizational needs. At the same time, further work will be needed concerning how exactly maps are being used in order to populate the layers with adequate, elegantly ordered, information.

7.5.3 Architecture Overview

Based on the challenges that emerged in our empirical study and the design implications derived from it, we developed a system addressing the inter-organizational information and expertise sharing. To foster inter-organizational information and expertise sharing, we must also pay attention to the heterogeneous software systems at each organization. We decided therefore to set up a web-based, service-oriented architecture to enable a system which exists outside the existing, organizational ICT and to offer an independent access. Our system consists of the two main modules *Inter-Organizational Information Repository* (IOIR) and *Inter-Organizational Situation Assessment Client* (ISAC) (Figure 12).

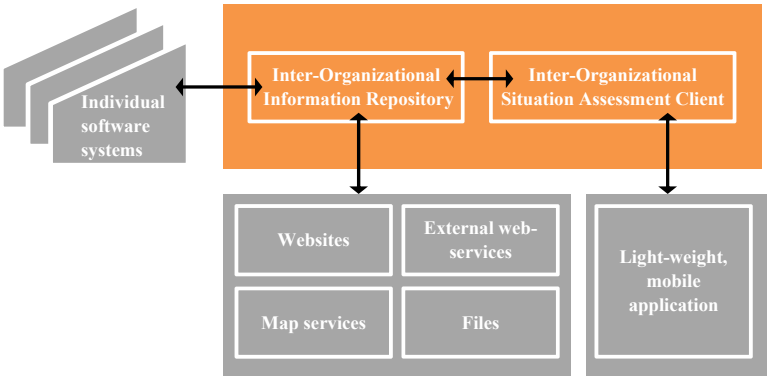

Figure 12: Technical system architecture

We decided to design a web-based, service-oriented architecture to enable collaboration especially on an inter-organizational level, independent of the individual technical infrastructures and systems of the responsible organizations. ISAC is designed as a situation map and allows various collaborative and sharing interactions. To allow situation assessment with mobile spatially distributed units, we also developed a mobile version of ISAC (Reuter et al., 2014; Reuter & Ritzkatis, 2013). IOIR is designed as a web-based information pool, which gives central access to distributed, external information resources like websites, files or various web services and provides interfaces to the control center software of each organization.

7.5.4 Inter-Organizational Situation Assessment Client (ISAC)

The fact that problems of accessibility as well as legal and policy restrictions exist is an obvious justification for our web-based service. At the same time, enabling inter-organizational coordination on the tactical and operational level requires an inter-organizational authentication service for each actor of the respective organization. On the tactical and operational level, the core tool of each organization is its own situation map for situation assessment. Therefore we designed an inter-organizational situation map.

We developed ISAC (Figure 13), which is based on Google Maps and offers the user different options for adding, changing, sharing or deleting information on the map. The information

can be represented by markers, locations, polygons, circles or free-hand drawings. After logging in, the user sees on the left the information tree that is structured through different main categories like weather, traffic, important locations or private information (1).

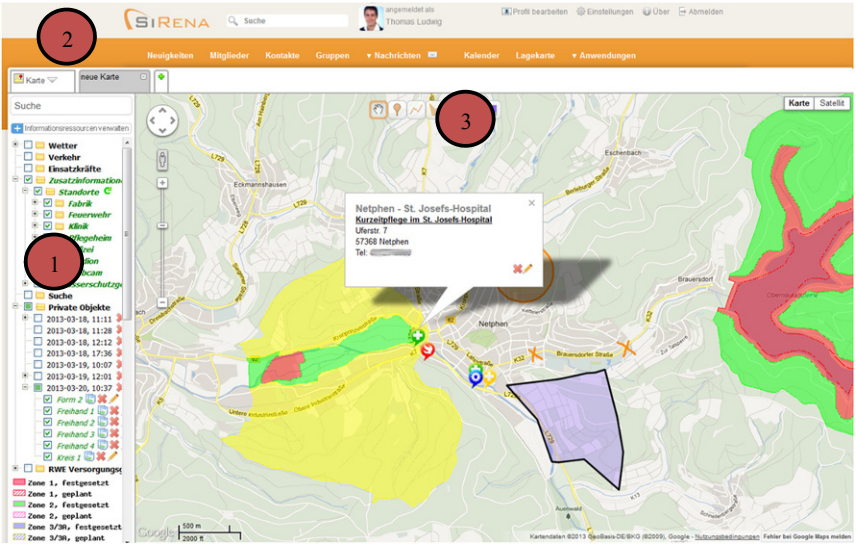

Figure 13: Inter-Organizational Situation Assessment Client

The information is structured by the inter-organizational information repository (section 7.5.5). To avoid information overload on the map, such information can be shown individually or it can be hidden or collected in different map layers. The tab-based map allows a person to create, label and save multiple maps to have them available on-time in different real emergencies (2). For example, one map can be prepared for a flood scenario with the necessary information like water levels and past flood areas, another map for the evacuation of a hospital with the necessary information like the local hospitals or shelters. The creating, changing and deleting of such information is described in the next section. Beside this information, additionally, annotations such as circles, polygons or free-hand drawings can be inserted to mark special, mainly temporary locations or situations, e.g. road blocks or collecting-points during operations (3). These annotations are declared as private objects that allow a person making personal drawings or short marks in addition to the general shared information on the left side.

It is also likely that multiple people will need to collaborate synchronously on a situation map during a crisis. To enable collaborative editing – necessary when rapid situation updates are required – we developed a WebSocket-based collaboration mode allowing a bi-directional, full-duplex communication. This collaboration mode lets the user make changes on his current map and everyone invited to his session can see the changes made at the same time. The initiator of a session has the option of assigning writing access to any of the invited participants or forcing them back. So, ISAC supports and fosters real-time inter-organizational discussions around a situation and at the same time deriving tasks from the overall operation for

one's own organization through the inter-organizational visualization/map-based functionalities like the collaboration mode or the display of external information. For the distributed situation assessment between on-site forces and those in the organizations' control centers, we developed a light mobile version of ISAC with the same functionality, but adapted for the small screens of smartphones and tablets.

7.5.5 Inter-Organizational Information Repository (IOIR)

The IOIR (Figure 14) which gives central access to distributed, external information that is otherwise not available to certain organizations. Through this module, organizations do not have to extensively search the web or call people from other organizations for every required bit of information. They have a web-based central access point to information resources, where the data is stored on servers of the respective organizations. These are responsible for the maintenance of this information (e.g. accuracy or timeliness), thus outdated contact information or phone numbers can be avoided. The repository makes integrating, creating, modifying and deleting information resource references possible. When adding an information resource, labels can be appended to identify a specific type of information (e.g. website, OGC* specified web map service, documents, etc.), keywords can be added and it can also be allocated to a general category. The information from IOIR that has a geographic reference can be shown on ISAC. In return, all the public information from ISAC is directly stored in IOIR.

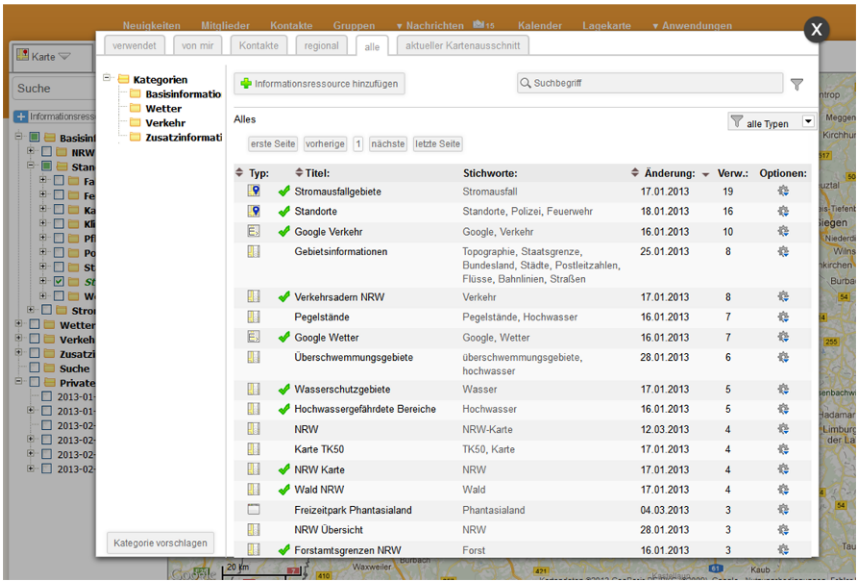

Figure 14: Inter-Organizational Information Repository

* The Open Geospatial Consortium (OGC) is an international industry association for developing publicly available interface standards.

Based on meta-attributes like type (Figure 14 in German: 'Typ'), title ('Titel') or keywords ('Stichworte') information resources can be adequately filtered. For additional filter mechanisms, the user has the choice of filtering information according to what is used by his contacts or the frequency of use according to others. Every information resource has comment functionalities, where users of all organizations can discuss the use, the content or the relevance of an information resource. Such functionality fosters an inter-organizational view on the same resource. By developing IOIR, a kind of central directory for web-based information resources has been created, which can be an opportunity for inter-organizational, collaborative information sharing.

7.6 Evaluation of ISAC and IOIR

The prototypes described in section 7.5 were designed, implemented and evaluated in two iterations with a particular focus on information and expertise sharing practices. After the first cycle, we conducted a formative evaluation based on scenario-based user tests and after the second cycle – 1.5 years later – the redesigned and improved system was rolled out for a field test under real-use conditions. Additional interviews with participating users were conducted 3-5 weeks after the roll out. Participants in the evaluations are listed in Table 21 and Table 22. In the following, we will describe the method used and the results of both evaluations.

7.6.1 Evaluation I: Scenario-based User Tests

The aim of the formative evaluation was to get user feedback about the general system design, possible use cases and accompanied design limitations, with the intention of feeding back into the development of the second prototype early on. The functionality of the first prototype was still limited and unsuitable for real-use testing, so we chose a scenario-based user testing under controlled conditions. The tests were conducted at the users' workplaces and lasted between 1 and 1.5 hours. Twelve users participated in the study (see Table 21).

At the beginning of the test, the prototype and its basic functionality were briefly introduced to the participants. In the next step they had to use the system independently and solve predefined tasks. Participants were asked to think aloud (Nielsen, 1993) and comment on their actions to be able to track and understand possible design and usability issues. In a subsequent semi-structured interview they were asked about their personal experience and assessment concerning their first impression; individual system description; system handling; conceivable use cases in personal work context; requirements to make the system usable; collaborative situation assessment; and further information needs. For the most part, feedback concerned usability issues. These were incorporated into the final design mentioned in section 7.5 and are not discussed here further. More importantly, the formative evaluation gave us valuable feedback concerning how information can be shared with others. The initial design concept enabled users to compile and prepare their individual maps by letting them add relevant information. These compilations could then be made available to other users. However, it became clear that this kind of sharing was not suitable for situational purposes during a crisis situation, as it did not make a direct exchange between the involved actors possible. In this context, the participants expected a synchronous map sharing and annotation tool, so that they could have the same view of the situation and thus a common basis for discussion. These

limitations were also taken into consideration during the second design cycle and were implemented in the final prototype.

No.	County	Organization	Role
E01	A	Police	Head of Control Center
E02	A	Police	Head of Section
E03	A	Fire Department	Deputy Head of Control Center
E04	A	Fire Department	Head of Control Center
E05	both	ENO	Operation Engineer, High Voltage
E06	both	ENO	Operation Technician, Low Voltage
E07	both	ENO	Higher Area, High Voltage
E08	B	Police	Head of Control Center
E09	B	Police	Head of Group
E10	B	Fire Department	Head of Control Center
E11	B	Fire Department	Watch Department
E12	B	Fire Department	Head of Group

Table 21: Participants evaluation I

7.6.2 Evaluation II: Field Test

Based on the feedback from the user tests we redesigned and improved the prototype. After that, our aim was to conduct a field test with 16 users from different organizations (see Table 22).

No.	County	Organization	Role
E13	A	Red Cross	County Head
E14	A	Fire Department	Administrator Control Center
E15	A	Fire Department	Staff of Control Center
E16	A	Fire Department	Head of Fire Department
E17	A	Police	Head of Section
E18	A	Police	Staff of Control Center
E19	A	Police	Staff of Control Center
E20	A	Police	Staff of Control Center
E21	A	Police	Head of Control Center
E22	both	ENO	Operation Engineer, High Voltage
E23	both	ENO	Operation Engineer, High Voltage
E24	B	Police	Staff of Control Center
E25	B	Police	Data Administration, Control Center
E26	B	Police	Staff of Control Center
E27	B	Fire Department	Workmanship
E28	B	Fire Department	Staff of Control Center

Table 22: Participants evaluation II

We organized a roll out workshop for each participating organization, where we gave participants their login data and a brief introduction into the system and its use. Both the situation assessment client and the information repository were released to the users for unrestricted use. After a 3-5 week evaluation period, we arranged and conducted semi-structured inter-

views with the participating users to find out if the system was usable under real-use conditions and what the conceivable use cases were. Most of the interviews were conducted individually and lasted between 30-45 minutes. Two interviews were group interviews (police and fire department in region A). Those group interviews lasted about 60 minutes each. The guideline covered 5 main topics:

1. Information about the interviewee, his/her role and qualification.
2. General questions about the usability of system and the user's first impression.
3. Analysis of the usage context, which tasks were performed, who was involved?
4. Inter-organizational use, which organizations could be involved, which information would be shared and which not, what are the chances and challenges when sharing information with other organizations?
5. Prospective, what is necessary to use the system during daily routine, what additional functionality is desired?

Each interview session was audio-recorded and transcribed for subsequent analysis, which was divided into three steps (C. Schmidt, 2004):

1. The transcripts were structured according to the questions of the interview guideline. Statements taken from the transcripts shed light on participants' reactions during the session.
2. Based on the transcripts, ex-post categories were formed for the analysis. This categorization included aspects about the implementation and integration of the system with existing infrastructures and practices in the application domain, shared content and collaboration scenarios, information visibility concerns in inter-organizational information and expertise sharing, and recommendations for improvements.
3. These analytical categories were used to create a coding guideline. It helped to cluster the data in terms of meaningful units to focus on specific problems.

It turned out that the system was used by every participant, but not, for the most part, in real-work contexts as anticipated. The main reasons for this are described in detail in the following section. This is a common problem with field tests (see e.g. Hertzum et al. 2012) and needs to be considered as a limitation of the study. Nevertheless, the evaluation reveals some valuable results about the system's usability, possible use cases, and information sharing practices with other organizations.

7.6.2.1 Integration with existing Infrastructures and Usages/Practices

Above all, we were interested in whether and how the application might be used in real-world conditions during the evaluation period and how the system might support the participant in a specific situation. Unfortunately, only a few participants really used the system in that fashion. One central problem we had to deal with was that some organizations did not provide the necessary ICT infrastructure to run our system fluently. More precisely, the installed web browsers in the control centers were outdated (e.g. one police station is still using Internet Explorer 6, which was released in 2001) and did not support important computer technology like JavaScript or Web-Sockets, which are necessary to run our application. This meant that the prototype could not be used at some participants' workplaces during the evaluation period.

Although the participants had access to a stand-alone computer where a suitable web browser was installed, the use was not feasible in work context:

> *"I don't have the opportunity to sit there [at the stand alone computer], because if I am involved in an operation, I can't stand up and leave my workplace" (E26).*

Another issue that stood in the way of use was the lack of information. Although the predefined information resources could give a sufficient overview of the system's functionality, they did not cover the entire amount of information which was already available in existing geographical information systems:

> *"Basically we have everything in our GIS. When I am in an operation and have my GIS on the screen, why should I open another GIS?" (E25).*

Although it is possible to add new information resources and thus transfer information from an existing GIS to our system, users saw this as only for testing purposes, because they had no certainty of a long-term application of the system. In addition to that, participants saw a major challenge in the distribution of system information. They argued that a useful application is only possible if

> *"it is used by everybody and if it is accessibly to everybody. It must not be used in a voluntary manner but has to be an inherent part of our work" (E26).*

Of course, in an evaluation scenario of the kind we were undertaking, such universality is impossible. Nevertheless, it strongly points to the organizational changes that are needed if such systems are to be used in real-world contexts.

7.6.2.2 Shared Content and Collaboration Scenarios

Regardless of those limitations, all of the participants were able to explore the system during the evaluation period, be it on their work computer or at stand-alone computers at work or at home, and could reflect on possible use cases for their individual work practices. In the case of the fire department, they actually used it for example to share information during a breakdown of a major telecommunication operator caused by a big fire in its distributing center:

> *"I have drawn a circle which represented the exclusion zone and several markers which represented places, where people were led to after evacuation" (E14).*

These collaborations, participants realized, also had the potential to create better information for the population:

> *"With such tools we should have the possibility to create a map which can be easily made public, so that citizens can also create an overview and see, for instance, current roadblocks" (E16).*

Information exchange among different support agencies (e.g. Red Cross and fire department), for instance with respect to information about areas where citizens have been informed about a major incident, was seen as a suitable use case with such tools (E13). The control center points out:

> *"We have to organize and inform the aid agencies, so that they do not work too independently, that's a typical problem we always have; […] we have to be*

able to lead them" (E15) – "therefore the map can act as an instructional object" (E16).

In the case of the police, there is currently no system to acquire and visualize roadblocks. Thus, during the evaluation period, one participant explored the system by adding current roadblocks to the map. Participants from other organizations also perceived these roadblocks and considered them to be very useful. It became clear that especially the sharing of information or sharing a situation map with other organizations (e.g. between control centers of police, fire department and crisis squads) or with spatially divided members of the own organization (e.g. between control center and forces on-site) is of great interest:

"I think there is a real chance to involve people into a situation, who were previously left out. Because this is something that our system here cannot handle" (E16). Or: "Breakdowns don't only occur during office hours. In specific situations we call our boss or the public relations department. […] Based on such a map I could show specific information, highlight something, and say: 'Here is this and that problem'" (E23).

This is relevant not only to the synchronous sharing functionality, but also to handovers during a shift change (the problem of information transfer during handover is dealt with in a range of literatures covering, for instance air traffic control, nursing, etc.; see Kerr (2002) for an example):

"Such visualization is helpful for shift changes. It is much better than thrusting a stack of paper in someone's hand, with information about the whole procedure" (E21).

Participants saw the additional value of the system primarily in the visualization of a bigger picture in major incidents and disasters:

"It would be good to have the same map here [control center] and in the command vehicle. […] But just in bigger situations with a duration of several days, not in case of simple room fires" (E28).

"It would be good for bigger operations, to quickly create a situation overview […] The only possibility is to work together - fire department, Malteser [human aid agency in Germany] and red cross - the breakdown of the telecommunication operator showed that again. In cases like that I could mark an area on the map and share it to express, that I will take care of that area" (E13).

For situations of imminent danger, however, the system was less feasible:

"Here the system is too sluggish. The situation is different for incidences that evolve over multiple days, like a flood. For this it is a fantastic thing" (E17).

Although participants mentioned that adding information to the application was easy to manage, it became clear that this process was extremely time-consuming and could not be done in stress situations:

"When I work here in the control center and there is a major situation and besides that I have to answer 10 or 15 emergency calls, I don't think that anyone has the time to work with it" (E25).

Even if the situation calms down, it is a challenge to maintain the situation map subsequently because *"the information from the beginning of the situation is tied to the heads of the staff and not written down anywhere"* (E17). The main issue here is the effort that is necessary to

add information to the map. This, we feel, is less a usability issue than a lack of predefined templates, shapes, and tactical signs. At the moment, every place mark a user wants to add to the map has to be created from scratch and recurring signs or shapes have to be redrawn de novo:

> *"As an example, we have predefined roadblocks for every chemical plant. In case of a gas leak, we have to man these place marks. […] This could be prepared beforehand. […] or collecting points, like this parking area. I know it has a capacity of 30 vehicles and that can be prepared. For me it is important that I don't have to start every situation from scratch" (E24).*

Besides better preparation and faster embedding of information into the map, predefined shapes or tactical signs would also help to get a common understanding of a situation without additional comments:

> *"There must be a uniqueness to such signs, thus it would be great if you could use tactical signs, so that every leader could read and interpret these signs. […] I wouldn't have lot of annotation work if I had these tactical signs" (E13).*

Another reason to use predefined and uniform shapes is easier comparability and easier assemblage of multiple maps. For example, in case of a predicted the spreading of a gas cloud after a chemical accident, *"it would be interesting if the assessment of the fire department is equal to ours or if there is need for coordination"* (E24). For this purpose, both organizations could share their maps and lay one on top of the other to compare possible deviations.

7.6.2.3 Information Visibility Concerns in Inter-Organizational Information Sharing

For security reasons, current ICT infrastructures at the participating organizations are characterized by full isolation. With this in view, it was particularly interesting for us to find out something about the willingness to share (internal) information with other organizations. The interviews emphasized that basically there were no concerns about sharing information with others, neither from the police nor the fire department or any other involved organization:

> *"During a major situation we have to exchange information. In this case we dispatch a liaison officer to them [fire department] and they send one to us. From then on there are no more secrets anyway" (E24).*

However, especially in police work, there is confidential information that has to be kept under wraps. This kind of information, it turns out, would not be shared anyway, neither via our application nor via phone or by radio:

> *"For example during a violent demonstration we also work together with fire department and ambulance services. But there is tactical information on the police side that will not get to the outside. […] Every operation where special forces are involved" (E21).*

With our system, a certain apprehension arose due to uncertainty that specific information could not be handled confidentially enough if too many persons had access to it:

> *"Especially in the case of pictures we would be very careful because we know that one or two [people] have good relations to the press and would leak them" (E24).*

However, general access restrictions would also obstruct desired and legitimized access to information, so that it might be sufficient to make access a visible matter:

> *"It might be interesting to see who actually looked at the picture, which suddenly appeared in a newspaper. Otherwise we have to restrict the content we add to the system" (E24).*

Apart from that, access constraints were only deemed to be useful to restrict the available information resources from displaying irrelevant data. However, this is not motivated by data security reasons but to keep the system and the displayed information clear:

> *"If it is sometime established statewide, […] we have to foster further restrictions […] that I don't have to know what happened in city A, B or C. That everybody only sees information from his own region" (E26).*

Current practices are limited a single situation map in the control center restrict access based on the physical presence in the control room, and so participants have little experience of managing access control. While using digital representations, which can be shared among the users, new possibilities and questions will arise (E16), including for instance decisions concerning role-based access restrictions, free access for all emergency services or explicit sharing of information.

7.7 Discussion

In contradistinction to many other approaches that develop ICT support for crisis management, we did not focus on *one* particular organization and its anticipated routines or on *one* particular activity (e.g. resource allocation, triage). We focused on the necessities of improvisation in a crisis situation where unfolding events cannot always be anticipated, events which are volatile in terms of actors involved and the external factors guiding behavior. Almost every actor needs information about the current situation and its development, but also produces information that could be of interest to others. We therefore focused on the issue of improvisation practices in information and expertise sharing at the inter-organizational level.

7.7.1 Improvisation Practices in Information and Expertise Sharing

The empirical study of information and expertise sharing practices by the emergency services (section 7.4) highlighted the specific ways in which improvisation techniques were brought to bear on coping and recovery work, situation assessment and information retrieval and exchange processes. Our findings indicate that inter-organizational communication and cooperation is necessary, but the current organizational and technical structures of each organization involved do not provide suitable interfaces. Due to the large number of heterogeneous systems, the exchange of information is limited to e-mail, phone calls or special trained liaison officers. The exchange of expertise is currently limited, for the most part, to contacts between long-standing employees. There is, in other words, a very *unequal social distribution of expertise*. While describing the practices in inter-organizational crisis management in detail, these findings confirm and extend the research opportunities in the area of "collaborative knowledge bases" mentioned by Turoff et al. (2004) as well the "unresolved issue [which] is the need for close relationships between those improvising" as mentioned by Cunha et al. (1999).

7.7.2 Advances in Improvisation Support

Based on the challenges that emerged in our empirical study and the design implications derived from it, we developed a socio-technical system addressing the practice of inter-organizational information and expertise sharing in two iterations (section 7.5). We set up a web-based, service-oriented architecture to enable a system independent access. While the first iteration focused on situation assessment, the second iteration also includes inter-organizational collaboration functionalities. Our lightweight infrastructure, usable with any web browser, and the specialized mobile app consists of the two main interconnected modules *Inter-Organizational Information Repository* (IOIR), a central access to distributed, internal and external information, and *Inter-Organizational Situation Assessment Client* (ISAC), a geo-collaborative application supporting ad hoc information and expertise sharing. Our modules enhance the work of Wu et al. (2013), whose system focuses on one specific geo-collaboration task or Monares et al. (2011), who just focus on mobile collaboration.

7.7.3 Evaluation and Methodological Issues

In the evaluation of the system (section 7.6), the formative evaluation after the first cycle led to a redesigned and improved system that was rolled out for a field test under real-use conditions: The summative evaluation outlined challenges related to integration with existing infrastructures and usages, scenarios for shared content and collaboration (e.g. exchanging roadblocks, enhancing situation assessment or collaboration outside the control center) as well as information visibility concerns in inter-organizational information sharing. Our study showed that our concepts and implementations support the emerging inter-organizational information infrastructure acting as an intermediary between the existing discrete ICT systems in the participating organizations. However, our incremental development process has not finished. Certain limitations, as described above, have been identified and we are continuing our evaluations in the field and the respective developments.

We are not the first to realize, but we strongly support the view, that real-time, real-world analysis and evaluation of crisis management is difficult, not to say impossible. Neither our initial studies, nor our prototype could be founded on classic forms of ethnographic study, for the reasons we rehearse above. Nevertheless, our study was conducted with a commitment to getting as close to real-world practices as possible, and to this end we conducted scenario-based interviews both with individuals and with groups. Compared to Convertino et al. (2011) and with respect to the concern that "existing geospatial information technologies […] have been designed for use by individuals" (Cai, 2005), we believe that our work comes closer to real-world analysis than most. In so doing we are not suggesting that we have discovered the fact of improvisation. Rather, we were and are interested in the precise ways in which improvising work is done, and the limitations that are placed on it by existing socio-technical infrastructures. In this respect we have moved the discussion on from the interests of management science (e.g. Weick 1993) which has tended towards post hoc understandings of previous disasters towards analysis of the prospective.

7.7.4 Architectural Considerations

All organizational actors already use own kinds of ICT infrastructure, usually protected against foreseeable emergencies caused by power outages (e.g. batteries, redundant command

stands), hacker attacks (e.g. separated systems, redundant communication infrastructures, sometimes including own cable networks) or natural and physical impact (e.g. guarded and armored fire/police stations). However (or because of these issues) existing heterogeneous systems are often encapsulated (caused by ICT security standards), which limits the possibilities for information exchange. Our approach to base a complementing ICT infrastructure on lightweight web technologies proved to be appropriate to demonstrate the possibilities of inter-organizational collaboration. Our approach can easily integrate information sources that provide OGC web services and we were experimenting with the emerging (German) standard DIN SPEC 91287:2012-07 on "data interchange between information systems in civil hazard prevention". Our findings also open perspectives for future research related to aspects of controlling the information flow between emergency services, but also between these organizations and the general public. This has been dependent on the physical presence in the control room and now becomes possible for a larger group. A combination of further improvements and the evaluation with a larger group of emergency services over a longer period will bring more results concerning the practical implications of such tools.

7.8 Conclusion

The research we describe above has entailed a three-year commitment, starting with an empirical study including initial analyses and reflections on existing inter-organizational practices, and continued with iterative prototypical implementations and then to practical evaluations in the application field. The overall goal was identifying the value of, and restrictions entailed in, information and expertise sharing in inter-organizational crisis management. This paper followed the methodology of *design case study* (Wulf et al., 2011). Our first objective was to empirically research collaboration practices in information and expertise sharing in an inter-organizational crisis management setting, where improvisation (as the literature indicates) plays an important role for coping and recovery work; our second objective was to answer the question, how ICT support should be designed to be able to adequately support such practices.

In sum, we have drawn extensively on literatures which demonstrate the problem of inter-organizational cooperation in the domain of crisis management, and specifically on the concept of improvisation. This has been previously addressed as a topic (e.g. Cunha et al. 1999; Mendonça and Wallace 2007; Mendonça 2007; Moorman and Miner 1998; Weick 1993). Nevertheless, we believe that our contribution is to bring the results of a long term qualitative study to bear on the specific issues of how, when and in what way improvisation takes place, and what the limitations on its effectiveness might be. In much the same way, we draw on existing understandings of information and expertise sharing (e.g. Ackerman et al. 2013; Harrald 2006; Hiltz and Turoff 1985; Quarantelli 1988; Rankin et al. 2011; Wenger et al. 1989), but do so in order to address the known problem that practitioners suffer "from a lack of options for sharing information among the organizations, but also from a lack of awareness of information about the activities of others" (Ley et al., 2012a) and which lead us to research opportunities in the area of "collaborative knowledge bases" which aim to rectify this (Turoff et al., 2004).

Our study, then, translated prior work on organizational behavior – which dealt with the 'that' of improvisation - to a concern with the 'how' of improvisation, geared to the design of technology suitable for such environments. We designed the inter-organizational situation as-

sessment client ISAC and the inter-organizational information repository IOIR. Information and expertise sharing approaches using GIS are challenged because "most spatial decisions using geographical information are done by teams, but existing geospatial information technologies […] have been designed for use by individuals" (Cai, 2005). Related approaches such as Convertino et al. (2011) present possibilities for how collaboration technology can reduce the coordination efforts among spatially distributed emergency teams, but their prototypes have not as yet been developed and evaluated with emergency services. Wu et al. (2013) present a "a new collaborative system for teams doing complex geo-spatial planning tasks", but their system focus on one specific geo-collaboration task: "Although the task is well grounded in empirical evidence, geo-collaboration activities can be very diverse" (Wu et al., 2013). Other approaches either focus on mobile collaboration (Monares et al., 2011) or on the integration of citizen involvement (Okolloh, 2009; Palen & Liu, 2007; Reuter et al., 2013). Our work has combined the different perspectives in improvisation in inter-organizational crisis management as well as information and expertise sharing (Ackerman et al., 2013) and presented a well-founded empirical study of work practices, a systematic and (we believe) generalizable approach to the design of ICT support, as well as its evaluations with practitioners.

8 Scenario B: Ad Hoc Participation in Mobile Collaboration (TOCHI)

Emergencies are characterized by high complexity and unpredictability. In order to assess and manage them successfully, improvisation work and informal communication, even beyond local and organizational boundaries, is needed. Such informal practices can facilitate ad hoc participation of units in situation assessment, but this may lack overall situation awareness. This paper presents a study on how emergent 'collaboration needs' in current work of response teams, who are located on-site and in the control center, could be supported by mobile geo-collaboration systems. First, we present the results of an empirical study about informal work and mobile collaboration practices of emergency services. Then we describe the concept of a mobile geo-collaboration system that addresses the aspects detected in the empirical study and that was implemented as an Android application using web sockets, a technology enabling full-duplex ad hoc communication. Finally we outline the findings of its evaluation in practice and its implications.*

8.1 Introduction

During disasters the emergency services and crisis managers are confronted with situations in which decisions have to be made fast. The speed of the decision making process is often directly connected to devastating (e.g. save human lives), economic (e.g. extinguish a burning factory) or ecological (e.g. stop escaping oil) consequences. Whatever the incident is, either a hurricane, or flood or a technical accident, the officer-in-charge has to assess the situation as quickly as possible to be able to use the available resources for making useful decisions. Assessing a situation is a very cooperative process, because the most of the needs which arise in emergencies cannot be completely covered by routine processes and previously predicted information demands (Ley et al., 2012a). The necessary information is often not available in a centralized manner, but instead has to be requested from the control center, special relief forces or from a third party (Ludwig et al., 2013a; Nilsson & Stølen, 2010) for getting an appropriate 'situation awareness'. According to Endsley (1995) *situation awareness* refers to the "state of knowledge" whereas *situation assessment* to the "process of achieving, acquiring, or maintaining" information. Geospatial data such as the location of dangers, of resources or field operations is particularly important for the process of situation assessment and therefore establishing situation awareness. This information is typically managed on situation maps by the operations management in the control center and on-site by the head of a section. Complicating matters, in an actual crisis, there is often no prior definition of who the collaborators

* This chapter has been published as an article (Reuter et al., 2014):

Reuter, C., Ludwig, T., & Pipek, V. (2014). Ad Hoc Participation in Situation Assessment: Supporting Mobile Collaboration in Emergencies. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *21*(5).

A previous and shorter version of this chapter has been published as a paper (Reuter & Ritzkatis, 2013), which has been nominated for the *Best Student Paper Award:*

Reuter, C., & Ritzkatis, M. (2013). Unterstützung mobiler Geo-Kollaboration zur Lageeinschätzung von Feuerwehr und Polizei. In R. Alt & B. Franczyk (Eds.), *Proceedings of the International Conference on Wirtschaftsinformatik* (pp. 1877–1891). Leipzig, Germany. http://aisel.aisnet.org/wi2013/117.

C. Reuter, *Emergent Collaboration Infrastructures,*
DOI 10.1007/978-3-658-08586-5_8, © Springer Fachmedien Wiesbaden 2015

will be and when it will take place (Turoff et al., 2009). Collaboration systems have to consider this: Appropriate tools might possibly be useful in supporting specific collaboration needs with previously unknown and unprepared actors in emergency situations. For example with the help of mobile devices it might be possible to obtain a visual overview of the situation faster than just with manual location reports or verbal situation information updates via radio.

The objective of this article is to examine mobile collaboration practices in crisis management on an inter-organizational level. The research question is how emergent 'collaboration needs' in the current work of inter-organizational response teams, who are located on-site as well as in the relevant control center, could be supported by cooperative information systems, especially mobile geo-collaboration systems. The notion of *emergence*, coined by Lewes (1875), refers to dynamic contexts that cannot be anticipated in their full extent before they actually occur. The paper is organized as follows: section 8.2 presents related work on mobile devices, geo-collaboration and ad hoc participation in emergencies. Section 8.3 presents our overall research approach of *design case studies* (Wulf et al., 2011), which consist of a first empirical analysis of mobile collaboration practices in the field (section 8.4), the development of innovative ICT artifacts related to the empirical findings (here: a mobile geo-collaboration system – section 8.5) and the evaluation of their appropriation in practice (section 8.6). Section 8.7 presents a discussion and outlines dimensions for effects of our approach.

8.2 Related Work

The cooperation of spatially and temporally distributed teams has always been a topic in the fields of CSCW and HCI (Johansen, 1988). Our CSCW and HCI-related work stands between the areas of inter-organizational crisis management, improvisation, mobile collaboration, ad hoc participation as well as geographic information systems (GIS). In this section we review the related work in these areas and outline the research gap which we would like to help close within our paper.

The terms "disaster, crisis, catastrophe, and emergency management are sometimes used synonymously and sometimes with slight differences, by scholars and practitioners" (Hiltz, van de Walle, et al., 2011). An enormous effort regarding coordination, cooperation and collaboration is essential whatever form disasters, crises, or catastrophes take. Based on an analysis of the response work to the September 11 attack, Mendonça (2007) suggests that some frame specifics of emergency management can be considered as characteristics: Firstly, (a) *rarity* of incidences limits opportunities for training and learning. (b) *Time pressure* forces a convergence of planning and execution. (c) *Uncertainty* is present because the development of an extreme incident is rarely predictable. Furthermore, extreme events have (d) *high and broad consequences*, wherefore there is a need to manage interdependencies within a wide range of physical and social systems. The (e) *complexity* of the event arises, which is partly due to the high and broad consequences. Finally, (f) *multiple decision-makers* and responding organizations may negotiate with each other, while responding to the event (see also McMaster & Baber, 2012). Based on interviews with emergency responders, Chen et al. (2008) describe similar characteristics but highlight also the "disruption of infrastructure support" as an important occurrence.

8.2.1 Information Exchange, Improvisation and Ad Hoc Participation

Many situations require spontaneous, ad hoc decisions and short-term (re-)planning and therefore the provision of different information. Quarantelli (1988) identified five different categories of problems associated with the information flow during disaster: (1) intra-organizational; (2) inter-organizational; (3) from organizations to the public; (4) from the public to the organizations; and (5) within systems of organizations. Wenger et al. (1989) suggest that the "serious communication problems [regarding] both police and fire departments […] stem less from lack of equipment or resources but primarily from the […] pre-disaster planning with respect to information flow". However, the collapse of information flow and role systems need not necessarily result in a disaster, if people develop skills in improvisation (Weick, 1993). Besides social practices, the design of computer-based systems also needs to be informed by an understanding of the cognitive processes involved in responding to unanticipated contingencies (Mendonça, 2007).

Suggestions for supporting improvisation in emergency management include graphical representations of data during crisis response; the centralization of data make it possible for actors to find the necessary information; and virtually-supported coordination in order to consistently create shared information in time (Adrot & Robey, 2008). Other approaches identified ad hoc re-planning and the ability to share material as design challenges for large-scale events (Ley et al., 2012a; Lindström & Pettersson, 2010; Turoff et al., 2009, 2004). Based on decades of research, Turoff et al. (2004) point out that "supplying the best possible up-to-date information is critical" and "crises involve the necessity for many hundreds of individuals from different organizations to be able to exchange information freely, delegate authority and conduct oversight, without the side effect of information overload". Information overload is also connected to information politics, as pointed out by Schmidt and Bannon (1992): According to their view, a perfect collaboration does not necessarily emerge from a situation where all information is available. McMaster and Baber (2012) share this understanding and suggest rather to talk to colleagues instead of provide an overwhelming amount of information. Hiltz et al. (2011) argue that the field of HCI needs to "investigate further how to integrate both formal and informal sources of information" and "how systems can be designed to make such an integration efficient". Therefore the support of collaboration and communication instead of mere information sharing is of high importance. Nonetheless, the sharing of accurate and timely information is a necessary (if not sufficient) precursor to collaborative work of this kind.

Information sharing, operational awareness, communication readiness, adaptiveness, and coupledness have been identified as barriers for interoperability (Kwon et al., 2011). Bertelsen and Bødker (2001) point out the need to support peripheral awareness not only with the coordination of activities within a control room, but also in distributed work. Infrastructural issues – which are also of importance in crisis – may limit the ability to share information: Semaan and Mark (2011) studied how Iraqi citizens used ICTs, especially mobile technologies, to overcome infrastructure breakdowns of the second Iraq war. They describe that people spontaneously created a "social infrastructure" with ICT with new arrangements, e.g. equipping all family members with different mobile phone carriers, setting up neighborhood electrical generators and switching among different technologies to find one that works.

8.2.2 Collaboration with Mobile Devices in Emergencies

A lot of research focuses on the use of ICT in crisis management, also in mobile contexts. Conception frameworks (Chen et al., 2008; Peng et al., 2007), based on empirical studies, determine which devices are appropriate for certain cooperation contexts in crisis management other than digital radio. Both deem tablet PCs and PDAs as the most suitable in terms of mobility. Since the frameworks' releases, smartphones and tablets have become more popular and powerful, and combine the performance of PDAs with the multimedia support of mobile phones. Both smartphones and tablets meet the requirements of everyday use and are fundamental elements of CSCW technology for mobile workers (Tamaru et al., 2005). Furthermore, they are used every day by the majority of people, which is important in order to create tools for spontaneous use based on these devices. The growing range of newer mobile technology such as LTE (or 4G) creates new possibilities for transmitting large amounts of data.

Various approaches already focus on supporting cooperation with the help of mobile devices. The officers-in-charge are the information providers and consumers, whereas units on-site are primarily information providers (Nilsson & Stølen, 2010). The officers-in-charge, either on-site or in the control center, are mainly decision makers, whose decisions result in actions performed by the on-site units. However, there are "minor differences between emergency response units within and between countries with respect to formalized routines and command structure" (Rakea & Njå, 2009). Büscher and Mogensen (2007) present prototypes which allow command centers to capture on-site movements live as well as information about the situation which can be assessed in order to be able to construct a better situation overview without having to disturb on-site units through verbal communication. Bergstrand and Landgren (2011) analyzed the impact of live incident videos in the control center and found that the videos improved situation assessment in the control center enormously. Due to the flow of communication from the bottom-up, the on-site units provided information colored by their situation and perspective or due to previous radio transmission, which led to problems regarding prioritization. Landgren (2006) suggests that verbal communication should be made persistent, visible and accessible in order to support accountability. Catarci et al. (2010) present a system in which each on-site unit uses a PDA, supervised by a process management system, which orchestrates the units and conducts external data services. The mobile devices are able to receive tasks, add comments to captured pictures and videos, to share these and display them on a map application. Another approach dealing with prioritization problems comes from Ludwig et al. (2013). Their semi-structured request-and-report system, based on Android, allows necessary on-site information to be generated by request and then illustrated on a map. The study shows that the accuracy of requests and reports can be improved by using an appropriate metadata structure in addition to creating multimedia-based information content. The use of maps is also the focus in Schöning et al. (2009). They present a prototype that "combines standard mobile camera devices with printed maps to ensure a quick and reliable exchange of spatial information".

8.2.3 Geo-Collaboration and Crisis-Related Map Mashups

Map mashups are often the basis for both mobile and conventional collaboration systems in crisis management. Zlatanova and Fabbri (2009) show that "maps are largely used as background information for location awareness and decision making". They argue that time restriction and human perception are some of the major bottlenecks for working with complex

models. Kraut et al. (2002) found that visual information in shared spaces improves communication efficiency and increases the knowledge of the task structure and the situation awareness, especially in complex problem solving. Liu and Palen (2010) surveyed 13 crisis-related mashups to derive high-level design directions. They include the use of temporal data to communicate different levels of knowledge granularity, learning from the past through the preservation of spatio-temporal information flows and the recognition of geographical vulnerabilities.

In terms of group work, "most spatial decisions using geographical information are done by teams, but existing geospatial information technologies […] have been designed for use by individuals", according to Cai (2005). His approach extends distributed GIS with collaborative functionalities and proposes a system architecture that integrates web service-based distributed computing paradigms. Accordingly, Schafer et al. (2007) present a software architecture that facilitates the development of geo-collaboration solutions and reuses existing geospatial information models. They emphasize the community-oriented nature of emergency management. The prototype CIVIL (Convertino et al., 2011; Wu et al., 2013) is based on that architecture, and supports map-based decision-making. Wu et al. (2013) contribute in the "design research on a new collaborative system [CIVIL] for teams doing complex geo-spatial planning tasks" and suggest to "provide both personal (role-specific) and shared (team) maps and support information transfer between them". Based on an evaluation, their developed guidelines include (a) integrating map services that people are familiar with, (b) allowing users to add personal comments and drawings that overlay on maps, (c) providing both shared and private maps as well as supporting the transfer of information between them, (d) providing visualization tools to present information and help information analysis, (e) allowing platform-independent, distributed collaboration and (f) developing architectures that allow delegation of non-critical information management tasks to online public services. The open-source tool Big Board, which can be used in the browser or as a mobile application, facilitates distributed synchronous collaboration by teleconferencing over maps to enable situational awareness. However, spontaneous integration of actors from other organizations is not supported. Furthermore the study does not present a detailed user study (Heard et al., 2014). Another mobile geo-collaborative application named MobileMap (Monares et al., 2011) was designed to help firefighters arrive faster at the emergency scene, to allow them to exchange digital information during emergency response processes and to reduce the need for radio communication. The paper points out that well known solutions are sometimes not appropriate e.g. for the volunteer nature of some firefighting teams due to special device requirements or because prices are too high.

8.2.4 Research Gap

Mobile phones are important tools to enable the inclusion of new forces in an ad hoc manner into the process of situation assessment, because such devices are always ready to hand. Many previously presented approaches provide findings relevant for our study. Wu et al. (2013) contribute in the "design research on a new collaborative system for teams doing complex geo-spatial planning tasks" roughly similar to our approach, but without considering ad hoc tasks in mobile contexts. Ludwig et al. (2013) studied mobile reporting practices in emergencies and contribute in approaches to support "articulation work with regard to the ad hoc gathering of information", but do not focus on shared map mashups. Monares et al. (2011)

also studied collaboration using mobile devices within a fire department, but as with Ludwig et al (2013), they also do not consider an integration of new actors outside the own organization to situation assessment in an ad hoc manner. Other studies provide good approaches (e.g. Convertino et al., 2011; Landgren, 2006; Zlatanova & Fabbri, 2009), but do not cover our question as a whole. The research on ICT, among mobile collaborative GIS, (a) to foster ad hoc participation in inter-organizational crisis management, (b) considering the actual collaboration practices and (c) explicitly focusing on their real - not just intended - appropriation and the impact on collaborative practices therefore continues to provide important research opportunities.

8.3 Research Approach

Our objective is to examine mobile collaboration practices in crisis management on an inter-organizational level. The research question of this paper is how emergent 'collaboration needs' in the current work of response teams, who are located on-site and in the control center, could be supported by cooperative information systems. We therefore have to understand intra- and inter-organizational collaboration, situation assessment and the decision-making practices of all relevant stakeholders involved. We use the *design case studies* (Wulf et al., 2011) approach, which consists of an empirical analysis of the practices in the field, the development of innovative ICT artifacts related to the empirical findings and the evaluation of their appropriation in practice. This research is inspired by Lewin's *action research* as "comparative research on the conditions and effects of various forms of social action and research leading to social action" that uses "a spiral of steps, each of which is composed of a circle of planning, action, and fact-finding about the result of the action" (Lewin, 1958). In our case "planning" is the empirical analysis of the given practices, "action" is the design and use of suggested ICT artifacts, and the evaluation leads towards "fact-finding about the results of the action". This interpretation is consistent with Hevner and Chatterjee's suggestion (2010) of integrating action research with design research. A *design science approach*, comprised of the design of an artifact for a relevant problem combined with rigorous evaluation methods for the design, is used to create the artifacts (Hevner et al., 2004).

These methods have been applied to study collaboration, situation assessment and decision-making practices during coping and recovery work in emergency response agencies. Our research focus is on improvised collaboration between statutory and unanticipated actors in multi-agency emergency response. The study was conducted in two regions in Germany in the years 2010-2013. County A is a densely wooded, hilly and rural county, whereas county B consists of 10 expanding urban communes. In both regions, we focused on several affected organizations: the infrastructure supplier (energy network operator (ENO)), public strategic administration (crisis management group, operations management), public operative administration (e.g. police, fire department) and citizens. The fire departments are organized differently in the two counties: county B provides professionals, whereas the fire departments of county A consist mostly of volunteer forces and only members of the control center have salaried positions.

According to our research approach, we will now first present the findings of our empirical study on mobile geo-collaboration (section 8.4) and then the development of a mobile geo-

collaboration system related to the empirical findings (section 8.5). Finally, we will present our evaluation (section 8.6) and implications (section 8.7).

8.4 Empirical Study: Mobile Geo-Collaboration in Crisis Management

8.4.1 Methodology

The bases for the data analysis were the results of multiple empirical studies from 2010 to 2012. The studies were embedded in a scenario framework describing a storm with many minor and connected incidents and energy breakdowns, which had been developed together with actors from the police and fire departments, county administration and an ENO. The purpose of the scenario was to be able to create a common understanding of an occurring emergency quickly and therefore it helped to increase validity and comparability in our interviews. First we conducted observations in order to acquire knowledge about practical work in inter-organizational crisis management. The observations were conducted in a control center during a normal working day (observation time: 9 hours), in the crisis management group and the operations management during a crisis communication training (4 hours) as well as at a major cultural event with about 400,000 visitors (6 hours). In addition to observations, we conducted 5 inter-organizational group discussions (each 4 hours with each about 10 participants) to understand the communication practices of inter-organizational crisis management (Table 23).

No.	County	Topic	Roles
W1	both	Challenges in practice, visit of control center	Energy Network Operator (ENO)
W2	B	Challenges in practice, visit of control center	County Administration, Police, Fire Department
W3	A	Challenges in practice, visit of control center	Department Head: Public Safety, Head of Civil Protection, Head of Police Control Center, Deputy Head of Control Center, District Fire Chief
W4	A	Analysis of user interactions and communication flows	Head of Police Control Center, Head of Staff Coordination, Deputy Head of Control Center, Local Head of Federal Agency for Technical Relief (THW), Local Head German Red Cross
W5	B	Analysis of user interactions and communication flows	Head Regulatory Authority, District Fire Chief, Red Cross: Disaster Management, Red Cross: Communications, Members of other aid agencies

Table 23: Group discussions (2010)

Furthermore, we conducted 22 individual interviews with actors from the participating organizations. Each interview lasted between 1 and 2 hours and followed a guideline, which was separated into three parts. The first part focused on the participants' role, qualification, tasks and work activities under normal conditions. The second part covered the participants' tasks during emergencies in our developed scenario framework. The third part covered applied information and communication systems and perceived problems with these tools (Table 24).

No.	County	Organization	Role
I01	A	Administration	Regulatory Authority
I02	A	Police Department	Head of Control Center
I03	A	Police Department	Head of Section
I04	A	Police Department	Patrol Duty
I05	A	Fire Department	District Fire Chief
I06	A	Fire Department	Deputy Head of Control Center
I07	A	Fire Department	Workmanship
I24	A	Fire Department	Head of Control Center
I08	B	Administration	Office Civil Protection
I09	B	Fire Department	Chief Officer /Chief of Fire Department
I10	B	Fire Department	Operation Controllers
I11	B	Fire Department	Clerical Grade Watch Department
I12	B	Fire Department	Control Center Dispatcher
I13	B	Fire Department	Head of Control Center
I14	both	Police Department	Member of the Permanent Staff
I15	B	Police Department	Head of Control Center
I16	B	Police Department	Head of Group
I18	both	ENO	Higher Area, High Voltage
I19	both	ENO	Operation Engineer, High Voltage
I20	both	ENO	Operation Technician, Low Voltage
I21	both	ENO	Dispatcher, Low Voltage
I22	both	ENO	Workmanship Technical Incidents
IM1	A	Police Department	Head of Control Center
IM2	A	Fire Department	Control Center Data Support / Digital Radio
IM3	A	Fire Department	Administrator Control Center
IM4	A	Police Department	Head of Police Station
IM5	B	Fire Department	Department Chief Control Center

Table 24: Interviews on collaboration practices (2010-2012)

Group discussions and interviews were audio recorded and later transcribed for subsequent data analysis. The analysis of the data material was based on the inductive approach found in *grounded theory* approach (Strauss, 1987). We chose this systematic methodology to discover insights about the work practices through the analysis of data. To be able to use this methodology, the transcripts were coded openly and the statements of the agents were divided into text modules and later into categories. The knowledge previously acquired in the literature study was used to heighten *theoretical sensitivity* (Strauss, 1987). A part of the grounded theory approach is *theoretical sampling*, which means that the selection of the studied units is led by the conceptual structure or theory that emerges during the analysis. One result of the first phase was that the particular collaboration between the police force and the fire service, based on situation maps, is necessary in order to make appropriate decisions. Both have different management structures: in the police force the operations are led from the control center ("*from behind*"), while the one in charge in the fire department is the officer-in-charge, who is on-site ("*from the front*"), and the control center only has a supportive function. To study mobile collaboration practices more closely, also in regards to the creation, exchange and use of information by the response teams and the control center, an additional 5, partially structured, interviews were conducted (each 1 hour) (Table 24).

8.4.2 Results: Informal Work and Mobile Ad hoc Participation Practices

In this section we show the correlation and necessity of informal work and mobile ad hoc practices in crisis management. We first show the need for improvisation and informal communication in order to respond to the high dynamics of an emergency. Informal communication predominantly takes place via mobile devices. This 1:1 communication channel by mobile devices lacks the situational awareness of the other units especially on-site. The current technologies of the different organizations address neither the direct cooperation with other organizations nor the cooperation with the unsalaried voluntary forces in a satisfactory and efficient way.

8.4.2.1 Unforeseen Situations and Complexity Requires Informal Communication

Due to the high complexity and unpredictability of an emergency, improvisation and variable ways of working are necessary. Different often unexpected organizations have to be contacted spontaneously, e.g. the residents' registration office for checking on the residents of a house, or the water protection authority for checking the consequences of a flood in an industrial area.

> *"It has to be like this, because no two situations are alike. I think that is the big advantage we have over other services [...] Because fundamentally the firefighters and us [police], we work differently compared to the other administrations [...] Otherwise we would just be helpless" (I02).*

The actors involved know that the capability to spontaneously integrate unexpected but required organizations is a big advantage in their work practice. However, emerging situations and spontaneously involved organizations as well as frequent by-passing of process structures, which were previously defined by the emergency services, require a high level of informal communication. Current ICT systems, however, do not support the mapping of such involved actors onto the predefined and digitally represented work structures and plans. Informal communication and contacts are therefore important both when addressing organizations and their respective units directly as well as for being able to work inter-organizationally in a trusted environment (I02). In a trusted environment, all organizations are willing to share the needed internal information, except critical and crime-related data in the operations of the police (IM2). Information like road barriers or collecting points and all other information in non-crime-related operations can be provided and shared – also by the police. It is a common practice when trying to obtain relevant information. Phones and mobile phones are the primary work equipment (I08), followed by e-mail and radio (I02) during such inter-organizational informal practices. Even if such communication channels are needed, caused by the complexity of the situation, the units are aware of the discrepancy with regulations and legal agreements:

> *"There are a lot of different ways to get information and they are not always in accordance with the law" (I05).*

> *"This type of verbal communication is not being accepted as evidence. That's why someone has to run after him [the section leader] all the time and record everything with a voice recorder and write it down" (I09).*

Communication through mobile phones is on the one hand fast and easy-to-use, but on the other hand the traceability of the conversations is often hard to establish. Digital radio is cur-

rently just being introduced; therefore 1to1 communication via radio has not been possible. The current practice therefore is that recorder persons have to follow the decision makers on-site as well as in the control rooms. Thus extra work is caused by the fact of the ad hoc, direct as well as informal – but required – communication mechanisms.

8.4.2.2 Informal Communication Enables Ad Hoc Participation but Lacks Awareness

It is obvious that informal communication through mobile phones enables ad hoc involvement of individual actors during an emergency (I02). Such flexible communication is especially used during the arrival phase of emergency forces on-site:

> *"The usual way is to brief you on the go [to the incident place] using a mobile phone: What is going on? Thereby you get a rough idea. This form of communication is of course more work for the supervisor to brief each unit individually, but that is because we just do not want to wait so long" (I04).*

Using the flexible ad hoc participation through mobile phones for briefing units on the go and units arriving later individually during the drive to the incident location has an enormous advantage of speed. This saving of time enables the units to act directly after arriving on-site which leads to immediate care of injured persons or responding to an emergency in accordance with the overall operation. Beside this major advantage, the individual briefing via mobile phone has one important drawback:

> *"The use of mobile phones makes it harder to notice a situation than through analogue radio. In the past, when everything was transmitted by radio, it was not a problem, because everyone could hear everything, but today, because of our poor 2-meter analog radios, mobile phone technology is being used more and more" (I02).*

Such a "*living-in-a-situation"* (as frequently mentioned by the participants), which is absolutely necessary for getting the big picture, is no longer possible due to the frequent (but required) fallback on mobile phones (I02). In the past the decision makers often assessed a situation only by getting information from an on-site leader who perceived the communication between on-site units through radio. While it is hard to get an appropriate overview of the situation through radio, it is much harder to get an overview through mobile phones:

> *"We see again and again that the off-site control center has a completely different picture of the situation than the on-site units" (IM01).*

The 1:1 communication channel, without awareness of the activities of other units and their surroundings through the radio, sometimes leads to misunderstandings between the on-site units and the control centers. For getting a better overview of the environment another current practice of on-site units is that the necessary additional information of an environment is obtained with someone's smartphone:

> *"Some colleagues have Internet access on their smartphones, which is often helpful for looking at a location on Google Maps using the satellite view" (I04).*

By taking a look at the maps, they coordinate actions for searching sections or blocking roads. The participants mentioned that right now it is not possible to integrate additional information to the map like important buildings as they are used to by their physical situation map. They

argue that there should be an option to integrate different external information even such as weather overlays on the map that is already used on-site:

> *"There's a cloud of smoke and then you can have a look. [...] The cloud will be there and in this layer and that area is endangered" (IM3).*

By seeing the situation on-site (e.g. the fire and its cloud of smoke) and external integrated information (e.g. wind directions) the units can calculate the temporal progress of the emergency and its further implications. But to establish an overall appropriated situational awareness, the units asked for the integration of internal operation related information *produced by them*, such as collecting points, to the already used on-site smartphone's map:

> *"It would make sense, if I had the possibility to add a text field on the map that lets you add a radio name or something like that" (IM1) and "that we can draw in areas [e.g. road barriers or collecting points] on our own" (IM4). "To avoid any discrepancies, the most important thing is that it [the on-site map] has to be 100% in sync with the situation map at the control center" (IM5).*

The units are aware that the already existing information gap between the on-site units and control center could get even bigger using technology which could get out of sync. Transmission techniques are therefore needed that are always available. The units have years of positive experience with using standards built upon the mobile GSM-network. Besides a few negative experiences such as what the participants call the *"New Year's Eve Effect*" where the GSM-network is temporarily overloaded:

> *"It would be best if it [information] could be transferred via WLAN or UMTS, then the control center could also look at it. That way, the overlap [same understanding of the situation] between the officer-in-charge on-site and the control team would be bigger. Otherwise, someone is talking about a fire here and the others think he is talking about a fire somewhere else" (IM2).*

8.4.2.3 Lack of Technical Support Precludes Involvement of Volunteer Forces

The professional forces have – apart from radio – no dedicated technical means to involve the (organized) volunteer forces, such as the volunteer fire departments or aid agencies, in coping and response work. Especially in Germany, volunteer forces are an important part of the (non-police) emergency services, but are not really integrated into the existing IT infrastructures and dedicated information systems. The problems start already during the alarm process:

> *"Unfortunately, the sirens have been gotten rid of, which is very bad" (I07).*

In Germany, there are no more sirens at the fire stations to alert the volunteer forces anymore. This is mainly due to the noise level. Following the abolition of the sirens, the only way to alert the volunteer fire fighters is by silent alarm via pagers. The addressing of volunteer fire fighters through pagers is seen as very critical:

> *"You cannot force them to use their pager. If someone is sweeping his garage or is in the garden and has his pager in the house, he does not notice the alerts" (I07).*

Besides the alert itself, the response to such an alerting is often a problem, because the pager has no feedback functionality to the professional services. The professional just alerts the volunteer fire stations without knowing the magnitude of the overall units available and must wait until the leader of the volunteer services gives an official status:

> *"I will alert my volunteer fire department. But I never know how many will come, because there is no roster" (I09).*

For this reason they have to be re-called via mobile phone – although phones are currently not part of the official alerting and response procedures. After a successful alarming, several further communication problems exist due to the multiplicity of systems between professional and voluntary forces:

> *"In the volunteer fire department, there aren't often really computer savvy people […] It needs to be easy for them" (IM2).*

The current systems often need very extensive instructions and are therefore not suitable for volunteer units who do not use them on a daily basis. But these forces still play an important role in major incidents (I05). Usually the volunteer forces act very local dealing with very small incidents like small fires. They are neither using, nor familiar with the professional IT-systems. Intuitive systems are therefore required, which are made for the *"IT dyslexic"* (I02). The units are not trained on the systems which should be used during emergencies (I06). Due to these problems, the units already fall back to aforementioned mobile phones (I07).

8.4.2.4 Missing Situational Awareness through the Phone Handicaps Liaison Officers

Problems exist beyond the single organization or organization type. Inter-organizational coordination (crisis management group and operations management) usually takes place via so-called liaison officers. Liaison officers are very experienced people with an extensive knowledge of the working practices and the current processes that take place in their own organization (I14). They sit at the control centers of the other involved -organizations and are connected to their own organization by mobile phones, which have access to the Intranet of their respective organization (I14). Since a connection to a control center only exists for their liaison officers and not necessarily to the crisis management systems of the other organizations, the liaison officers have to be able to decide what information needs to be answered and transferred to their control center immediately and what can be assigned a lower priority:

> *"It is very difficult because the handling of information can vary in different situations. […] You have to think again and again of how information can get from one organization to the other" (I14).*

Liaison officers have to decide very quickly who of my own organization needs what information when and how must it be delivered. On the other hand, they have to decide which information from their own organization must be transmitted to the organization they are currently working with. This decision process is on the one hand framed by law (legal agreements) on the other hand by human (cognitive skills).

> *"I need reliable information for a decision in a specific situation [and] the most secure information is the information which I have seen myself" (I05).*

Liaison officers have the problem "*that we cannot look through the phone. We cannot see what it looks like on-site*" (I06) and must rely solely on verbal language. The head of the police control center expressed: "*If you visualize the firefighters' position, as well as their capacity, that would be helpful for all*" (I02). All inter-organizational information that is to be exchanged has a geographical reference: "*We are interested in position spaces, operation spaces and many other things such as danger areas, operation volume or escape routes*"

(I15). It is, that is, desirable to get the 'big picture' of the situation (I15). By automatically providing and displaying information with geographical references, liaison officers would be significantly aided and the overall process would be much more efficient.

8.4.2.5 Summary

The rigid and pre-defined emergency services' process structures cannot satisfy the complexity and unpredictability of an emergency as well as its process wherefore a high level of informal communication and improvisation is required. Concerning these informal communication practices, (mobile) phones are the primary work equipment – especially when dealing with volunteer forces or when cooperating on an inter-organizational level through liaison officers. This communication technique on the one hand enables the ad hoc involvement of individual actors during an emergency, but on the other hand it provides for little awareness and renders it more difficult to notice a situation than through the use of radio. The "*living-in-a-situation"* (an expression always mentioned by the participants), which is absolutely necessary to get an overview of the situation, is no longer possible due to the frequent fallbacks to the 1:1 connection through mobile phone use. When a unit participates in an ad hoc manner, the on-site units use a workaround with existing maps on their smartphones to get a better overview and enhance the communication with visualization options. Just using those maps cannot fulfill all the requirements such as annotations or map sharing. But these options support the informal mobile phone calls and pave the way for the fast involvement of the units in the coping and recovery work.

8.5 Concept: Mobile Geo-Collaboration System (MoCo)

To research informal and spontaneous participation practices as well as possible cooperation mechanisms technically, we decided to develop the application *MoCo* (Mobile Collaboration App) taking the results of our empirical study into consideration. Addressing the empirical findings, the system tries to assist unforeseen situations by supporting informal communication and explicitly trying to maintain a high level of awareness while enabling ad hoc participation and visualization of the situation. MoCo is based on the existing GIS *ISAC* (Inter-Organizational Situation Assessment Client) (Ley et al., 2014, 2012a), which is adapted for mobile devices and extended to special mobile needs (Reuter & Ritzkatis, 2013). We decided to develop a smartphone-based application because currently smartphones are widely distributed, even among the volunteer forces and are used for visualization in addition to calls; furthermore units are privately skilled to use these devices. Since private smartphones are already present, tablets could also be used in the future in emergency work. We therefore designed a native Android app to address both device classes.

On the left side (Figure 15, B) the user has the option to slide in functionality to display a mobile version of an information repository for integrating external and internal information (Ley et al., 2013). The information repository is structured through different main categories like weather, traffic, important locations or private information. To avoid information overload on the map, such information can be shown individually or hidden or collected in different map layers. For example during a flood emergency, only information such as water levels and past flood areas need be presented; during the evacuation of a hospital only local hospitals or shelters are presented. External information, such as weather information provided by

the meteorological service or blackout areas provided by the ENO, can be integrated in two ways: it is possible to insert a URL for a OGC* specified Web Map Service (WMS) to use geo-referenced map images from the Internet that are generated by a map server using data from a GIS database. The data exchange is implemented according to the DIN SPEC 91287:2012-07 on "data interchange between information systems in civil hazard prevention". The second way is to add a Keyhole Markup Language (KML) Layer, an XML notation for expressing geographic annotation and visualization within Internet-based maps.

Internal information can be added manually on the map by clicking onto or searching for a location, assigning information to a specific category (e.g. police unit or fire department) and giving them a short description. The description will pop up when the information marker is tapped. Beside this information, additionally annotations (Figure 15, A) such as circles, polygons or hand-drawn sketches can be inserted to mark special, mainly temporarily locations or situations, e.g. road blocks or collecting-points during operations. These annotations are declared as private objects that allow a person to make personal drawings or short marks in addition to the general shared information on the left side.

The idea of a mobile, map-based visualization support for on-site units and an application like this one is not novel and has been studied in past (see section 8.2.2, e.g. Büscher & Mogensen, 2007; Monares et al., 2011; Wu et al., 2013), but here it is used as the basis for the innovative main functionality called *collaboration mode*, which can be displayed at the right side (Figure 15, C). The collaboration mode allows the user to make changes on the current map. The user has the option to easily invite someone spontaneously into his collaboration session to see the same view and all changes on the map synchronically using the smartphone application or the browser version. It implements the principle 'What You See Is What I See (WYSIWIS)'. When starting the collaboration mode, a dialog appears showing a list of the participations that are registered in a related inter-organizational crisis management system, which can easily be extended to involve other participants. The creator of the session (manager) can invite as many users (participants) as needed to discuss a situation in a dispersed manner. This enables manager to address several units in an ad hoc and dynamical way – also inter-organizationally, including on- or off-site units using our smartphone application or a modern web browser. When the invitations have been accepted, only the manager has write access. At the same time he has the option to assign these rights to someone else and can regain them forcibly. This restriction ensures that the map will not become overloaded and that everyone pays attention to the discussed information. In addition to mobile phone calls, the collaboration mode offers a multilateral communication environment instead of bilateral calls and the visualization should overcome verbal limitations, especially when talking about geo-referenced information, giving the user more tools for expression. Every annotation which represents e.g. a collection point, road barrier or some other point of interest can be shared with all participants of the collaboration session and can thus enhance awareness. The collaboration mode offers the option of enhancing mobile calls so that more than one person and distributed units can participate in the process of situation assessment and it creates a shared view of the geo-spatial representation of a situation (Figure 16).

* The Open Geospatial Consortium (OGC) is an international industry association for developing publicly available interface standards.

Figure 15: Screenshot of the mobile geo-collaboration system MoCo on tablet (A), the information pool to manage and select information resources (B) and the administration of the collaboration mode (C)

The collaboration mode can only be used with the support of web sockets, a web technology providing full-duplex communication channels over a single TCP connection. Web sockets are available in web browsers since mid-2011 and at the moment a secure and established version of the web socket protocol is implemented in Mozilla Firefox 6, Google Chrome 14 and Internet Explorer 10. In a mobile context, the connection between the mobile clients and the server is a special challenge. Taking this into consideration, instead of transferring complex objects, an exchange of chains of symbols was made possible, so that not an entire marker object is sent, but only the features of the marker (location, name, etc.). The marker object is recreated in the receiver application. This minimizes the data transfer amount. Furthermore the collaboration server is not established on the device of the inviting actor due to the possibility of losing the Internet connection.

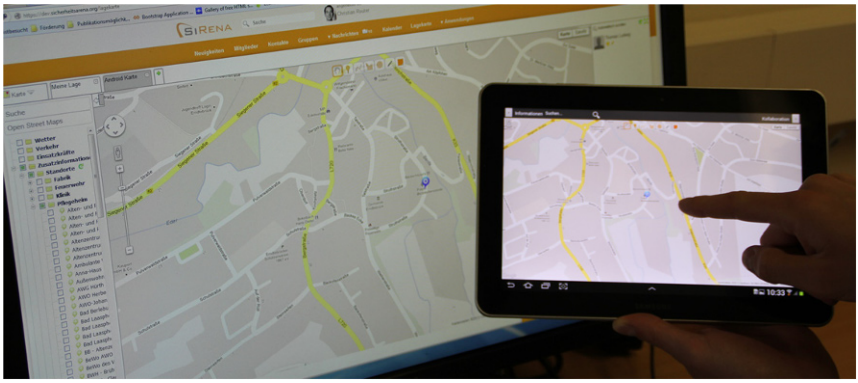

Figure 16: Collaboration mode in the browser and on tablet

8.6 Evaluation of MoCo

8.6.1 Methodology

In order to evaluate the empirical findings, requirements, and our supportive tool allowing ad hoc participation, we evaluated the prototype with 33 different users. The first development cycle led to a web-based situation assessment prototype, which was evaluated in an interim evaluation using scenario-based walkthroughs. First the prototype and its functionality were briefly introduced, then the participants had to use the application and solve predefined tasks. The subsequent interview covered: first impressions; system handling; conceivable use cases; requirements to make the system usable; collaborative situation assessment; and further information needs (Table 25).

No.	County	Organization	Role
E01	A	Police	Head of Control Center
E02	A	Police	Head of Section
E03	A	Fire Department	Deputy Head of Control Center
E04	A	Fire Department	Head of Control Center
E05	both	ENO	Operation Engineer, High Voltage
E06	both	ENO	Operation Technician, Low Voltage
E07	both	ENO	Higher Area, High Voltage
E08	B	Police	Head of Control Center
E09	B	Police	Head of Group
E10	B	Fire Department	Head of Control Center
E11	B	Fire Department	Watch Department
E12	B	Fire Department	Head of Group

Table 25: Participants evaluation 1st iteration (2011)

The second cycle extended the prototype to an inter-organizational geo-collaboration system and was evaluated under real-use conditions. For this we rolled out the prototype for a limited amount of users and after a 3-5 week evaluation period, we conducted interviews with 16 of the participating users on usability, the integration into working practices and inter-organizational issues (Table 26).

No.	County	Organization	Role
E13	A	Red Cross	County Head
E14	A	Fire Department	Administrator Control Center
E15	A	Fire Department	Staff of Control Center
E16	A	Fire Department	Head of Fire Department
E17	A	Police	Head of Section
E18	A	Police	Staff of Control Center
E19	A	Police	Staff of Control Center
E20	A	Police	Staff of Control Center
E21	A	Police	Head of Control Center
E22	both	ENO	Operation Engineer, High Voltage
E23	both	ENO	Operation Engineer, High Voltage
E24	B	Police	Staff of Control Center
E25	B	Police	Data Administration, Control Center
E26	B	Police	Staff of Control Center
E27	B	Fire Department	Workmanship
E28	B	Fire Department	Staff of Control Center

Table 26: Participants evaluation 2nd iteration (2013)

While those evaluations focused on the whole concept, additional evaluations were performed which focused on the realized Android application, allowing mobile ad hoc information exchange and collaboration (Table 27). During these evaluations the collaboration mode was demonstrated using both mobile devices and the browser version (Figure 17). All evaluations lasted on average about 60 minutes.

No.	County	Organization	Role
EM06	A	Police	Head of Control Center
EM07	A	Police	Head of Section
EM08	A	Police	Head of Section
EM09	A	Police	Executive Staff
EM10	A	Police	Executive Staff
EM11	A	Fire Department	Fire Chief, Admin Control Center
EM12	A	Fire Department	Municipal Fire Inspector
EM13	A	Fire Department	Volunteer Fire Chief
EM14	A	Fire Department	Volunteer Workmanship
EM15	A	Fire Department	Volunteer Workmanship
EM16	A	Fire Department	Volunteer Workmanship

Table 27: Participants evaluation mobile applications (2012)

Each interview session was audio-recorded and transcribed for subsequent analysis, which was divided into three steps (C. Schmidt, 2004): (1) The transcripts were structured according

to the questions of the interview guideline. Statements taken from the transcripts shed light on participants' reactions during the session. (2) Based on the transcripts, ex-post categories were formed for the analysis. This categorization included aspects about the implementation and integration of the system with existing infrastructures and practices, cases for the application of this approach and recommendations for improvements. (3) These analytical categories were used to create a coding guideline. It helped to cluster the data in terms of meaningful units to focus on specific problems.

8.6.2 Results: "Include People that were Previously Left Out"

Using our design we were able to derive the impact of mobile collaboration infrastructure on the improvisation practices of decision makers and on-site units. Firstly, we saw that the prototype allowed the configuration of an individual set of information was used for personal information retrieval, using various pieces of information from the Internet:

> *"It is perfectly aimed at all those things where everyone has his own list of favorites. You can put it together as you need it" (E23-13:53) or: "it is all in one" (E26-9:15).*

The configuration of this "own list of favorites" is crucial because even in the structured work of the control center, which is also shaped by legal requirements, individual dispatcher work is rather different and also uses various and diverse information. The empirical study had illustrated that the piece of information which is needed to make a decision varies from situation to situation as well as individual to individual (I03) and our evaluation confirmed it. It was noticed that MoCo has the potential to enrich information assessment by obtaining and seeing information from other organizations in a timely fashion:

> *"Interconnectedness would be interesting for us […]. Then we could invite the fire service or other organizations to this map. The fire service will certainly – not immediately – check where the police are stationed. But at some point you're going to check what others are doing" (E24-18:00).*

The information from other organizations could have direct impact on one's own operations and measures. Currently, those processes of coordination only take place via verbal communication channels, often through mobile phones. Functionality for collaborative sensemaking and its interoperability is therefore an important requirement:

> *"We have quickly created a common picture. And in the end, we can only operate successfully if we work together with the fire service, the Maltese ambulance service and the Red Cross. […] I could make a map for my fire service colleagues, and shade parts in order to tell them that they don't have to worry about that area" (E13-41:40).*

A special emphasis in the evaluation was put on the demonstration of the exchange of information. Especially when information is being exchanged during an emergency case, the interviewees saw an improvement with regard to their current work practices.

> *"In the executive staff group I also need other information: when I work with actors from several sections, I can set the section maps and they are automatically updated by the section leaders" (EM06-8:19).*

By providing a technical solution like MoCo, the head of a section can work as a supplier of information and in the control center the information automatically comes together. The func-

tion "*send me the map of what we have done so far"* (EM07) was rated especially positively. The most important issue concerning the changes of working practices was the possibility to *"include people into situation illustration that were previously left out"* (E16-25:44). The interviewees elaborated that currently it is possible to talk to each other or to send photos from phone to phone in 1:1 communication, but not to actively and easily collaborate and exchange information independently of the existing infrastructures. For such collaboration, several cases for ad hoc participation were observed by us and mentioned by different actors during our evaluation sessions. They will be described in the following.

Figure 17: Evaluation of MoCo on smartphones, tablets and laptops in the fire department (2012)

8.6.2.1 Control Center and On-Site Units' Coordination

The first case to include people that were previously left out means the cooperation of spatially distributed services of the control center and the forces on-site (Figure 18):

> *"Mainly, we do not work in the control center, we work on-site. […] We do internal things for ourselves and the incident command does it on-site. It would be good if we were always at the same information level as the command vehicle" (E28-20:22).*
>
> *Or: "For purposes of coordination, you should be able to see the same on-site as in the control center" (E01-37:10).*

On-site units often have to decide in real-time. Much information from other involved professional organizations or from citizens arrives at the control centers. But the transmission of information lacks speed as well as wide-spread distribution across all on-site units. Synchrony would therefore be especially important during the aforementioned kind of cooperation: "*A synchronous display of information is useful, exemplary especially for discussions on whether we should block this or that road*" (E02). For such situations the use of the smartphone version of our system was recommended:

> *"You should certainly use something like that on a tablet PC or a notebook when the colleagues are on-site. Here, for instance, you could add regions for a search for missing persons. The on-site forces could be divided based on this information" (E20-50:41).*

Such cooperation could in some ways replace phone calls with the disadvantage of 1:1 communication and a lack of situational awareness of the other actors:

> *"We get information from the fire service when, for example, there is a fire somewhere […]. [Using an] App for the smartphone, we could just add the dis-*

turbance instead of taking a call from someone, we could just directly add it to the map" (E22-19:15).

The transmission of coordinates was also an issue mentioned in order to support cooperation between the control center and the on-site units:

"Especially since there are often areas that don't have a name or number, but are somewhere in the open field. In this case I can also imagine that, rather than discussing it for a long time, you could add a marker and share it" (E23-26:30).

By using an application that supports map-based visualizations the error-prone discussions about locations (e.g. correct street, but wrong city) can be prevented, or at least reduced.

Figure 18: Evaluation: using radio and our mobile application on-site (top) and the web browser version in the control center (bottom) (2013).

8.6.2.2 Including New Forces from other Organizations or Regions

A second case for light-weight tools for sharing digital representations ad hoc is cooperation among organizations, e.g. with new forces from other regions, which is necessary especially in more severe situations, and which is closely connected to the issue of discussions about location:

> *"I could provide an on-site overview. For instance, some people from Burbach [another city] arrive, who know where our city is of course but do not know where the Bismarckstraße [street] is" (E13-32:19).*

The new forces from other regions do not have the technology, to figure out what location is meant and how they reach it. This time-saving feature can enhance access routes to the incident's location. Another example mentioned was coordination with other units, such as rescue dog forces, which are usually not part of the core crisis management team but have to be consulted in special cases, e.g. missing persons. Such cooperation support could improve the possibility of appointing other organizations to tasks via the control center:

> *"You could implement the entire situation and create search maps. The rescue dogs are the ones who need the most map material because they run criss-cross" (E13-21:24).*

> *"We must organize or inform them in such a way that they do not work too autonomously. We always have problems like that" (E15-40:36).*

The map could therefore act as an "*educational object*" (E16-41:14), where the locations of the forces are displayed in order to answer questions like, where exactly are the on-site forces? What are they doing? And where are the other forces located? (E02, E09). The answers are of extreme importance, mainly for the police, because their head of operation "*leads from behind*" and does not have contact with each unit. Besides the allocating and distributing of units, information sharing is important in such scenarios. The interviews emphasized that basically there were no concerns about sharing information with others, neither from the police nor the fire department, nor any other involved organization: sharing in such scenarios is important.

> *"During a major situation we have to exchange information. In this case we dispatch a liaison officer to them [fire department] and they send one to us. From then on there are no more secrets anyway" (E24).*

> *"Depending on the category of information, it could be shared automatically" (E01-39:30).*

However, especially on the police side, there is confidential information that has to be kept secure. But this kind of information would not be shared anyway, neither via our application nor via phone or by radio:

> *"For example during a violent demonstration we also work together with fire department and ambulance services. But there is tactical information on police side that will not get to the outside. […] Every operation where special forces are involved" (E21).*

8.6.2.3 Collaboration outside the Office / Office Hours

The third case of emerging cooperation scenarios affects collaboration scenarios outside of office hours. Usually actors are only equipped with technology in their office and during their

office hours. Using mobile phones with collaborative applications, it would be easier to include actors that are currently off duty in the process of situation assessment:

> *"Disturbances do not just happen during office hours but also, for example, on a Saturday night and in that case it would be useful […] A) Maybe some data is already in the system, blackout areas and so on. And B) I could show something by marking it and saying: 'Here we have this and that problem'. Then I could […] upload pictures, or other material I've got relating to an object to make the situation more transparent, because today we do all that via telephone. Sometimes with difficulties" (E23-24:00).*

An emergency can arise at any time. The units at the control centers as well as on-site therefore are often changed while responding to the emergency. An application like MoCo supports the handover during a shift change, because instead of reading all the reports, the forces take a look at the digital map, even while arriving either at the control center or on-site:

> *"Such visualization is helpful for shift changes. It is much better than thrusting a stack of paper in someone's hand, with information about the whole procedure" (E21).*

8.6.2.4 Perspective Outlook: Sharing with the Public

The possibility of also sharing the physical situation map in digital media leads to further opportunities:

> *"Someday we should have the option to publish a map we have created. Where the citizens can look and check what the matter is: this street is blocked and that street is blocked" (E16-42:03).*

Professional organizations sometimes have significant problems reaching the wider population living in the affected area or those who might be interested in the emergency (e.g. family members). By providing a digital version of a situation map, it is possible to share it (or parts of it) with concerned citizens. The existing functionality should therefore be enhanced:

> *"If I draw a circle around an incident location and annotate: 'Close the doors and windows', as public information" (E16-44:10).*

A big telecommunication network breakdown that occurred in the capital city of county A, led to breakdowns of the landline service, emergency numbers, control center websites and local radio. In this case, the Facebook website of the control center was used for citizen communication and information was published by the authorities. The interviewees mentioned if they had functionality for providing geographical information, as is possible with MoCo, it would be much easier to inform the citizens in an appropriate way.

8.6.2.5 Limitations

Of course such digital representations have limits. Many interviewees mentioned that they are best suited for longer emergencies, as a police representative said:

> *"For situations in which we have offenders on-site, it is not suitable. It's too clumsy; how we work now is better. It is different for situations that develop over several days, such as a fire or a flood. It is a great tool for that" (E17-37:07).*

Furthermore, large-area emergencies were mentioned. Other limitations are that the devices have to be available (E02). Nowadays that is often the case – even for volunteers – because MoCo works on normal smartphones as an Android application or browser version, which is quite widespread these days and will increase in the next few years. Furthermore, the quality of the network infrastructure, which is sometimes poor, especially in rural areas, and might break down during big storms, was mentioned (E02). Priority circuits could help those who are especially dependent on phones to use the mobile network efficiently. In some evaluations, it also became clear that there is no specific experience about aspects dealing with access control. Current practices with a single situation map in the control center restrict access based on physical presence in the control room. While using digital representations, which can be shared among the users, new possibilities and questions will arise (E16), including for instance role-based access restrictions, free access for all emergency services or explicit sharing of information.

8.7 Discussion and Conclusion

The collaboration between the units of all organizations involved in crisis management is generally shaped by legal regulations (e.g. regarding notification and documentation duties) and professional conventions (e.g. liaison officers). However, in a crisis, the rigid and predefined emergency services' process structures connected with these regulations and conventions often cannot satisfy the complexity (Palen & Liu, 2007). Supporting improvisation is, in our eyes, one of the crucial strategies. There has been previous research on the technical support the cooperation of emergency services on-site e.g. on the basis of mobile map-based applications (e.g. Bergstrand & Landgren, 2011; Büscher & Mogensen, 2007; Catarci et al., 2010; Ludwig et al., 2013; Monares et al., 2011; Nilsson & Stølen, 2010), on different aspects of geo-collaboration (e.g. Cai, 2005; Convertino et al., 2011; Liu & Palen, 2010; Schafer et al., 2007; Wu et al., 2013; Zlatanova & Fabbri, 2009), information visualization and sharing (e.g. Hiltz, Diaz, et al., 2011; Quarantelli, 1988; Turoff et al., 2004; Wenger et al., 1989), as well as on improvisation during emergencies (e.g. Adrot & Robey, 2008; Ley et al., 2012; Lindström & Pettersson, 2010; Mendonça, 2007; Turoff et al., 2009, 2004; Weick, 1993). However, none of these (mobile map-based) approaches address the improvisation practices related to ad hoc tasks in a collaborative manner. Approaches either do not consider ad hoc tasks in mobile contexts (Wu et al., 2013), do not focus on geo-collaborative aspects (Ludwig et al., 2013a) or do not consider being able to ad hoc integrate new actors outside one's own organization to situation assessment (Monares et al., 2011).

We therefore explored the practice and necessities of mobile collaboration with regard to improvisation work and ad hoc participation of units in emergencies. We suggested, implemented and evaluated an interaction concept including a real-time map with the potential of synchronous and very flexible information sharing. In our empirical study (section 8.4) on current work practices of emergency services with regard to collaboration in situation assessment and decision-making activities, we found that the spontaneity and volatility of the emerging information needs of units poses a significant challenge to involving them accurately, as well as providing a common situation assessment. The current practices show that a number of results need to be addressed when developing technological support for mobile ad hoc response work:

- Informal communication practices (mainly through mobile phones) are required to be able to respond to the dynamic nature of emergency scenarios.
- When individual actors are needed suddenly, mobile phone calls enable and guarantee their rapid ad hoc involvement into situation assessment.
- Besides the limitations of verbal speech, mobile phone calls with point to point communication lack the *living-in-a-situation* support and are therefore not able to facilitate situation awareness.

Based on these conditions and related to the detected work practices, we designed a mobile geo-collaboration application (section 8.5). With this application as our basis we implemented the innovative *collaboration mode* which focuses on an ad hoc and collaborative situation assessment across many expert units with the requisite spontaneously. In addition to mobile phone calls the decision to design a light-weight mobile application gives the units a technical option to involve additional forces into situation assessment and decision making. In addition to mobile phone calls, it provides a technical opportunity to involve (organized) volunteer forces, which are essential in (German) emergency management, but who are not as well equipped as the professionals. Such an option for involving participants who are needed on an ad hoc basis holds potentially positive effects in three dimensions, as indicated by our evaluation (section 8.6):

(1) *Spatial:* Multilateral visual support for on-site units and the control center. Through a concept like the collaboration mode it is possible to enhance the existent improvisational verbal communication on mobile phones with the visualization and synchronous view of a situation, so that all needed units are able to *talk about the same situation.*

(2) *Organizational*: Cooperation with external (inter-organizational) and volunteer units. Through a concept like the collaboration mode it is possible to extend the improvisational communication and situation assessment practices in such a way that the cheap and often already existing (private) technical devices are addressed to integrate additional organizations and particularly volunteer forces into emergency management with the aim of *all talking together* about the same situation.

(3) *Temporal*: Time-independent available cooperation beyond office hours. Through a concept like the collaboration mode it is possible to contact everyone not only independently of his working environment, i.e. a fixed desktop PC or situation map inside a control room, but also beyond typical office hours. Because an emergency does not occur on a time-schedule, the emergency services also have to comply with this time-independence. With an application like MoCo on everyone's device it is possible for *everyone to talk together about the same situation whenever it is required.*

Aside from these positive effects, there is a major issue when developing concepts and tools that support informal practices and improvisation work in general. On the one hand, such solutions can support existing work practices which necessarily deviate from previously defined structures to enable a flexible response to any emergency. On the other hand those developments undermine acknowledged, formal hierarchy structures, command chains and processes as stated by legal regulations and professional conventions. Organizations have to accept these informal work practices and need to find compromises between pre-defined and actually executed procedures to create opportunities for technical support. If this does not happen, the improvisation will be still limited to verbal speech on mobile phone calls. Using (private) smartphones according to a Bring Your Own Device policy may of course not be as liable as specialized devices and will raise legal, organizational and practical questions – however to

ad hoc integrate actors into situation assessment the available devices have to be considered – or rich collaboration cannot be stablished. McMaster and Baber (2012) point out the need to be able to share experiences with experienced colleagues, who can summarize the situation in a few words. In any event, our study showed that these conversations might be enhanced by visual representations of the situation as provided by MoCo. In some cases these representations cover all information needs of the respective units, in other cases additional established verbal reporting structures (Schmidt & Bannon, 1992) are necessary. By not just sharing all information, but with the opportunity to set private and public areas, reducing information overload (Hiltz & Turoff, 1985) is also possible. Regardless, our point was that accurate and reliable information is necessary, not that it is sufficient. We do not see our application as interfering with, or problematizing, the skilful work practices of experienced members.

Emergency management and response work are not the only application field where approaches for supporting the ad hoc participation in mobile collaboration are of value. Emergent or spontaneous collaboration will become more and more important for organizations, businesses and individuals in an increasingly networked world (Grudin, 2010). Working in emergent structures can be challenging due to unpredictability, incalculability and therefore uncertainty. To deal with these circumstances, flexible applications supporting the needs of improvisational work by heterogeneous teams are required. These heterogeneous teams are not necessarily at the same place, in the same organization or in the office when needed. Such flexibility is of course not always required and desired, however the responsible actors in critical and volatile situations, such as emergency services, special operations or responsible managers in business, may benefit from it. Our work illustrated three dimensions (spatial, organizational, temporal), which might be covered by tools for ad hoc participation, and which potentially have ramifications which go beyond those planned (Orlikowski, 1997). Basically, collaboration infrastructures are challenged to support collaborators, who are each embedded in a specific socio-spatial-temporal and organizational context in their effort to overcome the distance between them and to create a common ground for collaboration (Schmidt & Bannon, 1992). However, it seems likely that these dimensions are not the only ones that enact collaboration and have to be addressed in order to support the resilience of collaboration.

Further to the aforementioned issue, we intend to look into additional ways of improving *collaborative resilience* (B. E. Goldstein, 2011), which "examines a variety of ways to build resilience to violence, hazards, and resource decline […] such as the collective mobilization of change" in the future. We aim to find ways of identifying how citizens and spontaneous volunteers can be integrated into situation assessment as possible participants (Reuter et al., 2013; Starbird & Palen, 2013; Vieweg et al., 2010). Particularly in large-scale emergencies, the necessary actions can exceed the available manpower of professional and organized volunteer forces and offer potential for citizen involvement in response work (Reuter, Marx, et al., 2012). Such involvement also requires a degree of coordination and our application has potential for wider scale information sharing which can facilitate that process.

9 Scenario C: Articulation Work in Mobile Reporting (ECSCW)

Decisions of emergency response organizations (police, fire fighters, infrastructure providers, etc.) rely on accurate and timely information. Some necessary information is integrated into control center's IT (weather, availability of electricity, gauge information, etc.), but almost every decision needs to be based on very specific information of the current crisis situation. Due to the unpredictable nature of a crisis, gathering this kind of information requires much improvisation and articulation work which we aim to support. We present a study on how different emergency response organizations communicate with teams on-site to generate necessary information for the coordinating instances, and we described, implemented and evaluated an interaction concept as well as a prototype to support this communication by a semi-structured request-and-report system based on Android devices. We learned that (1) the accuracy of request and reports can be improved by using an appropriate metadata structure in addition to creating multimedia-based information content, (2) requirements of trusted and fast information need to be respected in support concepts although they may even be contradictory, and (3) the coordination strategy of the emergency response organization also shapes the way this interaction needs to be designed. [*]

9.1 Introduction

Nowadays cooperation often goes beyond spatial and organizational boundaries. One challenge for cooperation in heterogeneous settings is to provide information in the appropriate amount, level of detail, format and point in time. In such settings, the sender is faced with the challenge of perceiving the outer context, as well as anticipating what the recipient already knows. If both are successful, communication can concentrate on the essentials, otherwise failures arise as a *lack of information* or an *information overload* (Toffler, 1970). In CSCW a distinction between (mainly distributed) cooperative work, that covers the tasks itself, and articulation work, that includes all activities to coordinate the tasks among individuals, is common (Schmidt & Bannon, 1992). Articulation work is necessary if one participant is not able to accomplish the whole task by himself. If we look at the case of emergency services, it is obvious that one unit cannot manage the situation alone, therefore collaboration and, consequently, articulation is required. In terms of emergency management, articulation work includes reports of on-site units to the control center, information provided by the control center or even communication between different units or organizations (Reuter, Marx, et al., 2012). Emergency services face an "unlimited variety of incidents that require interpretation, deci-

[*] This chapter has been published as a full paper (Ludwig et al., 2013a):

Ludwig, T., Reuter, C., & Pipek, V. (2013). What You See Is What I Need: Mobile Reporting Practices in Emergencies. In O. W. Bertelsen, L. Ciolfi, A. Grasso & G. A. Papadopoulos (Eds.), *Proceedings of the European Conference on Computer Supported Cooperative Work (ECSCW)* (pp. 181-206). Paphos, Cyrus: Springer. http://link.springer.com/chapter/10.1007/978-1-4471-5346-7_10

Further results about MoRep have been published as a paper in the *Proceedings of Mensch & Computer* (Ludwig et al., 2013b) as well as in the *Proceedings of Informatik* (Ludwig & Reuter, 2014).

C. Reuter, *Emergent Collaboration Infrastructures,*
DOI 10.1007/978-3-658-08586-5_9, © Springer Fachmedien Wiesbaden 2015

sion and coordination" (Normark & Randall, 2005). The increasing emergence of mobile devices, data flats and almost all-encompassing Internet during the last years created new possibilities that allow communication and may support cooperation from anywhere. However, the dynamics and specifics of emergencies aggravate finding appropriate approaches to articulate information needs among all actors (Heath & Luff, 1992).

In order to support articulation and reporting, we concentrate on a scenario, where on-site units and off-site units have to share a common understanding of a situation. The focus lies on preventing lack of information as well as information overload, at the same time increasing the quality of information, which should ensure a better basis for cooperative decision-making. In a qualitative empirical study of emergency services we explored their mobile collaboration practices, as well as possibilities to support those practices via mobile devices and applications. From these pre-studies, we have summarized the requirements for a mobile interaction approach, which allows semi-structured information requests and corresponding reports to stimulate a high-quality information basis. After introducing the resulting Android application *MoRep*, which is supposed to support communication among emergency services, it will be evaluated by emergency services representatives concerning its impact on working practices and potentials to support articulation work in emergencies.

9.2 Related Work

Unexpected problems, dynamic changes of situations or environmental and knowledge limitations lead to the need for improvisation (Stein, 2011) - especially in crises and emergencies. To support improvisation during emergency management it is essential to know the characteristics of the field. Based on an analysis of the response to the 2001 World Trade Center attack, the following characteristics of emergency management can be considered as reasons for improvisation (Mendonça, 2007). Firstly, (a) rarity of incidences limits opportunities for training and learning. Furthermore, (b) time pressure forces a convergence of planning and execution. (c) Uncertainty is present because the development of an extreme incidence is hardly predictable. Furthermore, extreme events have (d) high and broad consequences, therefore there is a need to manage interdependencies among a wide range of physical and social systems. The (e) complexity of the event arises, partly due to the high and broad consequences. Finally, (f) multiple decision makers and responding organizations may negotiate while responding to the event. Nevertheless, all organizations that help guaranteeing civil security have developed systematic approaches to deal with these uncertainties and to allow for planned, coordinated activities in crises. Still, many situations require spontaneous, ad hoc decisions and short-term (re-)planning. The collapse of role systems need not result in a disaster, if people develop skills in improvisation (Weick, 1993). The ability to improvise remains a valuable asset for individuals and organizations, and is usually cultivated in crisis trainings and grows with experience (Ley et al., 2012a). Computer-based systems can support these processes, if the design is informed by an understanding of the cognitive processes involved in responding to unanticipated contingencies (Mendonça, 2007).

The type, quantity and quality of information, that an agent needs within a given decision making context to complete a specific task, is called information demand, whereas objective and subjective information demands are not always identical. The objective demand includes information, which should be available according to a specific task. The subjective demand

includes all information that is relevant in the agents' opinion. The information supply includes all external and internal information to which an agent can access at a certain time. O'Reilly (1980) studied how the amount of information affects the quality of the decisions made. He shows that actors, who claimed not receiving enough information to complete the tasks, were less satisfied, but made better decisions. On the other side, actors, who claimed that they were overloaded, were more satisfied, but the decision quality was not as good. But the impression that the *lack of information* has less negative effects than the *information overload* is relativized by the finding that a lower satisfaction of actors is closely linked to an "increased tendency by senders to distort information during transmission" (C. A. O'Reilly, 1980). Therefore both problems have the same relevance. They are characterized by subjectivity, which outlines one of our main argument: "What one perceives as information overload, may be perfectly manageable to the other" (Mulder et al., 2006). However, not only the amount of information plays an important role in decision making, but also the quality and the format (Ho & Tang, 2001). Both are subjective as well and can vary according to the individual (Naumann & Rolker, 2000) or scenario (Christofzik & Reuter, 2013).

As already mentioned, in emergency management, decisions have an extensive impact. They are based on incremental information from on-site reports and messages. Especially the forces need to make decisions "under conditions of incomplete or inaccurate information in a context of changing and possibly ambiguous hazard consequences and response objectives […] under considerable time pressure" (Paton, 2003). Bharosa et al., (2009) showed that, during exercises, Commando Place Incident Team (COPI) leaders spent on average "30 min or more collecting information and directing the operations of their own agency, followed by a 15-min interaction with other COPI members". Lundberg and Asplund (2011) analyzed groups involved in regional and international operations, with regard to the flow and exchange of information and communication and found that these organizations mistrust their IT systems or do not accept them, because they do not want to pay for training as well as the proper equipment. To assure trust, acceptance and a safe handling of the systems, the systems should be used in the everyday work, not just in emergencies (Kyng et al., 2006). Further problems exist in the area of situation awareness. The lack of communicating task-oriented, dynamic information and the related information overload lead to serious problems during the response phase (Prasanna et al., 2011). Further on, in collaborative environments, the different roles and expertise of group members make sense making even more challenging, because group members do not only need to understand task-related information but also need to comprehend the relative relevance of the information available (Paul & Reddy, 2010). Other occurring problems concern the finding of a correct recipient, unclear channels of communication (Ley et al., 2012a), time-consuming, ineffective forms of messages (Lundberg & Asplund, 2011) and different interpretations of used terminologies (Reuter, Pipek, et al., 2012). Some of the problems could be solved by appropriate communication technologies albeit the main challenge is to articulate the individual information need in an easy way.

Information technology can support articulation work (Schmidt & Bannon, 1992). Currently, radio is the most important communication technology for emergency services in Germany. The digital radio, which is presently being introduced, makes it possible to use a single shared nationwide network, which creates new forms of communication. In contrast to analogue, the digital radio enables to transmit data on a narrow-band, but the rate is limited to 3 kbit/s, which does not allow transmitting much data, like multimedia. Based on empirical studies

Guerrero et al. (2006) and Peng et al. (2007) developed conception frameworks, which determine appropriate devices besides digital radio for certain cooperation contexts. Both frameworks deem tablet PCs and PDAs as the most suitable in terms of mobility. Since the frameworks release, smartphones and tablets have become more popular and powerful and combine the performance of PDAs with the multimedia support of mobile phones, where the integrated sensors will be extended in the future (Gomez & Bartolacci, 2011). Both, smartphones and tablets meet the requirements of everyday using and are fundamental elements of CSCW technology for mobile workers (Tamaru et al., 2005). Besides the devices, the growing range of mobile technologies such as LTE creates new possibilities for transmitting big amounts of data.

Various approaches already focus on supporting cooperation with the additional help of mobile devices. There officers-in-charge are information providers and consumers, whereas units on-site are primarily information providers (Nilsson & Stølen, 2010). The officers-in-charge, either on-site or in the control center, are mainly decision makers, whose decisions result in actions performed by on-site units. Büscher and Mogensen (2007) present different prototypes to enable command centers capturing live information about on-site movements and situation assessment in order to be able to construct a better situation overview without having to disturb on-site units via verbal communication. Catarci et al. (2010) present a system, in which each on-site unit uses a PDA that was supervised by a process management system, which orchestrates the units and conducts external data services. The mobile devices are able to receive tasks, to add comments to captured pictures and videos, to share these and to display them on a map application. Another more content-oriented concept was introduced by Singh and Ableiter (2009). Their application *TwiddleNet* makes it possible to send and receive multimedia data, where the smartphones took on the dual-role of a server and a client. These data are available as a feed and are accessible via pull or push service. Those applications, which allow almost real-time reports, including multimedia data with location information, are able to increase situation awareness (Betts et al., 2005).

Bergstrand and Landgren (2011) analyzed the communication impact of live videos from the incident place to the control center and found that the videos improved situation assessment in the control center enormously. Due to the bottom-up flow of communication, the on-site units provided information driven by their own motivation or previous radio transmission, which led to problems with prioritization: "*When you decide to use the camera, you also decide not to do other things*" (Incident Commander in Bergstrand & Landgren, 2011). Wu et al. (2011) presented, in contrast to Bergstrand and Landgren (2011), a 2-way system including top-down communication, which is based on CIVIL, a mobile application allowing up- and downloading geo-referenced data. Professionals as well as citizens can use the application, which means that citizens become an active part of crisis management. Problems arose due to the amount of data, because a majority of the pictures caused an overloaded map application. A suggested solution was a picture cluster, but the question remains of "how to choose a representative photo to describe the entire group of pictures" (Wu et al., 2011). Such a similar problem arose while using the application *diretto* (Erb et al., 2011), which allows transferring images and other formats to a previously asked query. The system *Ushahidi* (Okolloh, 2009) has a similar approach, but without previously asked questions. An application which is aimed at supporting collaborative situation awareness and decision making in the specialized case of a chemical industrial accident is *DIADEM* (Winterboer et al., 2011). With DIADEM,

the control center can ask selected agents to take pictures, which are automatically geo-tagged and displayed on a digital map in the control center.

Most approaches pursue a kind of push mechanism, where the information is received in the form of notifications and the recipient has no option to articulate the information need or to specify the needed format. Apart from problems that occur with voice transmission (Schöning et al., 2009), Bergstrand and Landgren (2011) showed that – despite possible enhancements of situation awareness – already available photos from on-site response teams are not regularly used. Therefore, decision makers should have the possibility to improvise and articulate their individual information needs in an appropriated way. Prototypes of Büscher and Mogensen (2007) allow pulling information in an appropriate way, but these do not address directly improvisational activities and try to substitute verbal requests. Other existing systems (Catarci et al., 2010; Winterboer et al., 2011) allow to request information, where these requests are often merely text messages and the decision makers have no option to articulate or specify their information needs and formats in a further dynamic, fine-grained, but still simple way.

Taking the existing reporting practice and existing approaches into account the research question of this paper is: How should emergency services articulate their information needs and how can mobile applications support articulation work in emergencies? The following empirical study will explore mobile collaboration practices of emergency services, as well as possible means to support these practices via mobile devices and applications.

9.3 Research Field

The findings and the concept in this paper are derived from a study focusing on collaboration, situation assessment and decision-making practices during coping and recovery work at emergency response agencies in Germany. The study was conducted in two regions. County A is a densely wooded, hilly and rural county, whereas county B consists of 10 growing and urban communes. In both regions, we focus on several organizations affected: Infrastructure suppliers (e.g. power supplier), public strategic administration (e.g. crisis management, county administration), public operative administration (e.g. police, fire department) and citizens. The organization of police and fire fighter forces differ among the counties: County B provides professionals, whereas fire fighters of county A are mostly members of voluntary fire departments. Here, just members of the control center have salaried positions.

9.4 Empirical Study

The basis for the data analysis was the result of various empirical works during the years 2010 to 2012 in the application field. The studies were embedded in a scenario framework, which was developed together with actors from police and fire department, county administration and an electricity provider. It includes a windstorm with many incidents and energy breakdowns. The purpose of the scenario was to be able to quickly create a common understanding of an occurring emergency and therefore it helped to increase the validity and comparability in our interviews. We conducted five inter-organizational group discussions, each lasted about 4 hours. The aim of the group discussions was to understand communication practice of inter-organizational crisis management. Furthermore, we conducted 22 individual interviews with actors from the participating organizations (Table 28). Each interview lasted between 1 and 2

hours and followed a guideline, which was separated into three parts. The first part focused on the participants' role, qualification, tasks and work activities under normal conditions. The second part covered the participants' tasks during emergencies in our developed scenario framework. The third part covered applied information and communication systems and perceived problems with these tools. Group discussions and interviews were audio recorded and later transcribed for subsequent data analysis.

No.	County	Organization	Role	Control center	On-site leader	On -site other
I01	A	Administration	Regulatory Authority	X	X	
I02	A	Police	Head of Control Center	X	X	
I03	A	Police	Head of Section	X	X	
I04	A	Police	Patrol Duty			X
I05	A	Fire Department	District Fire Chief	X		
I06	A	Fire Department	Deputy Head of Control Center	X		
I07	A	Fire Department	Workmanship			X
I24	A	Fire Department	Head of Control Center	X		
I08	B	Administration	Office Civil Protection	X		
I09	B	Fire Department	Chief Officer / Chief of Fire Dept.	X		
I10	B	Fire Department	Operation Controllers		X	
I11	B	Fire Department	Clerical Grade Watch Department			X
I12	B	Fire Department	Control Center Dispatcher	X		
I13	B	Fire Department	Head of Control Center	X	X	
I14	B	Police	Member of the Permanent Staff	X		
I15	B	Police	Head of Control Center	X		
I16	B	Police	Head of Group		X	
I18	both	ENO	Higher Area, High Voltage	X		
I19	both	ENO	Operation Engineer, High Voltage		X	
I20	both	ENO	Operation Technician, Low Voltage		X	
I21	both	ENO	Dispatcher, Low Voltage	X		
I22	both	ENO	Workmanship Technical Incidents		X	

Table 28: Interviewees of the empirical study (phase 1): information and collaborative practices

No.	County	Organization	Role	Control center	On-site leader	On-site other
IM01	A	Police	Head of Control Center	X	X	
IM02	A	Fire Department	Administrator of the Control Center	X	X	
IM03	A	Fire Department	Control Center Data Support / Digital Radio Coordinator	X	X	X
IM04	A	Police	Head of Police Station		X	
IM05	B	Fire Department	Department Chief Control Center	X	X	X

Table 29: Interviewees of the empirical study (phase 2): mobile collaboration practices

The empirical study showed that, especially in police and fire departments, decision makers depend on on-site information to be able to make appropriate decisions. Therefore, the organizations of the second empirical phase in 2012, which researches the effects of dynamic information requests and their fine-grained specifications to create a high qualitative base for making decisions, were fire and police department with their different management and lead

structures. The police coordinate operations directly from the control center *("lead from the behind"*), in the fire department, however, the officer-in-charge is on-site and the control center only supports him *("lead from the front"*). To be able to study the mobile collaboration practices more closely, additional five partially structured interviews were conducted in 2012 which lasted in average 60 minutes, in which the current practices were analyzed, also in regards to the creation, exchange and use of information by the response teams and the works in the control center (Table 29).

In the following, the empirical results concerning the information and communication practices and the articulation of information needs are presented.

9.4.1 Information and Communication Practices

Emergency management requires making decisions in-situ based on current conditions. Hence, it is necessary to keep track of the occurrences. Some of the information, which is used for the work tasks in operations management, is provided by "official" information systems. In major catastrophic events or in case of weather alerts these internal information resources are enriched by many external, *informal information resources*, which are necessary in various situations. Many actors individually collect supplementary information from various sources (e.g. the current weather condition outside the building, phone calls or webcams that are focused against the wind direction) to obtain a better overview of the situation: *"You need as much information as possible"* (I24). Or: *"I need verified information for a decision about a particular situation"* (I05), which needs to be *"as detailed and accurate as possible to give an exact representation of the situation"* (I06). Nevertheless, information from own personnel is judged as being very valuable. The heads of control centers (I01, I09) mentioned that visual on-site impressions are crucial, because if you *"explain to someone that there is an accident with 300 injured people, both of us have a very different imagination of the situation"* (I09). Therefore, *"the most reliable information is what I have seen myself"* (I05), where the difficulty exists *"that we can't look through the phone and we don't see how it looks like on-site" (*I06). The response team on-site already knows, that it can be important to send visual data to the control center, because *"if you've seen it yourself, you have a better overview of the situation"* (I10). Currently verbal communication is executed via radio. In the control center *"the flood of communication kills us in our daily work"* (I03), where the permanent risk of *"being overloaded by information"* (I03) exists, that *"in the end you don't understand what's going on anymore, because there is too much input and you can't handle the information"* (I03). On the other side, the on-site team complains about having not enough information: *"It would be great to have more information on-site"* (I07), because currently *"the office-in-charge wants something done and then we have to understand what he means"* (I07).

The information demand is very subjective: *"What we need in order to be able to make a decision varies from individual to individual"* (I03) and cannot be specified in advance. Nevertheless, all agents agreed that particular criteria need to be met: (a) The emergency work is based on situation maps, therefore *"the necessary GPS coordinates need to be included, so that you know the location the information comes from and don't have to guess"* (IM05). (b) Sending and receiving information in different data formats is desirable (I05), while pictures and videos are seen as most relevant (IM04) and long text messages critical (IM03). (c) It is necessary that it is visible which user took the picture (IM03) and that (d) the information is

time-stamped (IM01). The information between the control center and on-site units' needs to be 100% synchronized (IM05), because *"during an operation there is nothing worse than talking about different things"* (IM05).

When communicating no unit in the hierarchical structure may be left out, even if it means a larger amount of time (IM01), for example, a sub section leader will always communicate only with his section leader and not directly with the head of operations (IM01). The control center always communicates at the level of section leaders (IM01), where information from the section leader does not need to be evaluated and can be used immediately (IM01). Involving citizen-generated information into crisis management is seen critical: *"Someone who does not have a background in emergency services would hardly be able to deliver necessary information in such a situation"* (I02). Sending pictures by citizens *"will get out of control if everyone takes pictures. [...] If you've had an accident or anything else happened to you, you wouldn't want a stranger to take pictures"* (I01). Of course scenarios exist where citizen-generated information might be useful and could contribute to situational awareness (Vieweg et al., 2010), but due to the interviewees mentioned that applications for supporting direct communication should only be available to emergency services, we blanked out the dimension of citizen-generated information in our paper.

9.4.2 Articulation of Information Needs

A wide range of emergency response actions show that situation assessment is often a collaborative task. To deal with the uncertain and changing environment during emergencies, usually a big number of people are involved in gathering or analyzing data, decision making and monitoring of implementations and consequences. However, in order to articulate information needs, infrastructures are needed. Independent from knowledge about both frameworks for selecting devices for specific contexts (Guerrero et al., 2006; Peng et al., 2007) the interviewees confirmed: "*if we're talking about an ideal situation, then I have a smartphone in my patrol car and the officer-in-charge uses a different device that gives him even more functionality"* (IM04). Right now the communication path is still via radio, but smartphones are already used for purposes like using Google Maps for satellite views or navigation (I04), because the control center gives an address and the on-site team often does not know the exact location. Moreover, mobile devices are not only interesting for the on-site units, but also for the actors in the control center since they are not present 24/7 so that they have mobile access to information (I13). The participants asked for a simple and easy-to-use hardware *"with as few features as possible, so that a unit, who has never used it before, can be trained quickly"* (IM04) and it *should* be used almost daily to establish routines (I06). An important feature is to be able to take videos or photos quickly and record voice data and write short messages all without using a pen (IM03). The hardware needs to be quickly ready for use, *"if we need to boot an additional notebook, then it won't be used"* (I04).

Usually the on-site teams are responsible to deliver relevant information, so information is provided via push mechanisms. This practice has some disadvantages. One problem also occurred during our interviews: On-site teams often do not know which information they have to transmit or they prioritize outgoing reports very low, especially volunteer forces (IM01, IM02). Therefore the current control center practice is to request information from the incident place actively (pull mechanism) and to not wait for appropriate reports. By requesting information actively, it is possible to prevent that *"everybody just takes pictures and sends*

them back, without really knowing what is going on" (IM05). During the dynamic requests for information, the return format of information often needs to be specified (IM04). In case of such requests, the control center *"should see the location of a unit and instruct him to take a picture"* (IM02). Currently the determination of the units' locations only works verbally via radio: *"I take my radio and contact him: Where are you? At best he will answer: I'm here or there"* (IM05). *"Ideally, besides the location, you see whether the unit is busy or not"* (I03). These articulations currently take a lot of time. Therefore the forces mentioned that, based on the location, there should be an option to navigate units remotely: *"If I see their locations and also the plans on a map, I could say: "Go five meters further, that's where the next hydrant should be"* (IM02). Due to the high dynamics and improvisation within response teams, people can be spontaneously assigned to new roles. Therefore, requests need to be always assigned to roles, never to persons (IM01, IM03). Besides the influences from an incident itself, *organizational factors* and structures can bear unpredictable challenges. That is why each actor will have to be able to divert from given routines to be capable of acting even if the given structures and circumstances change: *"If a system is strongly rigid and structured, and then one component is missing, mostly the whole system will collapse. For this, informal acting can be helpful" (*I01).

9.5 A Semi-Structured Mobile Reporting Concept

Decision making in crisis management depends on incremental written or mostly verbal on-site reports. The empirical results on current practices of emergency services show a need for improvisational action in order to get appropriate reports. Information producers in the form of on-site units are not always able to anticipate the needs of their counterparts in the control centers, so arising information overload or lack of information negatively affect decisions.

Control centers are mainly interested in impressions from the incident place supported by visual multimedia data to get remotely a situation overview. The cycle of semi-structured information requests and reports (Figure 19) visualizes the concept grounded on the empirically studied work practice. If the written or verbal on-site reports do not satisfy their needs, the control center needs to have the option to actively articulate information needs. Currently this dynamic requesting activity is not supported: Using the radio verbally, the control center complains about being flooded with information and the on-site units are left with much space for interpretations: *"The office-in-charge wants something done and then we have to understand what it means"* (I07). Therefore a mechanism which allows semi-structured information requests and does not leave space for interpretations could support their cooperation. Due to the fact that information needs vary from individual to individual, reports should be easy to specify for each user, and some context information always needs to be captured automatically: the coordinates of the location, the source and the time, which identify the information as a whole (IM03). These context data need to be available when looking at the information. By requesting or reporting information, the predefined hierarchical organizational structure has to be considered, for example, the sub section leader is not allowed to send information to the control center directly, because otherwise the section leader is skipped. On the other hand, the control center is not allowed to request information from the sub section leader directly, because otherwise the section leader is skipped again.

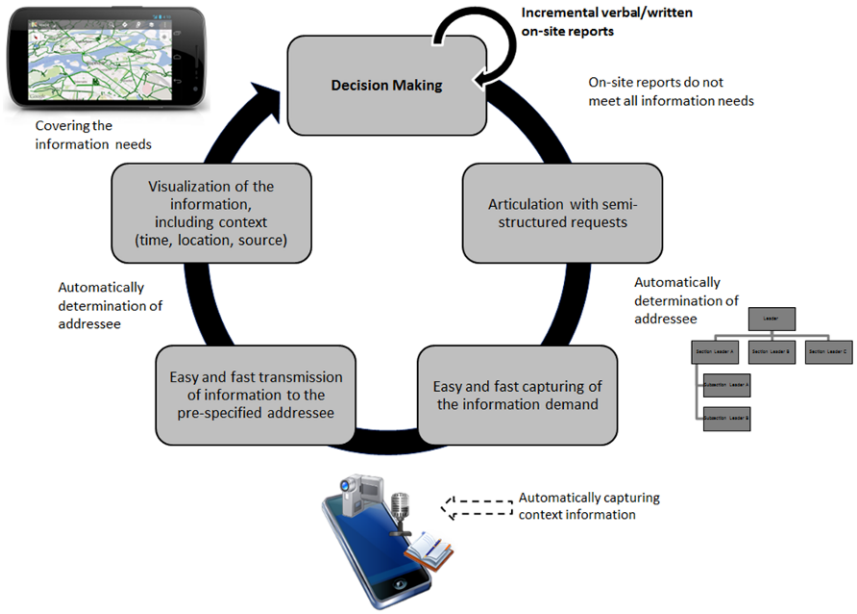

Figure 19: Supporting decision making through mobile semi-structured information requests

Determining addressees of requests needs to be possible by its location or role: Location-based requests give a location overview on all subordinates of which information can be requested, which enriches the awareness between the control center and the on-site units. For role-based requests the addressee can be determined by its role (e.g. *sub section leader area 1)*. A supportive mechanism must be applied to smartphones as well as tablets to guarantee a proficient handling including following rights:

- *Requesting information* allows a response unit to fine-specify and articulate the kind of information needed. At this, transmitting a destination location for a remote-navigation of the unit and setting the priority for a more appropriate assessment of the task's urgency must be possible.
- The *independent sending of information* allows authorized units to send information, directly, without previous requests. For instance, this permission is relevant for section leaders, as their information does not have to be authorized anymore.
- *Sending information by previous request* allows a unit to send information by himself, but only as an answer to a previous request. This restriction should help to avoid information overload for decision makers due to information needs to be requested first.

9.6 Implementation of a Mobile Reporting Application (MoRep)

In order to verify the concept and research its effect we implemented a mobile application. By using Android 4 the application MoRep can be used on smartphones as well as tablets. The technical concept is based on REST* architecture as form of the SOA-paradigm, where the services are implemented by HTTP-servlets. Using modern communication technologies, such as Google Cloud Messaging, innovative notification mechanisms are implemented that simplify communication and allow a parallel use to radio communication. In the following, the application MoRep will be briefly introduced.

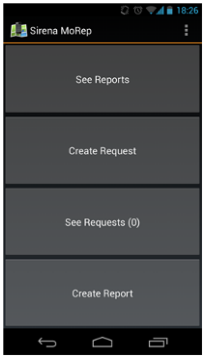

Figure 20: Main screen

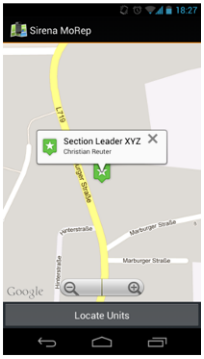

Figure 21: Localizing the response units

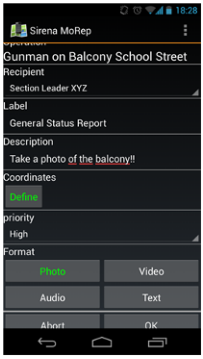

Figure 22: Request form

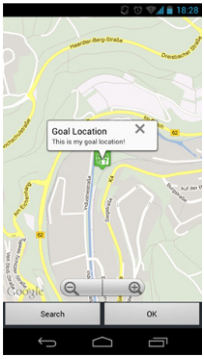

Figure 23: Determining the location

Start up: After authentication, the user receives current information of his role and permissions. The main screen is designed according to these permissions. Figure 20 shows a user with all rights: Seeing reports, requesting reports from subordinates, answering requests made by superior as well as writing reports independent from previously request.

Requesting reports: When requesting reports, a location- and role-based determination of onsite units is possible. By the first option, the user can scan for subordinate response units (Figure 21), where the unit is displayed on the map characterized by role and name. By selecting the unit, the request form is opened (Figure 22). There the user has to enter specified characteristics and the desired format of a report. He has the option to define a destination location for the remote navigation (Figure 23). Afterwards the request can be sent. For role-based requests the recipient can be chosen from a combo box, where all the possible recipients are listed, from whom information can be requested, no matter what their location is.

* Representational state transfer (REST) is a style of software architecture for distributed systems such as the World Wide Web.

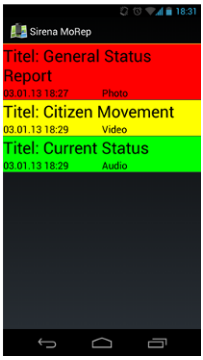

Figure 24: Request overview

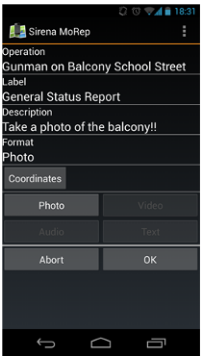

Figure 25: Report on request (I)

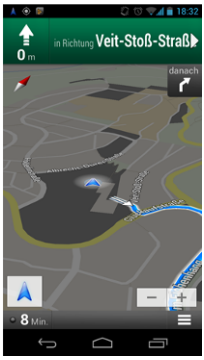

Figure 26: Target navigation

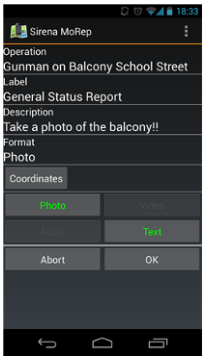

Figure 27: Report on request (II)

See requests / creating report: In the request overview (Figure 24) open requests are displayed for the user sorted by priority and time. A request can directly be answered with a report, where a form (Figure 25) appears, in which the text fields have already been predetermined by the creator of the request. If a target location was transmitted, the coordinates-button will be shown that offers the possibility of navigating to that location (Figure 26). By entering the format button, the standard application for generating files is opened; subsequent the text button is activated to make an optional text input (Figure 27). A report that is not based on a request can also be created from the main screen. In that form the recipient is immediately determined as the next superior unit.

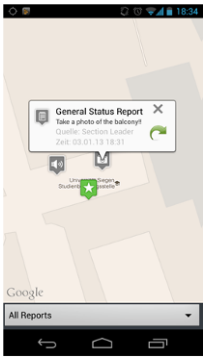

Figure 28: See reports

Figure 29: Content of report

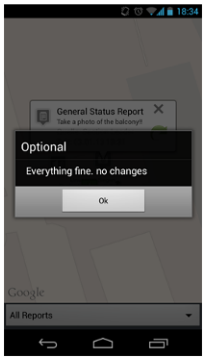

Figure 30: Additional text

See reports: The main element is a Google Maps map (Figure 28), on which previously created reports are shown with icons that indicate the data format. The user can view all reports or only those he requested. It is also possible to add this view to any Geographical Information System using Web Map Services. In the information window the source and time are displayed that, in combination with the geo-location, meet the criteria specified for suitable information (IM05). If it is entered, the content will show (Figure 29).The text symbol on the

left side of the window indicates an additional text (Figure 30) the arrow symbol creates an easy forwarding of information to the superior.

9.7 Evaluation of MoRep

Although our system had been fully implemented, IT security regulations and privacy and documentation concerns of the emergency response organizations prevented us from having an in-use evaluation. We evaluated with practitioners in police and fire stations how mobile dynamic semi-structured requests can support current decision processes by providing a high-quality information basis and avoiding information overload as well as lack of information. In order to evaluate the findings, concepts and our supporting tool related to the work practices we evaluated the prototype in a scenario-based walkthrough and following interviews. Again the participants were members of the police and fire department, but this time also volunteer emergency forces were included, due to these are potential end-users as well (IM01, IM02). The evaluation sessions lasted in average 45 minutes and eleven persons from police and (professional and volunteer) fire departments participated in different sessions. With this selection of interview partners the impressions and experiences of communication partners on different levels within the chain of command could be gathered and evaluated.

No.	County	Organization	Role	Control center	On-site leader	On-site other
EM06	A	Police	Head of Control Center	X		
EM07	A	Police	Head of Section	X	X	
EM08	A	Police	Head of Section		X	X
EM09	A	Police	Executive Staff			X
EM10	A	Police	Executive Staff			X
EM11	A	Fire Department	Fire Chief, Administrator Control Center	X	X	
EM12	A	Fire Department	Municipal Fire Inspector		X	
EM13	A	Fire Department	Volunteer Fire Chief		X	
EM14	A	Fire Department	Volunteer Workmanship			X
EM15	A	Fire Department	Volunteer Workmanship			X
EM16	A	Fire Department	Volunteer Workmanship			X

Table 30: Interviewees of the empirical study (phase 3): evaluation of MoRep

Within each evaluation MoRep was introduced functionally and it was demonstrated how it could support in different situations by referring to operations mentioned by the interviewees in the empirical study. The demonstration was an interactive session, where the users directly explored the application. The participants were asked to make remarks using *thinking aloud* (Nielsen, 1993). After the demonstration, the participants were asked questions regarding the practice-oriented use, e.g.: What are possible implications of using semi-structured requests in emergency response? Under what conditions can the concept and application support current working practices? What are limitations concerning the usage? The workshops were recorded and later transcribed.

Figure 31: Evaluation of the mobile application in the fire department

Using our design we were able to derive the impact of mobile dynamic semi-structured requests on improvisation work practices of decision makers and on-site units.

9.7.1 Extending Articulation Work with Semi-Structured Mobile Requests

The concept of semi-specified mobile reports as a consequence of dynamic, semi-structured information requests cannot cover major emergencies over their entire time, but it can easily be used for "*basic information and a common understanding of the situation*" (EM08). In contrast to phone calls, it is an additional way of communication and articulation, which can enrich reports with visual data (EM09). The mechanism of fine-specifying and requesting report demands was seen as very useful in case of insufficient reports. Therefore the decision makers have the option to enhance the routine reporting structure and informally request information. The on-site units have the duty to answer those requests (IM04). Requesting information by the units' localization as well as their role were important aspects to establish awareness between the spatially distributed units and to get an overview of the situation assignment of the units (EM07). By being able to determine units by their role was regarded as stress reducing, because the actors did not have to think about the correct addressee (EM08). Another important feature of applications that support the communication between on-site units and the control center is the fast transmitting and forwarding of information. Being able to forward information to the superior was regarded as being one of the most important functionalities, which enriches the entire information flow (EM06, EM08).

9.7.2 Improving Situation Awareness through Semi-Structured Requests

The handling of semi-structured information requests as one of the core concepts has two supportive dimensions: First, it supports local volunteer fire fighters that indeed know the location of the incident place, but do not necessarily have the experience in judging the importance of information for the control center respectively the officer-in-charge and which information needs to be reported (EM06). Therefore semi-structured information requests

provide and foster training effects. Second, semi-structured information requests support professional units from other counties, who assess the importance of information better than volunteer units do, but who often – especially in large-scale emergencies – do not know the location. Therefore, the requests foster situational awareness of the units. For example, the head of the studied police station mentioned that they will have new recruits starting very soon and the majority of them are not familiar with the region. Thus, they will use their smartphones to navigate which is why transmitting locations is very important (EM06). They are already using GoogleMaps on private smartphones (EM10), wherefore "*introducing something different makes no sense, because everyone knows and uses GoogleMaps and it is up to date*" (EM11).

9.7.3 Taking Organizational Specifics and Improvisational Practice into Account

The different leading structures of the police ("*from the behind*") and the fire department ("*from the front*") have an important impact on using the concept in the work practices during emergencies. At the police department, the control center has the entire responsibility for an operation. For this purpose it maintains software, which manages the included actors and their dynamically assigned roles. Through this matching they have always an overview of the command and reporting flow (EM06), wherefore an automatic connection between those control center systems and the mobile applications could easily be implemented to guarantee up-to-date role assignments and correct command- and reporting flows in the applications like MoRep. In contrast to the police departments, the fire departments in our study do not maintain such software systems. The officer-in-charge on-site has the entire responsibility for an operation and the control center has just supportive task to the officer-in-charge. The control center has the problem "*if I send him coordinates, then it is a process, where I directly influence the operation and you need to decide if that makes sense and on which level you have the permission to do that"* (EM11). It's not the control center, but the officer-in-charge would use such mobile systems to support the communication between the on-site units, because he stays at a location while the other units are distributed around the incident site (EM11).

9.7.4 Enhancing Debriefing with Multimedia-Based Documentation

After an emergency the automatically saved requests and transmitted information can be used for the documentation *"where I need the timestamp and the content what happened. Right now there is no standard"* (IM03). This documentation could be the basis for debriefing of the past operations: *"Currently we use Internet videos of photographers and information of journalists from the incident place for debriefing afterwards"* (EM11), because, except written reports, no other data for documentation or training exist.

9.7.5 Predefined Communication Path vs. Improvisation Work

Even though it was mentioned as very useful, that communication paths are predefined by the application, there were still doubts whether the on-site units will utilize this feature (EM07). Through the predefined command and reporting structure the concept is currently too static to cover all improvisational activities during emergencies. While on the one hand the hierarchy of the police could be easily adapted to the mobile applications, on the other hand, there are still open issues and a need for action to the technical implementation and to maintain the

actuality of the organizational structure of the fire department. But all participants were aware that mobile applications like MoRep only *"support an additional way of communication and that in case of emergencies you can still make a call"* (EM09), to guarantee options for high-flexible extensive improvisation activities.

9.8 Discussion and Conclusion

In emergencies, gathering the necessary information to generate a situation overview is crucial for emergency services to make informed decisions. The interplay between control centers and on-site units is an important information chain that is shaped by legal regulations (e.g. on notification and documentation duties) and professional conventions (e.g. reporting agreements). But in crises, the routines connected with these regulations and conventions do not cover all information needs: Situational aspects connected with the crisis require stakeholders to improvise and to engage in articulation work about information needs and resources that emerge as the crisis goes on.

There has been previous research on the technical support of response units on-site to share reports with control centers including multimedia data. But in some situations those reports were ignored (Bergstrand & Landgren, 2011) or disregarded, simply due to the sheer amount of incoming notifications (Wu et al., 2011). Applications such as DIADEM (Winterboer et al., 2011) or diretto (Erb et al., 2011) enabled the control centers to actively articulate information needs and request needed information. The requests were described by short text messages, which still left plenty of room for misunderstandings as with voice transmission.

In this paper, we explore the practice and necessities of articulation work with regard to the ad hoc gathering of information in emergencies, and suggest and evaluate an interaction concept involving semi-structured multimedia reports. In our empirical study on current work practices of emergency services with regard to collaboration in situation assessment and decision-making activities, we could establish that the spontaneity and volatility of emerging information needs on all sides pose a significant challenge to communicate them accurately as well as to provide accurate feedback. Existing practices show that, in order to cope with requirements like time-criticalness of feedback or reliability of information, a set of framing conditions needs to be addressed when developing technological support:

- *Targeted requests:* The missing information in a decision situation is often very specific to a location, a critical infrastructure or another situational aspect. These specifics of information needs have to be articulated and understood.
- *Trusted reports:* Decisions in the control center may affect lives of crisis victims and may have legal consequences. Therefore, staff members require high quality information for the specific decision in situ, which cannot be secured in terms of technical information quality only, but also in terms of trust, which is established through the professional expertise of the source creating the information.
- *Documented action:* To enable debriefing and provide material for training purposes the requests as well as the reports have to be documented.

It is important to note that these framing conditions may lead to conflicting information quality requirements in a concrete situation: The faster reports may come from an information source with a lower expertise, and the report from a trusted information source may not be available fast enough to inform the decision-maker at hand. As a result, not only time, loca-

tion and content type of information are important metadata for requests as well as report interactions allowing an easy interpretation and assessment of the content, but also role, contact data, location and experience of the person providing the feedback. Documentation and interpretation needs may be addressed by establishing a content structure for request and report messages that relates to professional signs and languages of the emergency response service and that allows free comments. The interpretation of information in the context of a specific decision may turn out to be a collaborative effort requiring additional interactions.

We developed, implemented and evaluated an interaction concept using semi-structured request and reports based on Android devices, and allowing location-triggered as well as role-triggered interactions (MoRep). The feedback we got from practitioners using the prototype confirmed that the suggested content and metadata structures would improve the expected information accuracy and quality. But it also revealed further side aspects of organizing this interaction, for instance the material that would be gathered may help improving debriefing processes and educational initiatives.

In particular, the organizational structures and coordination strategies influence information needs and interaction details. In some cases it is required to delegate and forward information requests to people who are even closer to the site of interest in a documented, traceable way. The police with their "*leading from behind*" coordination strategy has a more static role and responsibility structure and the direction of the main information flow is towards the control center, whereas fire fighters with their "leading from the front" coordination strategy have changing roles and responsibilities on-site, and an information flow directed mainly to the on-site coordination. Request and report strategies of our prototype need to adapt to these differences by maintaining the organizational and information structure. In the long run, these predefined information structures also carry a notion of potential information needs to all forces involved in the interactions and may also raise the general awareness on information necessities.

Our research efforts described here are part of a larger research initiative to improve the *collaborative resilience* (B. E. Goldstein, 2011) of and in critical infrastructures. In contrast to many crisis management approaches in the field of IS and HCI, we do not aim to further capture and refine holistic process representations or to extend sensor data collection and visualization to be better prepared for crises, but rather to improve improvisation capacities in crises by addressing smaller ad hoc collaborations we found to be important to practitioners. We believe to have found an interesting one here, and would now further explore its integration into new emerging technological and organizational infrastructures like the German emergency service digital radio network (*BOS-Digitalfunk*) or recent inter-organizational infrastructures for coordinating regional crisis management work (Ley et al., 2012a).

10 Perspective: Integrating Real and Virtual Emergent Volunteers (ISCRAM/WI)

Recent studies have called attention to the improvement of *collaborative resilience* by fostering the collaboration potentials of public and private stakeholders during disasters. With our research we consider real and virtual volunteers in order to detect conditions for cooperation among those citizen groups through social media. Therefore we analyzed the usage of Twitter during a tornado crisis to look for role patterns and aspects that helped volunteer groups in the virtual to emerge, and matched the data with an interview study on experiences, attitudes, concerns and potentials professional emergency services recounted in the emergence of volunteer groups in the real. While virtual groups seem to easily form and collaborate, the engagement of real volunteers is decreasing according to the perception of professionals. We discuss the dynamics in both tendencies and suggest design implications (use of existing social networks, promotion and awareness, connection among volunteers, connection to emergency services and systems) to support both types of volunteer groups, which lead to a software prototype.*

10.1 Introduction

Disasters such as the Indian Ocean tsunami 2004, the Japanese earthquake and tsunami 2011 or the Hurricanes Katrina 2005 and Sandy 2012, but also smaller events, require public authorities and relevant organizations to engage in urgent and lifesaving actions very fast and effectively. This requires resources that are only available if people who are not part of the official crisis management initiatives - these are especially the citizens affected - can help themselves. “Collaboration between the private and public sectors could improve the ability of a community to prepare for, respond to, and recover from disasters” (Board on Earth Sciences and Resources, 2011). This ability is called *collaborative resilience* (B. E. Goldstein, 2011) and the great challenge is to establish reliable cooperation patterns between heterogeneous stakeholder groups like police, fire-fighters, infrastructure operators, public administration and the (affected) citizens that sustain even in disasters. Stallings & Quarantelli (1985) define those volunteers or *emergent groups* as “private citizens who work together in pursuit of collective goals relevant to actual or potential disasters but whose organization has not yet become institutionalized”. According to the crisis communication matrix, mainly volunteers represent the communication among the public (Reuter, Marx, et al., 2011a). The essential influencing factors for their emergence are (a) an extra community setting, which legitimizes the group; (b) a crucial event, which is perceived as a threat; (c) a supportive social climate

[*] This chapter has been published as a full paper (Reuter, Heger & Pipek, 2013):

Reuter, C., Heger, O., & Pipek, V. (2013). Combining Real and Virtual Volunteers through Social Media. In T. Comes, F. Fiedrich, S. Fortier, J. Geldermann, & L. Yang (Eds.), *Proceedings of the Information Systems for Crisis Response and Management* (ISCRAM). Baden-Baden, Germany.

Earlier and shorter versions of this paper have also been published in the *Proceedings of the International Conference on Wirtschaftsinformatik* (Heger & Reuter, 2013) and the *Workshop-Proceedings of the International Conference on Computer-Supported Cooperative Work* (Reuter, Heger, et al., 2012).

C. Reuter, *Emergent Collaboration Infrastructures,*
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with positive values, norms and beliefs regarding the necessity of collaborative actions; (d) an existing social network, so that communication can take place; and (e) available resources such as information, knowledge or skills (Quarantelli, 1984). Contrary to myths, citizens of affected areas seldom panic, are not helpless or dependent on external rescuers and do not loot (Helsloot & Ruitenberg, 2004). Mostly, they are even the first to care for victims and to conduct search and rescue activities. The primary motivation for volunteering in such an group is a "compelling need to help in some way, particularly a need to assist victims, and a desire – even obsession – to 'do something' in order to contribute something positive and find something meaningful in the midst of a disaster" (Lowe & Fothergill, 2003). About 30 years ago Quarantelli (1984) identified three different groups: an active core (~1%); a larger supporting circle for specific tasks (~10%); and a great number of primarily nominal supporters who occasionally assist (~90%). The constantly changing environment due to the crisis situation results in "unstable task definitions and flexible task assignments, fleeting membership, and pursuit of multiple simultaneous, possibly conflicting purposes" (Majchrzak et al. 2007). Emergent volunteers have to operate in a permanently changing environment. Activities, which happen simultaneously, depend on or should not interfere with each other, have to be coordinated under time pressure (Petrescu-Prahova & Butts, 2008). For that, intensive communication between the group members is needed. The evolution of social software established infrastructures for virtual collaboration, which enable emergent activities during crises in different ways and may influence established behaviors (Palen & Liu, 2007).

As it is common to distinguish between real and virtual communities, a distinction within volunteer groups seems reasonable: Virtual volunteer groups originate in the Internet and mainly carry out their activities online. The analogous term *digital volunteers* (Starbird & Palen, 2011) is described as people with "new behaviors of mass interaction that ICT enables". Real volunteer groups fight against the effects of a crisis locally and may appear in the form of neighborly help. They may use the Internet as a potential supportive resource among many others. Of course, those groups can and often do overlap. The literature explores emergent volunteer groups from the real (e.g. Dynes, 2006; Stallings & Quarantelli, 1985) as well as from the virtual (e.g. Palen & Liu, 2007) perspective. While virtual volunteers may be located anywhere and thus can help through digital contributions, real volunteers are always onsite. So far, a combined view of those groups for detecting possibilities for cooperation and of fostering collaborative resilience has rarely been considered in research.

10.2 Research Outline

Our work aims to combine the views on virtual and real emergent volunteer groups in order to detect conditions for cooperation and synergies through social software. Therefore our research question is: How can social media support the cooperation between virtual and real emergent volunteer groups?

Firstly, we will focus on virtual activities by studying related work about social media use by volunteers in crises and by empirically analyzing the usage of Twitter during a tornado crisis in the USA in April 2011. We chose an event, which took place in the US because of the country's already widespread use of social media and especially Twitter. Our study aims to extend research of virtual volunteer groups by illustrating temporal developments and, building on this, by categorizing different types of user behavior. These factors are of interest in

order to search for possible combinations and overlapping features. Secondly, we will focus on real volunteer activities. After presenting related work on volunteers in emergencies we will describe the results of our study based on interviews with emergency services. In doing so, we intend to research how they perceive emergent volunteer groups and whether points of intersection can be created for a close cooperation between these groups. Subsequently we discuss our findings on which software-based support potentials can be identified, present the preliminary results of the evaluation of our prototype and summarize the most important results.

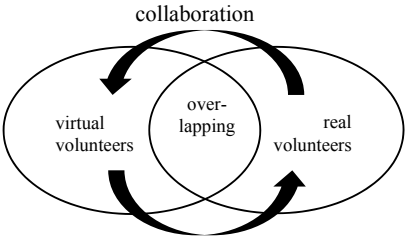

Figure 32: Virtual and real emergent volunteer groups

10.3 Virtual Activities, Temporal Developments and Role Patterns

10.3.1 Related Work: Social Media Use in Emergencies

Social media is widely used by private citizens collaboratively coping with a crisis. Studies show that *microblogging* is used for collecting and distributing information, communicating and answering help requests (Starbird & Palen, 2011). Twitter serves as resource for situation updates (Vieweg et al., 2010) and as platform for coordinating activities, exchanging opinions and emotionally coping with a crisis (Qu et al., 2011). For intensive coordination work, however, Twitter-users switch to other software, such as Skype (Starbird & Palen, 2011). *Social networking services* enable its users - who are represented by profiles - to connect with each other and offer various interaction tools, such as sending messages, sharing photos and videos, providing information within a profile or group profile, publishing notifications, reporting the current status, announcing events and discussing in forums. They are intensively used to create collective intelligence, serve as information source and contain quality control mechanisms (Palen et al., 2009). Existing services like Facebook have the advantages that they already possess a net of social relationships before the actual crisis takes place and its functionalities do not have to be learned in crises. *Wikis*, like Emergency Wiki, Quake Help Wiki or Scipionus, are useful to collaboratively collect information and knowledge and to create collective intelligence but have deficits in the aspects of communication and, as a consequence, of coordination (White et al. 2008). Sahana, Ushahidi and Google Crisis Map are examples for crisis-related platforms, which are specifically customized for crises and which integrate several web-based applications. They are used by people who are physically present on-site as well as by digital volunteers (Starbird & Palen, 2011).

Twitter is applicable for studying virtual volunteers because it is intensively used during crises and the communication of its users takes place publicly. Therefore many studies focus on

the usage of Twitter in crises. While looking into the habits of Twitter users, it was discovered that there are so-called *information brokers* (Hughes & Palen, 2009), who collect information from various valid sources and pass it on to help victims of the crisis (Sutton et al., 2008). In these exceptional situations, broadcast and brokerage of information play a more important role than in everyday Twitter activities (Hughes & Palen, 2009). The information itself can be classified in four distinguishable types: generative (original), synthetic (synthesizing external information), derivative (as a result of informational interaction) and innovative information (inclusion of cross-domain expertise and interpretation) (Starbird et al., 2010). Another categorization of Twittered contents includes situation update, opinion expression, emotional support and calling for action (Qu et al., 2011). According to the study the attention of these categories shift over time and information is spread differently. As mechanisms of self-organization, resources, activities, tasks and domains are relevant (Starbird & Palen, 2011).

Retweets, which are re-published tweets by another user, are regarded as an important tool on Twitter and are used as a recommendation system for information and the original author of a message. Local media are valued sources but retweets are used for more specific and local information (Starbird et al., 2010). People, who are not affected or only slightly affected, use Twitter more often than citizens and organizations that are affected much more seriously. The first group may refer to virtual volunteers, the second group more to real volunteers. However, the information generated by those who are not physically involved is of great help to those affected (Sutton, 2010). Starbird et al. (2012) tested the hypothesis that "crowd behavior can serve as a collaborative filter for identifying people tweeting from the ground" and found that "machine learning techniques […] can be effective in identifying those likely to be on the ground". Although all these papers allow insights on virtual activities during crisis, a systematic distinction between different role patterns is missing, which seems to be important in order to detect possibilities to combine real and virtual volunteers. Based on the illustration of temporal developments the following empirical analysis aims to extend research by creating a possible categorization of those role patterns.

10.3.2 Methodology: Event Description and Data Collection

This study investigates Twitter activity during the 2011 'Super Outbreak'. On Wednesday, April 27, 2011, and on the following day, 211 tornados were registered in the USA. More than 340 people died during this tornado crisis. High material damages on houses, streets and cars were reported. According to Governor Bentley, about one million people had no electricity in Alabama. Because of this disastrous situation, rescue forces searched for dead and survivors in plenty of cities. The tornado peaked on Wednesday. Further torrential rainfalls and tornados were recorded on Thursday. The data collected dates from Thursday when several tornados, tornado warnings and tornado watches were active. The number of tornados and the geographical distribution of the warnings and watches decreased in the course of the day.

Our research bases on Twitter data collected with the aid of *The Archivist* (http://visitmix.com/work/archivist-desktop/) which uses the Twitter Search API. Our search keyword was "tornado". 79,318 tweets were accumulated which were published between 12:17 (EDT, April 28th, 2011) and 03:16 am (EDT, April 29th, 2011) and written by 59,282 different users. The timeframe corresponds to the warning phase with current tornado warnings, the emergency phase with active tornados as well as the recovery phase in those areas, in

which tornados raged on Wednesday. Information about the user name, the publishing date and the publishing time is available. The abbreviation "RT" indicates whether a message is a retweet or contains retweets. The term "@username" signifies a possible recipient. The messages are listed in form of an Excel table. Besides the usage of quantitative analytical functionalities, several tweets were selected, read and classified manually with the help of qualitative coding. Because our work aims to derive further requirements for social software supporting emergent volunteer groups, we believe that the aspects of timeliness in a fast changing environment as well as user types including their different behaviors and interests are of great importance. The purpose of this study is made clear by the following questions: (1) Which temporal developments and shifts can be observed? (2) Which behaviors of the Twitter users can be distinguished (role patterns)?

Time Analysis: In order to reveal temporal developments and differences, the messages are divided into one-hour intervals beginning from 12:17 until 01:16 pm. Hence, 15 intervals arise as a result. Moreover, all messages are searched for key words, which can unveil a message's content. Not only is the word itself captured but also those words, which contain the key word.

Identification of Role Patterns: After getting an understanding about temporal developments and contents in help activities, we aimed to categorize users, who are actively involved in these activities on Twitter, and to describe different role patterns. The aim is to figure out which kinds of users need to be supported by social software for emergent volunteer groups. Such a view is lacking in other studies. The relevant criteria are the behavior of the users and the content of their tweets. Because of the high amount of data, we analyzed the most active Twitter members which may correspond to the active core or supporting circle of virtual volunteers (as outlined by Quarantelli, 1984). Not necessarily all volunteers and activities are of digital origin but this study focused on role patterns of virtual volunteers. We chose those users who outstood by publishing a high number of tweets or by being retweeted particularly frequently. We selected and analyzed 41 twitterers with the most tweets (1982 tweets, 2.50% of all collected tweets) and 51 twitterers who were retweeted the most (7742 retweets, 22.32% of all retweets). The fact that 22.32% of all retweets were written by only 51 users shows that many retweets focus on very few users, whose information is probably extremely valuable. In total, the 85 most active users were analyzed. They are not the sum of 41 and 52 due to overlaps. We searched for structural characteristics. We used open coding (Strauss, 1987) to analyze the material and to uncover interesting phenomena. We tried to find different combinations, which represent attitudes or role patterns, which we could summarize under a short descriptive title.

10.3.3 Findings (1): Temporal Developments

At first, it can be stated that the number of tweets decreases almost steadily. Whereas over 10,000 messages per hour are tweeted on early afternoon, only 5,494 messages per hour are published on early evening and 1,209 messages between 02:17 am and 3:16 am. This development matches the circumstance mentioned above that the number of tornados and warnings decreases in the course of the day. Thus, the higher the danger or the perception of the threat is the more active virtual volunteer groups become. The decreasing number of tornado warnings is also reflected by the declining number of the terms "warning" and "tornado watches" (Figure 33). A contrary development results when the key word "help" is searched for. From

these opposing trends of warn and help activities it can be concluded that a gradual shift of the activity focus takes place. For virtual volunteers, help activities are especially then of interest when potential threats have faded away.

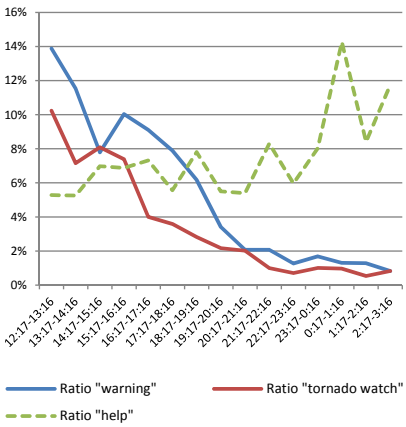

Figure 33: “warning”, “tornado watch” and “help”: When the help activities begin to shift to the focus, linking external sites increases while the percentage of retweets decreases.

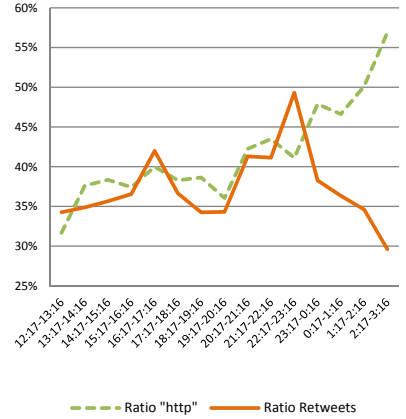

Figure 34: Links and retweets: For virtual emergent volunteer groups, help activities are especially then of interest when potential threats have faded away.

Within the analysis it becomes apparent that retweets and the usage of links play an outstanding role. 39% of the messages contain links and 37% of the tweets are or contain retweets, which are an important instrument for distributing information. When the help activities begin to shift to the focus, linking external sites increases while the percentage of retweets decreases. A possible explanation is that the external offers of news, photos, videos and help constantly grow and, therefore, the necessity of distributing important information recedes. When exploring the contents, to which the links refer, it is noticed that there is a great variety of websites referred to, but no central point for self-help activities exists (Figure 34). During the day there were clear shifts concerning the activities. The reasons are not always clear. At the beginning, warnings are in the focus, afterwards the damage reports. The emotional support shows like the entire relief activities, a slight upward trend. The analysis suggests that informing and helping are typical activities of volunteer communities.

10.3.4 Findings (2): Role Patterns

After finding temporal developments we searched for role patterns. Our analysis for role patterns (see methodology) provides four types of users with specific and differencing characteristics. They are given following names: the helper, the reporter, the retweeter, and the repeater. As the categories are not disjoint and users can belong to more than one of them, the sum of their percentage is over 100% (Table 31).

Role pattern	Characteristic	Task	Occurrence
The helper	Is often retweeted and publishes many tweets	Involved in help activities	28%
The reporter	Is often retweeted	Generates information	68%
The retweeter	Publishes many tweets	Distributes information	16%
The repeater	Publishes many tweets	Spreads a message	19%
The reader	Reads tweets	Reads information	-

Table 31: Role-patterns of twitterers

The *helper* is the kind of twitterer who is involved in various helping activities and can be especially distinguished by their tweet-content. They make emergency appeals, show ways of donating clothes or participating in search and rescue groups, give advice about correct behavior or emotionally support victims. People experienced in crisis give general tips and instructions for the affected. Participants of real emergent volunteer groups use Twitter to publish their status and also belong to the category of helpers. Participants of virtual groups support their activities. Helpers are less fixed on information processing, but are more involved in communicating, connecting with other people and coordinating activities. Because the range of help activities is big, it would surely be possible to divide them in further subcategories, like real or virtual helpers, charity fundraiser or emotional supporters, citizens or organizations.

The *reporter* makes sure that information enters the Twitter-space and provides generative, synthetic and innovative information (see Starbird et al., 2010). They often correspond to organized news channels, which, per definition, cannot be part of an emergent group and can rather be seen as intermediaries between such groups and the official crisis management. It can be stated that media is intensively used as external information source for help activities. Eyewitnesses, who report about the crisis on the Internet are an important component of an emergent group and belong to the category of reporters.

Many users concentrate on retweeting information, which was brought in by the reporters, and are called *retweeters*. They distribute the most important information (e.g. emergency appeals, warnings, news, photos), which was generated by other users, to their followers or directly to certain users. Followers are those twitterers who subscribe to messages of other users. The retweeter produces derivative information and is characterized by a high number of tweets. They are not retweeted themselves since they are never the original source. The retweeter may correspond with the already identified information broker (Hughes & Palen, 2009).

The *repeater* possesses only one or very few main messages (e.g. charity appeal, political opinion, important information) which they want to make known to many Twitter-users. In order to be heard, they repeat the message again and again. That is why a high number of tweets characterize them. The repeater provides generative as well as synthetic information, which they then try to distribute. Amongst repeaters, a popular method is to write to prominent twitterers, who have a high number of followers, in order to win attention.

There is another group which could not be identified by analyzing the data but obviously exists: the group of the *readers*. We assume that the readers make up the vast majority of all users. They can be seen as passive participants and consumers of the data the other four groups provide. The readers inform themselves about the crisis situation because they are in-

terested in or even affected by the crisis. Although they do not make any own contributions the great number of readers and the potential switch from a passive to an active participant make them worthy to be considered.

The categories presented here show typical and definable ways of using Twitter as a social platform in crises. The analysis reveals that every twitterer, who is particularly active within a crisis, can be matched to at least one of the categories mentioned above. The combination of a reporter and retweeter can be commonly found, that means a person who focuses on generating and distributing information. Another widespread combination is the one of a helper and repeater. Amongst the reporters, professional news and weather channels are the overwhelming majority. It can be stated that participants of self-help activities seldom exploit all possible means to participate but only cover a partial area, for example, the area of informing about damages or coordinating donations. Furthermore, not all twitterers represent volunteers, but especially the helpers are strongly involved in help activities. In order to detect possibilities for these virtual groups to interact with real volunteers, the next section focuses on their perception by emergency services.

10.4 Real Volunteers in the Perception of Emergency Services

10.4.1 Related Work: Volunteers in Emergencies

In the previous section we saw temporal developments and a possible categorization of role patterns of virtual emergent volunteers. This section focuses on real volunteers and their perception by emergency services. Several studies address the perception of official emergency services on real emergent volunteer groups. Lanzara (1983) points out that when procedures cannot be pursued effectively in emergencies, the need for higher learning capacities like social identity, deeper socialization, or commitment to action of the society affected comes to the foreground and societies then rely less on formal but more on informal, ephemeral actions. Dynes (2006) adds that emergencies create new social capital (obligations/expectations, norms/sanctions, authority relations, social organizations, intentional organizations) which might be used. Stallings & Quarantelli (1985) state that emergency management has to take emergent volunteer groups into account because these are not necessarily dysfunctional, not inherently in opposition to public authorities and cannot be eliminated by prior planning. A survey with citizens and emergency services (Lorenzen, 2005) presents deficits in the communication between these two groups and in taking self-responsibility. Pfeil (2000) shows regional differences in the structures of emergency management (e.g. collective self-help in Cologne and individual self-help in Bonn). Further differences are found in the acceptance of participation of citizens. In general, official emergency management defines limits for involving citizens. Pfeil (2000) reveals that citizens' initiatives strengthen the willingness for self-help activities. To summarize, the findings of the studies are partly contradictory and show an ambivalent attitude towards self-help on behalf of the officials. On the one hand, volunteer groups are conceived negatively (Lanzara, 1983; Pfeil, 2000) and on the other hand their existence is valued as an essential factor when fighting a crisis (Lorenzen, 2005). Furthermore, it is stated that official plans do not consider self-help (Dynes, 2006; Stallings & Quarantelli, 1985) although, as spotted by another study, self-help is an important part of official relief actions (Lorenzen, 2005). The reasons for these contradictions are probably local and tem-

poral differences. Furthermore most of the research in that field was done before the emergence of social media and virtual volunteers. The following empirical study aims to highlight which points of intersection can be created for a close cooperation between emergency services and volunteers.

10.4.2 Methodology: Research Field and Data Collection

The basis for the data analysis was the result of various empirical works in the application field. The studies were embedded in a scenario framework, which was developed together with actors from police and fire department, county administration and an electricity provider. It includes a windstorm with many incidents and energy breakdowns. The purpose of the scenario was to be able to quickly create a common understanding of an occurring emergency and therefore it helped to increase the validity and comparability in our interviews. One part of our study focused on self-help activities of citizens and on the cooperation with them. We conducted five inter-organizational group discussions, each lasted about four hours. The aim of the group discussions was to understand communication practice of inter-organizational crisis management. Furthermore, we conducted 22 individual interviews with actors from the participating organizations (Table 32).

No.	County	Organization	Role
I01	A	Administration	Regulatory Authority
I02	A	Police Department	Head of Control Center
I03	A	Police Department	Head of Section
I04	A	Police Department	Patrol Duty
I05	A	Fire Department	District Fire Chief
I06	A	Fire Department	Deputy Head of Control Center
I07	A	Fire Department	Workmanship
I24	A	Fire Department	Head of Control Center
I08	B	Administration	Office Civil Protection
I09	B	Fire Department	Chief Officer / Chief of Fire Dept.
I10	B	Fire Department	Operation Controllers
I11	B	Fire Department	Clerical Grade Watch Department
I12	B	Fire Department	Control Center Dispatcher
I13	B	Fire Department	Head of Control Center
I14	B	Police Department	Member of the Permanent Staff
I15	B	Police Department	Head of Control Center
I16	B	Police Department	Head of Group
I18	both	ENO	Higher Area, High Voltage
I19	both	ENO	Operation Engineer, High Voltage
I20	both	ENO	Operation Technician, Low Voltage
I21	both	ENO	Dispatcher, Low Voltage
I22	both	ENO	Workmanship Technical Incidents

Table 32: Interviews

Each interview lasted between 1 and 2 hours and followed a guideline, which was separated into three parts. The first part focused on the participants' role, qualification, tasks and work activities under normal conditions. The second part covered the participants' tasks during

emergencies in our developed scenario framework. The third part covered applied information and communication systems and perceived problems with these tools. Group discussions and interviews were audio recorded and later transcribed for subsequent data analysis.

10.4.3 Findings: Real Volunteers in the Perception of Emergency Services

From the fire service's point of view self-help should especially take place for rather easy activities: "*particularly during heavy rainfalls self-help would sometimes be very helpful; if you know that you keep several things in the basement, you can wipe away 2 cm by yourself. […] Instead of calling us and writing down that you have 2 cm water in the basement" (*I05). Activities which can be done by oneself should not be reported to official bodies in order to not unnecessarily impede the fire service's work by reporting bagatelles. One informant mentioned *"People call us and say: 'The road is closed, tell me where I should go now!', and that of course overwhelms us, and of course we cannot do the thinking for so many people"* (I06). This shows that self-help is desired by official emergency services and helps to reduce their workload.

Real volunteer groups are also seen as valuable because they often have an information advantage. This advantage consists of a more detailed knowledge about damages and the environment: "*When somebody calls us, who has seen something and then can talk to the operations manager or group leader on-site, then we certainly ask whether they live nearby or came around at random or whether they have a gas tank or the like behind their house or what kind of a heating system they have" (*I07). With digital media, such as pictures, "*citizens cannot contribute to the description of a situation*" (I03), anyway the Police use "*pictures, which were made by reporters, to get appropriate information about the situation*" (I04). According to the fire service, a close cooperation between official emergency services and emergent volunteer groups is hardly realizable, not because of unwillingness or contemptuousness but especially because of a missing legal basis: "*Everything we do must have a legal basis. […] A civil self-help group is not a unit of the emergency service. After all, we couldn't utilize them, even if we wanted to" (*I06).

A widespread phenomena regarding self-help is mentioned by three fire-fighters (I07, I06, and I09). Collaborative self-help is much more pronounced in small villages than in big cities: "*The more you are in the countryside the more the citizens support each other and the less they call for the state. The denser and more anonymous the population becomes the oftener they call for the state" (*I09). One describes the attitude as follows: "*There has to be someone who is responsible for clearing my empty basement and ideally for free, because I'm a taxpayer*" (I06). Sometimes people are not willing to help because of legal objections: "*Who is liable for that if I clear the tree to one side, or vandalize a different vehicle?*" (I06). The last quotes already suggest that unduly high expectations from the citizens are seen negatively. In addition, a temporal shift is perceived. A change in the citizen's mentality to pass on the own responsibility to others is complained about: "*You can notice very clearly that the demanding attitude has risen extremely in the last 15 to 20 years. You receive a call that a gully cover is slightly off the mark. Normally, somebody just puts it inside again. But no, nowadays you call for the state*" (I19). *"We had some cases where trees were reported on the street, which were only thick like one arm. You just need to get out of the car, take it and bring it to the side, then the street is free"* (I06). That is why a higher sensitivity for self-help is recommended: "*It*

would be in our interest to sensitize the people so that self-help becomes effective again" (I15).

Overall, it can be stated that official emergency services appreciate the existence and the activities of volunteers. However, they complain about a decreasing willingness of citizens to get involved in such activities and therefore wish to encourage self-help mechanisms. They also appreciate and make use of certain information advantages on behalf of the local volunteers regarding the environment. That means that additional information provided by volunteers can improve the work of emergency services, Because of the missing legal basis it can be assumed that emergent volunteer groups play a rather minor role in the formal plans for dealing with crises.

10.5 Supporting Collaboration between Real and Virtual Emergent Volunteers

The aim of this paper is to describe paths to better connect the overlapping groups of virtual and real volunteers. The Twitter study has revealed developments in the activity focus and has figured out different user types of virtual activities: the helper, reporter, retweeter, repeater and the reader. Especially the group of *helpers* is involved in real and virtual help activities. The interview study resulted in several findings regarding the perception of official emergency services on real volunteers. Virtual as well as real emergent volunteer groups come into existence in order to fight against the negative effects of a crisis and draw their legitimacy from this activity. The interviews indicate that their existence is also appreciated by official emergency services. Social media is a driver for virtual groups especially to express warnings, to generate and spread information, to distribute offers of help and to generally communicate. Real volunteers utilize such platforms especially for the coordination of their activities by, for example, publishing status reports via Twitter or using more complex forms of social software, like Ushahidi, Sahana or Google Crisis Map.

The procedures that are currently established within virtual and real volunteer groups do not manifest their full potential and provide room for improvement in addressing (a) the missing central point for both virtual and real groups; (b) a coordination platform specifically designed for real volunteer groups and taking those specifics into consideration; and (c) the emergency services' perception of decreasing self-initiative regarding real self-help. Social media could be used to support both kinds of groups and to foster their existence. By connecting virtual help communities, which have an increasing importance, with real communities, synergetic effects could be achieved and a necessary strengthening of local self-help could follow. Based on the results of both studies and related work the following implications are proposed and implemented in a web-based software prototype (Figure 35), that is connected to an existing emergency management system (Ley et al., 2012b):

10.5.1 Implication 1: Using Existing Social Networks

The existence of a social network before the crisis is a condition for the emergence of volunteer groups in the real (Quarantelli, 1984). For virtual volunteers these networks are already established via current social networking services, like Twitter or Facebook. Furthermore they are used as a communication infrastructure, even on-site. A tool for collaboration in crises

could theoretically try to create such a network or, even better, make use of existing social networks by establishing connections or building plugins in those social networking services. We decided to develop a prototype connected to Twitter and integrated in Facebook to use existing connections, users and publicity, but isolated from a technical point of view in order to have the data even if the network service is unavailable.

10.5.2 Implication 2: Creating Promotion and Awareness

The interview study emphasizes the importance and necessity of promoting self-help activities by exhibiting the wish of emergency services to encourage self-help mechanisms. Awareness about the existence of volunteer groups and knowledge about the possibility to support them can foster their emergence. If volunteers use existing social networks, information is easy to spread. The existence of a crucial event, which is perceived as a threat, is another precondition for the emergence of volunteer groups (Quarantelli, 1984). Our Twitter study shows that the level of virtual activities is strongly dependent on how the threat is perceived: The decreasing number of tornado warnings is also reflected by the declining number of the terms "warning", which are contrary to the use of the word "help". Therefore, illustrating increasing or decreasing threat could motivate potential volunteers to participate even in the real. Our Twitter study detected four different role patterns, but the probably largest group of user types is that of the readers, who do not actively participate. They could be encouraged to participate, even for small efforts, such as assessing the usefulness of pictures related to a disaster. Furthermore organizations have the possibility to publish information from their crisis management system and ask for (virtual) volunteers.

10.5.3 Implication 3: Fostering Connection among Volunteers

In order to achieve synergetic effects between the virtual and the real, these groups must be internally connected to each other. Virtual emergent volunteer groups could directly support both people affected and real communities by providing relevant information. The system provides the possibility to plan activities and to coordinate actions. In contrast, actors who concentrate on virtual self-help could be encouraged to get involved in real emergent volunteer groups. One approach to foster collaboration is to display users or user-names in a specific way or color related to the role patterns, based on data about their current usage and their kind of contributions. On-site twitterers, detected by algorithms (Starbird et al., 2012), who need digital or real would be easier to recognize if displayed. The identification of active users, which are not on-site, but are willing to support on-site helpers or other stakeholders, are other possible use cases. With the help of this, concerns about the reliability of information contributed by anonymous users, as also mentioned in our interview study, could be partly reduced.

10.5.4 Implication 4: Connection to Emergency Services and Systems

In our Twitter study we detected that social software handles various kinds of information, e.g. photos, videos, documents or external, medial information, which are important for virtual volunteer groups. Mechanisms to enable the identification of valuable information, for instance, based on the judgment of the crowd (e.g. rather passive users, who do not help on-site), could especially be useful for disaster relief agencies. Therefore social software should

support external points of intersection between private citizens and emergency services. According to the results of our interview study, a close cooperation between official emergency services and real volunteers groups currently seems hardly viable. However, the studies show that an exchange or the use of information is reasonable and realistic because of information advantages by different groups, such as the *reporters*. They sometimes represent news channels, can act as intermediaries and their information is also esteemed by the authorities, as seen in our interview study. A monitoring of the activity of specific roles (on-site; active), as detected in our Twitter study, could be valuable in order to get important and trustful information. The prototype is connected to an existing emergency management system in order to enable emergency services to easier use that information.

10.5.5 Preliminary Evaluation Results

An intensive participation of potential users is necessary in order to research collaboration potentials. We continuously tested the prototype described above with several users, with different background, social media use and connection to emergency management. Furthermore we did six scenario-based walkthroughs using *thinking aloud* (U1-6; age between 22 and 55; duration: between 30 and 60 minutes). They covered (a) local neighborly help and coordination as well as (b) virtual activities and information exchange using the prototype.

Figure 35: Screenshot of the prototype with groups, activities, tasks and comments (anonymized)

The informants mentioned conditions to use such a platform: own consternation, mobile access, publicity of the platform, and the lack of information from the media. The possibility to use it on mobile devices is crucial (U4, 5). In order to strengthen the trust within the community, it was proposed to expand the profile information with an activity overview (U3, 4): "*I think it would be a good idea [...] to add a crisis relevant timeline to each profile*" (U3). Others suggested to add the possibility to explicit confirm information (U5, 6). Nearly all users mentioned that it is necessary to use geographical representations of the situation instead of simply using text from other social media, and that geo-related information should be summa-

rized based on the location or topic (U2, 3, 4, 5). The possibility to use the application when the Internet is unavailable for some time was also mentioned (U4). Therefore the relevant information, based on the own location or profile information, should be downloaded when Internet connection is available. Others suggested the installation of virtual contact points in order to be able to request information from authorities or volunteers (U5). A critical requirement that has not been considered is the support for resource mobilization: U6 proposed a central, semi-automated resource location in order to list existing community resources that are already specified and resources required in order to "*have a central point of contact and resources that everyone who needs a water pump, can go there and borrow*" (U6). The perceptions listed above present first insights and show possible concerns and further requirements in collaboration systems for volunteer groups.

10.6 Conclusion

A research agenda aiming to increase the collaborative resilience of communities has to understand and address all possible cooperation scenarios between the stakeholders involved. In this contribution, we turned to emergent volunteer groups as one of the most volatile social constructs we can observe in crises. We distinguished two kinds: the virtual and the real, which are partly overlapping. There seems to be an obvious contradiction between tendencies of a stronger engagement in disaster relief activities via social media versus a decreasing feeling of immediate responsibility and engagement of real volunteer groups in the perception of professional organizations. We were able to observe and identify different role patterns, and have identified challenges for *real* emergent volunteer groups that may be at least partially met with the help of social media.

The section of collaborative resilience we were looking into here also made very clear, that aside from improving the technological support, we also have to work on cultural and organizational challenges. Maybe caused by public pressure, authorities react with a strong articulation of "we are taking care" to the challenges a disaster poses. But that also manifests a division of work between the citizens and professional crisis response organizations that – depending on the nature of the crisis – ultimately will overstrain any resources of professional actors. When discussing the activation of the ordinary citizen as a resource in crisis management, we encountered different attitudes. Collaborative resilience research should also explore and support a gentler slope of responsibilities, expertise and direct engagement in and around crisis management.

This paper presented how synergies between those real and virtual emergent volunteer groups could be fostered through social media. The contributions are (1) the results of a study about the use of social software during a tornado crisis in order to detect different types of user behavior leading to role patterns (see also Reuter et al., 2012), (2) the results of interviews with emergency services in order to research how emergent volunteer groups are perceived, and (3) concepts for possible synergies between real and virtual volunteer groups (see also Heger & Reuter, 2013) including the preliminary results of the evaluation of a software prototype. Our design implications include to (a) use existing social networks, to (b) support promotion and awareness, to (c) foster connection among (virtual and real) volunteers, as well as with (d) emergency services and systems.

Limitations and future work: The empirical methods we used have limits. The Twitter data we collected does not contain all relevant tweets which were published in the timeframe we analyzed. Our methods of analysis could also not capture the exact content of all tweets. However, they allowed us to draw conclusions beyond the literature. The interviews were conducted on a different location than the Twitter data and may not be comparable in all questions. However, they gave us some insights. The prototype was only tested by a few users. Open fields of research are supporting the perception of threat as mentioned in the concept, and improving coordination, decision-making and resource-management of real emergent volunteer groups, which have not been addressed here.

Part III:
Analysis

The third part combines the different perspectives as well as the already published papers and analyzes them with regard to their theoretical and practical implications.

Chapter 11 (Empirical Results) summarizes the main empirical findings of the given practices and describes the infrastructural phenomena that have an effect on possible ICT support in emergent collaboration practices. Chapter 12 (Concepts and Artifacts) contains challenges for, and concepts and implementations of innovative ICT artifacts (SiRena, ISAC, MoCo and MoRep) to support those emergent collaboration practices, and which relate to the empirical findings. Chapter 13 (Evaluation) presents the results of the evaluations of these concepts in the application field using three scenarios: information aggregation and visualization in situation assessment (scenario A), ad hoc participation in mobile collaboration (scenario B) and articulation work in mobile reporting (scenario C).

Chapter 14 (Towards Emergent Collaboration Infrastructures) builds on the results of the previous chapters and discusses them in order to answer the initial research questions. It outlines the *collaboration sphere* and presents methodological implications for infrastructuring in emergent collaboration. Chapter 15 (Summary) outlines the contribution, states the overall conclusion and presents perspectives for future work.

11 Empirical Results

The empirical study illustrated emergent collaboration practices in crisis management. This chapter summarizes the findings in both official and actual work processes as the first phase of a design case study in order to reveal work infrastructure limitations and to be able to derive recommendations for the concepts and artifacts, which contribute to the improvement of emergent collaboration infrastructures.

11.1 Work Processes and Responsibilities

Different laws define the work processes of BOS, which contain all organizations responsible for threat prevention, such as police and fire departments, aid agencies and THW. According to article 30 of Germany's constitution in conjunction with article 70ff on the division of legislative powers, the German federal states are responsible for threat prevention measures, as long as they do not involve defense (Bundesrepublik Deutschland, 2012).

Civil protection is divided into police and non-police threat prevention (German: *Nicht-polizeiliche Gefahrenabwehr*). The police are responsible for danger management, for public security and public order, and for the prevention of crime as well as for making the necessary preparations to assist and act in cases of danger (§1.1 PolG NRW, 2013). Each federal state has its own police force. Non-police threat prevention is provided by public authorities and organizations, which are active in, according to the states' laws, fire prevention, emergency services and civil protection. In North Rhine Westphalia this is regulated in the law for fire prevention and assistance (FSHG, 2013). These include fire departments, aid agencies (emergency medical services) as well as assistance via the THW. THW is an unincorporated federal institute with an own administrative foundation within the portfolio of the interior ministry (§1.1 THW-Gesetz, 1990).

The townships, such as Siegen, Netphen or Kerpen, must maintain capable fire services, which are in conformity with local circumstances, in order to fight fire as well as give assistance in cases of accidents and emergencies caused by natural events, explosions or similar incidents (§1.3 FSHG, 2013). The counties, such as Siegen-Wittgenstein and Rhein-Erft, conduct and coordinate operations during incidents in which the life or health of numerous people or considerable material assets are threatened (§1.3 FSHG, 2013). For this purpose the (district-independent) towns and counties maintain control centers as well as facilities for conducting and coordinating fighting major incidents (§1.3 FSHG, 2013). Private aid organizations assist in case of an accident or a public emergency if they have declared their willingness to the state to cooperate (§18 FSHG, 2013).

If the effects of an incident exceed the capacities of a town administration or of the active local incident command in the response phase, they must make a proposal to the superior authority – which corresponds to the district administrator and the district fire chief – to proclaim a *major incident* based on tactical and administrative situation assessment. When a major incident is proclaimed the overall responsibility for conduct and coordination is transferred to the district (§29.1 FSHG, 2013). The district makes use of the *operations management* (German: *Einsatzleitung*) for executing the operational-tactical measures and an *crisis com-*

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mittee (German: *Krisenstab* or *Stab außergewöhnlicher Ereignisse*) to execute administrative-organizational measures (FwDV 100, 1999). The crisis committee consists of the committee's chairperson, the coordination group, the section for population information and media relations, the permanent members, and the incident-specific members. The operations management deployed within a major incident (§30.1 FSHG, 2013), is composed of the senior representatives of all organizations which contribute relief forces to a major incident. They are generally divided into subject areas and are subordinate to the incident commander, who is assigned by the county administrator or senior major. If the major incident exceeds the counties' resources, the federal states support the counties and communes in the execution of their tasks and take over the overall coordination of the operation in cases of extensive danger, damage and crisis. The usual management structures of BOS differ. The police coordinate operations directly from the control center ("*lead from the behind*"), in non-police threat prevention – usually lead by the fire department – the officer-in-charge is on-site ("*lead from the front*") and the control center only supports him.

More than 80% of the BOS members are volunteers (Weinheimer, 2008). The fire departments in Germany have around 30,000 professionals, 30,000 members in the plant fire brigade, but more than 1,000,000 volunteers (Deutscher Feuerwehrverband, 2009). Likewise 99% of the THW members work on a voluntary basis and merely one percent are employed. This demonstrates the significant role of volunteers in (German) emergency management – and work infrastructures have to reflect this. Furthermore, it is obvious, that during major emergencies, collaboration among BOS is necessary. Unless laws and regulations usually describe this, they act more as general guidelines than to determine work in detail.

11.2 Work Practices and Infrastructures

In addition to official work processes, the actual situation leads to many emergent work practices that aim to deal with the perceived breakdowns. Those are not totally covered by regulations or supported by official ICT infrastructures. This section illustrates emergent work practices with extracts from our empirical work. The methodology has been described in chapter 3.3.1.

11.2.1 Inter-Organizational Communication Challenges

During emergencies BOS cooperate and collaborate also on an inter-organizational level. During our workshops they outlined, that "*each organization [...] has its own way of working*" (W2) - and these require that different terms are used. The different terminologies in the respective organizations as well as the involvement of both professionals and volunteers can lead to communication problems, in which the seriousness of a situation is understood as being more dramatic than it actually is:

> *"There is someone who has injured his finger and a member of the THW reports the accident. That message was almost understood as a fatality".* Because of the different focus, it is *"very, very difficult to get an alignment of terminology. Even when police talks to the firefighters, there is a very large communication gap between them."* (W2)

These misunderstandings can even occur within the same organization, in different communities. As an example, neighboring fire departments were mentioned in which *"completely dif-*

ferent rules, totally different philosophies" (W2) existed. When communicating with other organizations or companies, different uses of the same terms occur even more often. This becomes apparent in an example of a fire in an industrial building. In this case, 19 people in a factory were reported to have been injured, but they actually meant *"injured as defined by the company, meaning 19 people who had to be seen by a doctor. They do not have to be hurt"*. This differs significantly from the use of the term in BOS: *"If the emergency service speaks of people having been injured, this means they have to be cared for and brought to a hospital"* (W2). There, too "*different terminologies lead to different results*". In fact, in the understanding of BOS, "*two people were hurt; others only had to be examined by the company doctor"* (W2). In this case, heterogeneous actors were not aware of the existence of terminological differences and led to challenges in inter-organizational communication.

11.2.2 Encapsulated Technical Infrastructures

Figure 36: Work infrastructure in the control center

Besides the language, technical infrastructures also differ. The work practices of the respective organizations require specific application systems. This very heterogeneous infrastructure limits the possibilities for information exchange. Manual workarounds therefore emerged. The police operations management system (STABOS) has no interface to the control center system (eCebius); people therefore export data from eCebius as PDFs, transfer them via e-mail and import them to STABOS (I15-0:37:42). Another workaround is the information exchange between ENO and fire departments: ENO usually provides its information about areas with power blackouts via e-mail, not using geographical representations as in the system used in the control center. The control center therefore manually draws important blackout areas in their GIS. Such manual workarounds work; nevertheless, they do not foster and encourage

information exchange and collaboration. At the voluntary fire departments, we observed no ICT infrastructures, besides radio and the actors' private smartphones.

11.2.3 Formal Correctness and Improvisation Work

Structures are important to be able to handle basic tasks. Flexibility is necessary to be able to react to dynamic situations, caused by the difficulties described in the last sections. Structures are not necessarily efficient in every case: "*Our aim is not the formal correctness of all processes, but the fast and good solution of the problem"* (I02). Besides the fact that BOS have a very clear communication structure (I02-20:53), they do not consider themselves civil servants, in the way that an administrative officer or a taxman does:

> *"We [police] and the fire department work in a way which is different from all other authorities: We do not have a litany that we follow strictly, because then we would be lost."* (I02-19:06)

This shows that they recognize the need for a certain degree of improvisation, independent of the detailed and planned processes that instruct others. The decisions on the field level are not just based on regulations, but also on assessments of the situation and are done "*within the given clearances*" (I09): "*We have standard measures and things, which we decide at the spur of the moment*" (I13-40:23). The fact that each problem is unique allied to the need to act quickly, plays a significant role in crisis management. Improvisation is therefore necessary:

> *"Improvisation is essential, next to extensive planning. You can have the best predefined response plans, but there is always a situation, where you have to improvise."* (I01-1:07:41)

Flexibility is already part of BOS' working procedure: "*All workflows are flexible. This is necessary, because each situation is different"* (I02-19:06). One police officer explained: "*Once there is a problem, our command center gives us lots of room to act, to solve the problem*" (I04). When we take a closer look at emergency response work, we can see that improvisation is a common practice, analytically separate from the execution of one or more response plans: "*We usually improvise. We try to make the best out of each situation*" (I11-21:08). However, improvisation usually does not occur in the pure form: "*There is always a mishmash of formal structures and informal ways"* (I01-38:05).

11.2.4 Challenging Information Assessment

One important task where improvisation occurs is situation assessment. Unfortunately, not all the information that is necessary to assess the situation is available through official infrastructures. Aside from official IT systems, many other information resources are also used. That information has to be searched for in many different places:

> *"There are 40 windows, where I have to look up wind speed, water levels […]. We have to search for each piece of information somewhere else."* (I05-5:31)

Additional weather information is important because the German Meteorological Service (DWD) only offers forecasts, while the weather information of a German insurance company is more precise (I02-1:24:18). Furthermore, information on traffic jams is also needed (I05-1:37:49; I07-1:00). On-site units usually request additional information from the control cen-

ter (I03-44:42). When a fire breaks out, officers, for instance, ask the registration office, how many people are registered in that house:

> *"The registration office is interesting. If we have a fire, we ask them how many people are registered there. If five people are standing in front of the house, we can judge how many might be inside."* (I04-10:06)

11.2.5 Use of Private ICT

These requests, and reports using emergency radio, support much of the communication necessary between the control center and the on-site units or amongst the on-site units. Unfortunately, this technology does not offer rich interfaces, but is often the only (official) communication technology provided. Besides the control centers, on-site actors are also dependent on an optimal overview of the situation. For this purpose, some of them use their private smartphones as an additional information medium, because BOS do not provide their staff with such technology:

> *"Some of the colleagues have an Internet connection on their smartphone that is often useful, for example to get an aerial image from the locality via Google Maps to check other information. This can be helpful for mediation, when you need a phone number […]. Generally, we don't have navigation systems on board and there is often the problem: 'Go to house number 17' and when you have found number 5, the next three numbers are hard to read and then you suddenly find a house number 28 and then there is the question: Where are the others?"* (I04-26:21)

During an emergency, private phones are also used to establish a communication connection; if, for instance, the radio breaks down. These phone numbers are not listed in the official systems and agents do not *have* to take the devices with them (I15-32:25). Furthermore, it is not possible to document the calls, which is necessary for possible investigations after the emergency – people responsible for documentation therefore have to manually record the calls of the decision maker (I09-44:07). The use of private ICT is especially important for volunteers, who usually do not have sophisticated ICT support.

11.2.6 Informal Contacts and Social Networks

The informal use of technologies as well as informal contacts and informal communication are important in order for actors to be able to be able to address topics directly and to work together in a trustworthy environment and on an inter-organizational level:

> *"During last windstorm 'Emma' the district fire chief called me [police] on Saturday morning at half past eleven on my mobile phone and asked: 'Do you have any plans for today?'. I replied: 'No, not really'. Then he said: 'OK we meet a 2pm'. This is all below a formal alarm. The personal contacts that grew over years in such a small authority are very important. Alternatively, with the Red Cross. If I need tents, than I know the contact person. There are many contacts on different levels."* (I02-30:56)

Personal contacts are also important for receiving relevant information in time (I05-24:01). Another advantage is that mistakes are also communicated on an inter-organizational level, because of the high level of trust, actors do not fear indiscretion (I02-37:03). The "*further improvement of social - not technical - networks and the display of contacts would be im-*

portant for crisis management", especially for the fire departments (I06, 1:25:43). This could also improve the accuracy of phone lists, which was mentioned by several actors (I05-1:12:17):

> *"You always have to run after the current telephone numbers during an event, because we do not check the actuality of all contacts."* (I02-45:5). Or: "*There have grown huge telephone lists, which are hard to keep up-to-date, because numbers and functions change."* (I06-1:27:57)

Collaborative management of contacts is especially important for people who are 'irregular' actors who need to be contacted in crises, such as, for instance, the caretaker of a school, who is contacted in order to open the school for an evacuation, but whose telephone number has in the meantime changed:

> *"If we would have a platform to manage those contacts that are up-to-date, because the actors maintain themselves."* (I06-01:28:43)

11.3 Implications

Highly novel problems require ad hoc decision-making based on the information available in the situation. This requires improvisation, collaboration and informal contacts, which are usually not considered by the formal processes nor work infrastructures. ICT devices play a crucial role in the ensemble of tools and technologies. In order to address the challenges of emergent collaboration, technical support that considers these specifics is needed. The empirical study revealed the work practices and enabled an understanding of their work infrastructure: current ICT is not appropriate to deal with all emergent inter-organizational collaboration needs. Besides the aspects mentioned in this chapter, additional phenomena relate to improvisation work (chapter 5), situation assessment (chapter 7), ad hoc mobile collaboration (chapter 8) and reporting practices (chapter 9) and therefore motivate the research on appropriate concepts allowing emergent collaboration.

12 Concepts and Artifacts

The aim of the concept development and technical implementations of ICT artifacts is to provide infrastructural support for emergent collaboration. The empirical studies outlined different emergent collaboration practices that reveal work infrastructure limitations. No systems that structure and formalize procedures are therefore needed, but rather self-organized collaboration systems need to be supported, in accordance with the aim of CSCW to support "self-organization of cooperative ensembles as opposed to disrupt cooperative work by computerizing formal procedures" (Schmidt & Bannon, 1992). This chapter describes the key challenges and designed components as the second phase of the design case studies with a focus on emergent collaboration as the object of study in this dissertation.

12.1 Overview and Architecture

In order to allow emergent collaboration in (inter-)organizational crisis management, we designed concepts and artifacts addressing the specifics of emergence (Figure 37). The artifacts are part of the socio-technical concept *Security Arena*, which aims to improve the cooperation in coping and recovery work between BOS, ENO and citizens with various technical and organizational approaches (Balduin et al., 2010). The basic component is designed as a web-based *Inter-Organizational Social Network* (SiRena). SiRena is the technological basis for the other modules, containing user profiles, access control, and basic communication functionalities as well as the basis for the continuous participation of end-users. Further included artifacts are the *Inter-Organizational Situation Assessment Client* (ISAC), a situation map that allows various collaborative interactions and sharing, and gives central access to distributed, external information resources, such as websites, files or various other web services. *Mobile Collaboration* (MoCo) is a mobile application for collaboration among spatially distributed users. MoCo uses ISAC components and extends its functionality to ad hoc include new users in situation assessment. *Mobile Reporting* (MoRep) is a second mobile application for on-site reports and helps to articulate in-situ information needs.

While the conception of the artifacts has been the result of various collaborations (Christofzik & Reuter, 2012, 2013; Ley et al., 2014, 2012a, 2012b; Ludwig et al., 2013a, 2013b; Pipek et al., 2013; Reuter et al., 2014; Reuter, Pipek, et al., 2012; Reuter & Ritzkatis, 2013), the research presented in this thesis focuses on the perspective of emergent collaboration. The following sections describe these artifacts, starting with challenges for various BOS actors, followed by the concepts and implementations with a special focus on emergent collaboration functionalities. In the descriptions a distinction between three different scenarios addressing different phenomena is given: Awareness and networking (conceptual basis), information aggregation and visualization in situation assessment (scenario A), ad hoc participation in mobile collaboration (scenario B) and articulation work in mobile reporting (scenario C).

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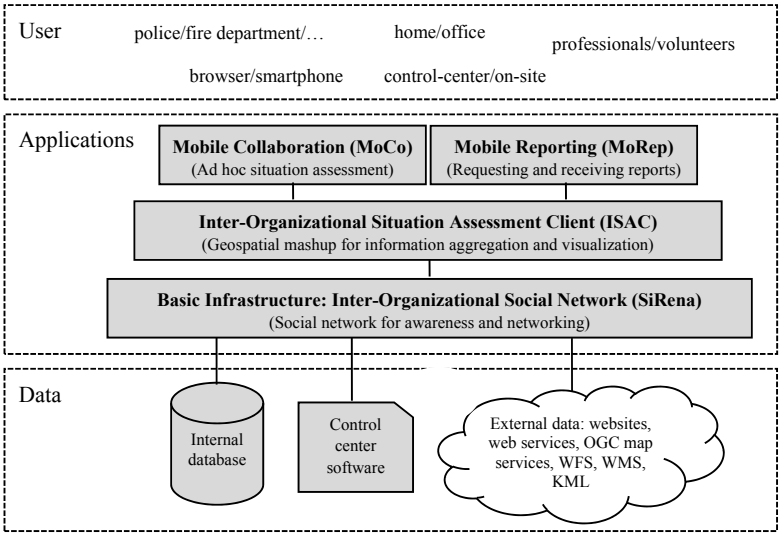

Figure 37: Architecture of the designed technical artifacts for this thesis

12.2 Basic Infrastructure: Inter-Organizational Social Network (SiRena)

12.2.1 Challenge: Awareness and Networking

Both, informal and formal communication is important in crisis management (Ley et al., 2012a). Formal communication ensures that all relevant actors are involved. Additional informal contacts help to cope with unforeseeable situations and are used for informal information requests. In both types of communication actors have to be aware of the organizational structures in their own organization as well as in the other organizations involved. By presenting this information on an inter-organizational level, it is possible to create awareness regarding the responsibilities and contact persons, but also about different work cultures and inter-organizational terminologies (Reuter, Pipek, et al., 2012; Reuter, Pohl, et al., 2011). Redundant and outdated information at the different organizations, for instance the phone number of the housekeeper of a school who might be needed to open the building for an evacuation (see chapter 11.2.6), can be avoided by providing a central repository for BOS. Networking and knowledge management are also important motives for a social network for BOS (Reuter, 2011).

12.2.2 Concept and Implementation: Social Network 'SiRena'

In order to address these challenges we designed a web-based social network exclusively for BOS (chapter 7). The goal of our social network is to allow insights into the current work practices of other organizations and to allow networking and information exchange by professional and volunteer BOS. The emergent character of crises, restrictions in the very heteroge-

neous technical infrastructure and the need to be able to include new actors very easily were the reasons for creating easy to use, lightweight web-based tools. The majority of BOS members are volunteers, which usually do not have a sophisticated technological support, but instead tend to use their private devices. Web-based solutions are also independent from existing organizational and technical system restrictions, which especially exist in the police. The reasons for setting up a private social network for BOS was to verify hosting security, to guarantee the BOS' data privacy, to be able to provide a basic infrastructure for further modules and to create a basis for the continuous participation of end-users.

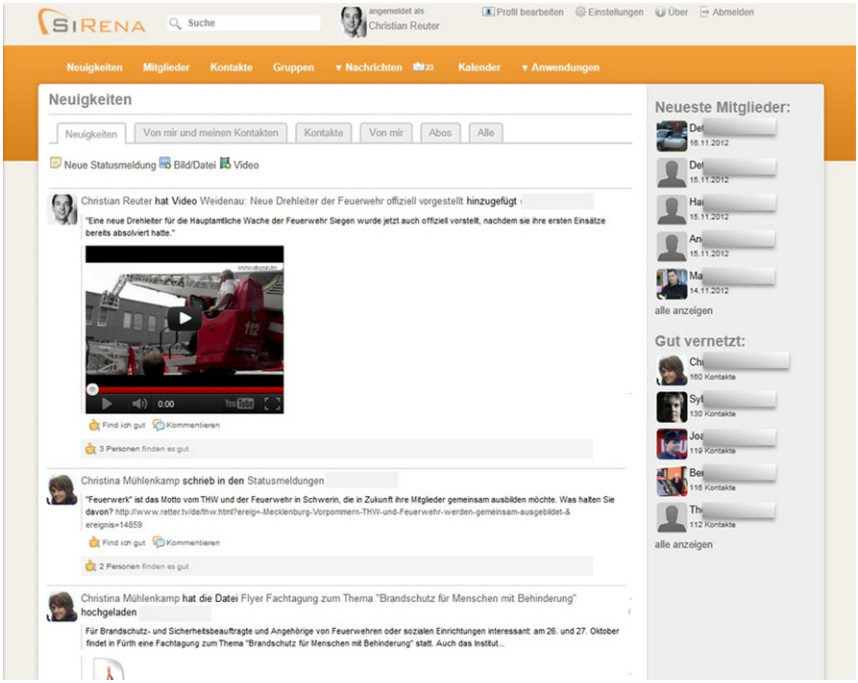

Figure 38: Inter-Organizational Social Network: activity stream

Similar to other social networks, when entering the SiRena the activity stream is displayed (Figure 38). It filters the existing activities based on different tabs (especially my contacts, subscriptions and all), and also provides a way to deliver status messages and add documents, files, images, or videos. Groups are the main element in the system. To ensure data protection, (inter-organizational) working groups can be public and thus accessible to all users or private, so that they require further invitation. Much collaborative functionality is available, such as collaborative file handling including the creation, management, editing and exchange of documents, media and files, a calendar and a discussion forum. To communicate, the system provides both an internal messaging system and a chat. SiRena is designed as a *walled garden*, which means that it requires an invitation by a member of the respective organization. Within SiRena, every user is represented by a profile (Figure 39).

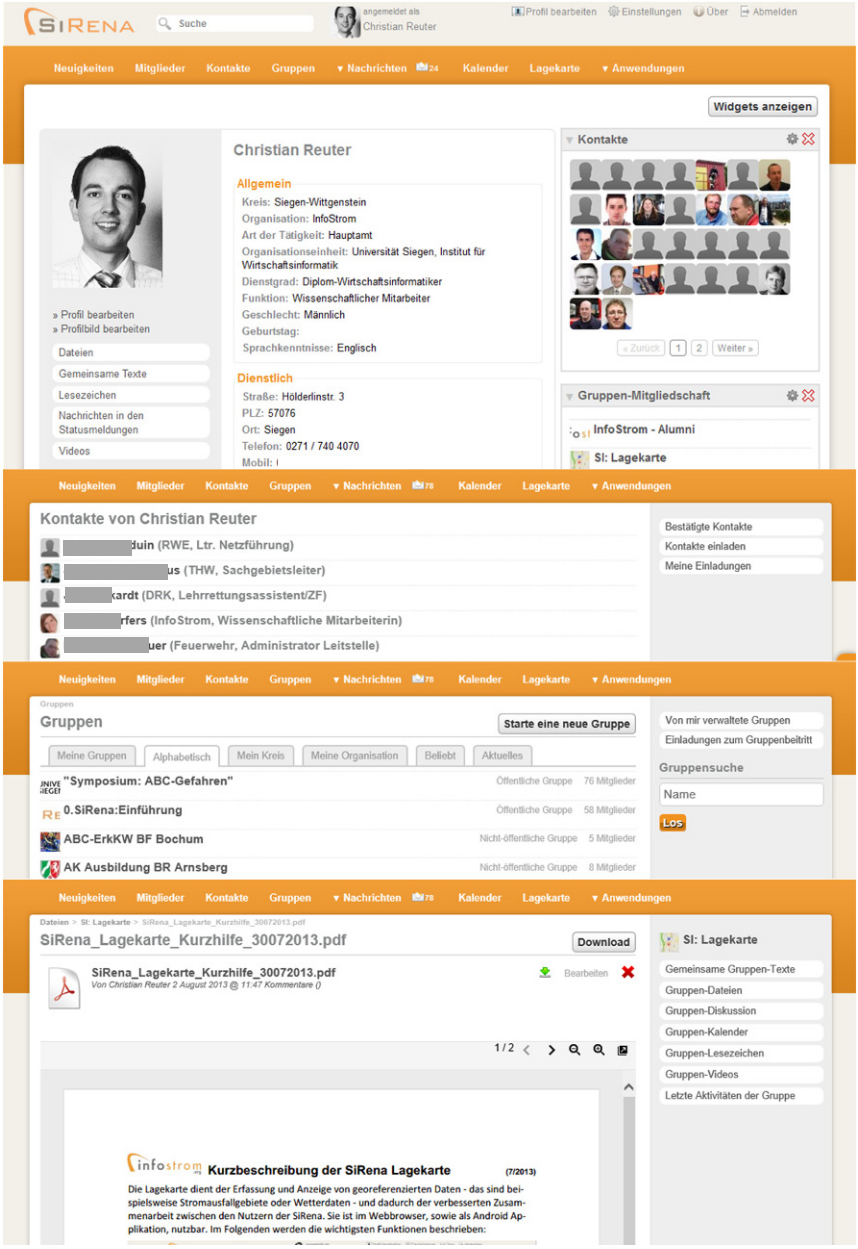

Figure 39: ISAC: profile, contacts, groups, documents

The technical basis for the system is the web-based open source social networking engine *Elgg* (http://www.elgg.org). Elgg offers the components needed to create an online social environment. It provides modules for blogging, microblogging, file sharing, common social networking functionalities, groups and the possibility to create personal plugins. Elgg was founded in 2004 by Ben Werdmüller and David Tosh as a social networking approach for e-learning and is licensed under the terms of the GNU General Public License (GPL) as published by the Free Software Foundation. The core social networking modules have been adapted to the application context of BOS, such as extending the user profile fields to the geographical region, the organizational unit, the rank and special skills. This is intended to help users to get to know members of other organizations (Ley et al., 2014).

Elgg runs on the LAMP (Linux, Apache, MySQL, and PHP) platform and at its foundation is an entity based data model with the central basic class, ElggEntity, which is divided into four main categories in order to cover all elements within the network: ElggObject represents files, blog entries or bookmarks; ElggUser represents all users; ElggSite is responsible for the sites and ElggGroup for all collaboration functionalities like groups. Furthermore, an activity-stream, access control, user management, a news system and a web service API are available. The plug-in system allows creating and installing plug-ins, which include *actions* (functionalities) and *views* (user interface).

Functionality	Description
Social network	Social network for BOS to foster exchange among organizations, based on the web-based open source social networking engine Elgg
Dashboard	Display of news, updates in groups, new documents, files, media and calendar entries on the first screen.
Profiles	Enhanced visibility of the organization and the rank, even in the overview. Possibility to add contacts, to see user profiles, to invite people, also to change personal information, such as adding special skills for crisis management.
Messages and chat	Personal messages, delivered as internal messages and via e-mail. Possibility is to chat with people who are online in the system.
Groups	Create, manage, join or leave, public or private groups, which act as a basis for document sharing, collaborative text editing, and calendar entries. Groups act as access control mechanism for several specific applications.
Document management	Display documents, such as images, PDF or office documents in groups, preview using Google Docs
Plug-ins	Possibility to implement or install plugins, which can be accessed based on the membership in a group. Examples for plug-ins are ISAC, MoCo and MoRep.

Table 33: SiRena - functionalities at a glance

12.3 Scenario A: Inter-Organizational Situation Assessment Client (ISAC)

12.3.1 Challenge: Information Aggregation and Visualization

Especially during non-routine events, situation assessment typically takes place in an ad hoc manner (Ley et al., 2012a). Even routine situations, however, require that BOS retrieve various pieces of information, which are not necessarily available to one's own organization and have to be assessed or requested (e.g. weather services, electricity network operator, logistic companies, etc.) via different media channels (e.g. phone, WWW, e-mail, face-to-face, etc.) (Ley et al., 2014) or even by unmanned aerial systems (Thamm et al., 2013). The importance and significance of single pieces of information depends on the availability of other information (Christofzik & Reuter, 2013). We observed that ENO provides his information about breakdown areas via e-mail attachments to the fire department, but not on their digital situation map. Appropriate representation of the often spatial information from many different sources on a map as well as individual support of situation assessment, allowing the adaption of information compositions due to their personal needs, is currently not possible (Ley et al., 2012b). Technophile and technophobe users need instruments that let them customize information compositions in real-time and select as well as add information. Currently, each organization uses its own map for situation assessment, which does not allow these actions.

12.3.2 Concept and Implementation: Geospatial Mashup 'ISAC'

In order to address the challenges of information aggregation and visualization, we designed the *Inter-Organizational Situation Assessment Client (ISAC)*, a web-based geo-collaboration mashup using Google Maps and realized it as a plugin within SiRena (chapter 7). Users have the opportunity to show or hide information resources on the map easily, to add additional and new information resources to the map, and to add place marks with annotations at specific locations on the map. The aim is to support various actors in situation assessment, to ensure a quick situation overview.

The system allows users to add, change, delete, display and hide different types of internal and external information. Internal information, such as placemarks, can be created at a specific location with a text or a file by clicking on the map or using the search function. Markers can be set as private, so that they are only visible for the person who created it, or global, assigned to a layer and then available for everyone who uses this layer. To ensure careful changes markers have a change history, making it possible to reconstruct the most recent changes, like in Wikipedia. It is furthermore possible to add external information like weather information or layers created by external providers using Web Map Services (WMS), Web Feature Service (WFS) or Keyhole Markup Language (KML). It is furthermore possible to mark and highlight different parts of the map: Annotations such as lines, forms, circles, polygons or free-hand drawings are appropriate to mark special locations or situations, e.g. roadblocks or collecting-points. We have observed that actors of BOS adapt information compositions due to their personal needs. To avoid an information overload, the user is able to save specific map compositions. For example, one map can be prepared for a flood scenario, another for the evacuation of a hospital.

The connection between this Google Maps (API3) based application and the database (MySQL Server) is realized with REST Web Services, which work with the data in XML and KML format. The web server is Apache Tomcat.

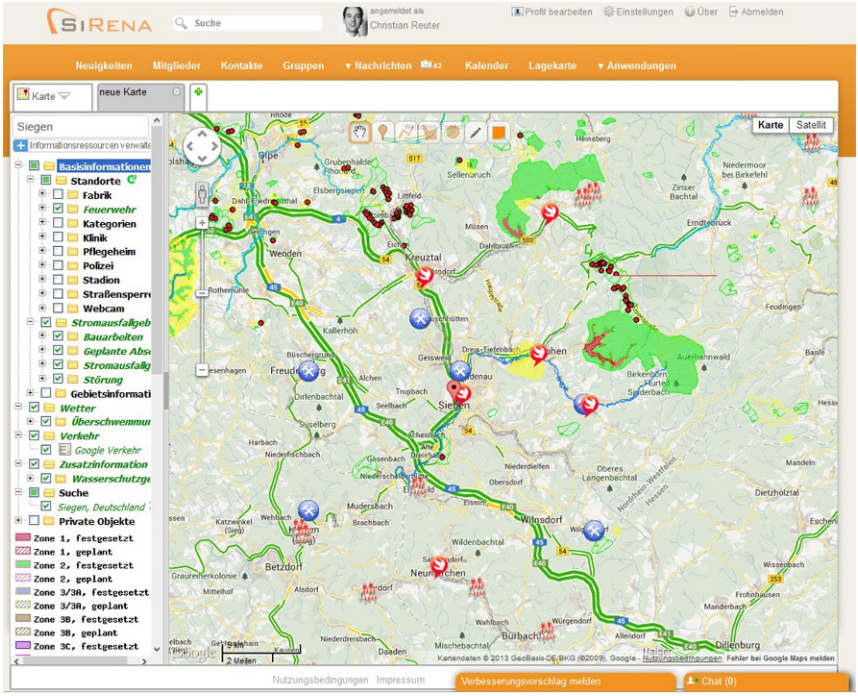

Figure 40: Inter-Organizational Situation Assessment Client (2013)

Functionality	Description
Geospatial mashup	Mashup using Google Maps (API 3) with the possibility to configure, save and share an own information view with a selection of some of the various information.
Marker	Add, edit or delete marker, which are represented with a location, description, optional an appended file and history of the last changes (in order to prevent anonymous changes). It is possible to set them as private or public and assign them to a layer, such as fire departments, hospitals or industry.
External data	Possibility to include external (geo-referenced) information such as websites, WMS, WFS and KML
Annotations	Add, edit, delete and share annotations on the map with lines, forms, circles, polygons or free-hand drawings.
Collaboration mode (see MoCo)	Share information and annotations and collaborate with other users using Web Sockets that allow bi-directional, full-duplex communication.

Table 34: ISAC - functionalities at a glance

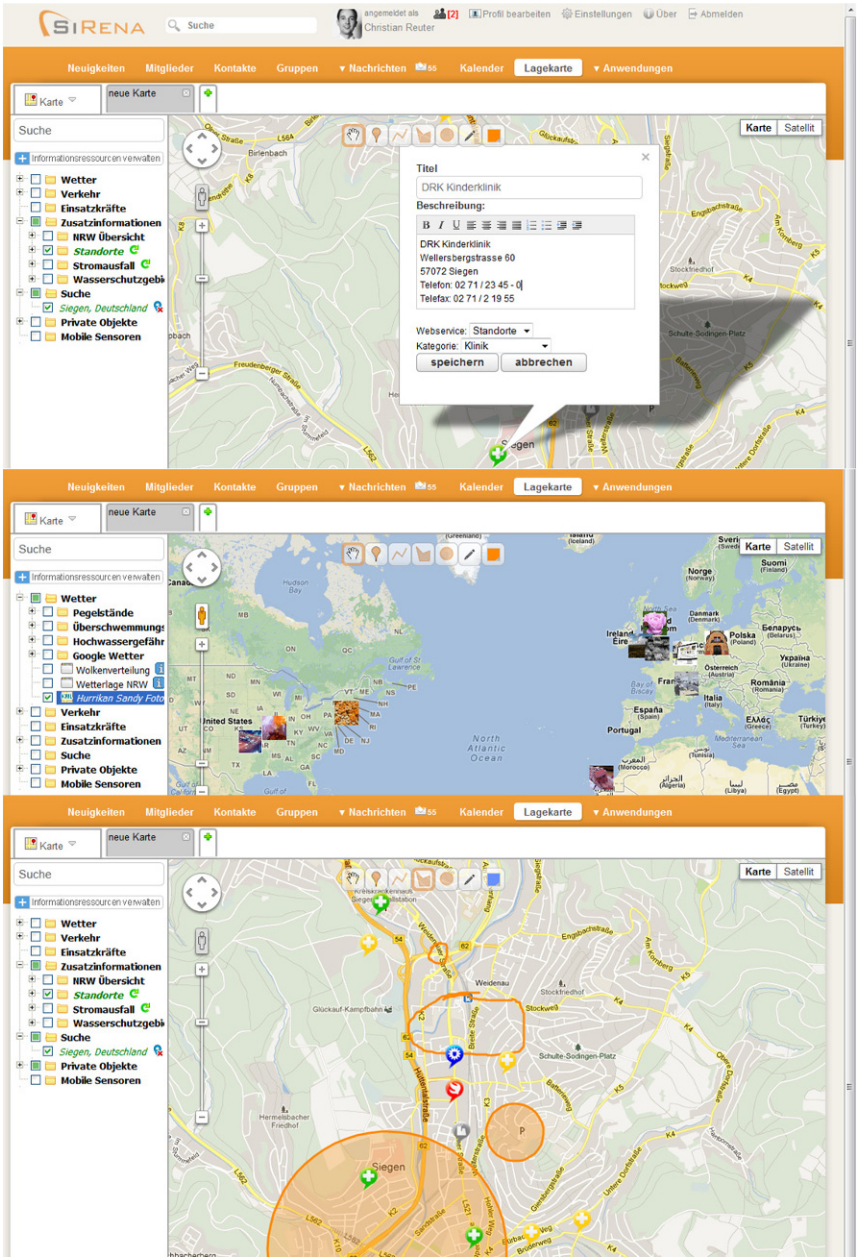

Figure 41: ISAC: Edit marker, show pictures, annotations

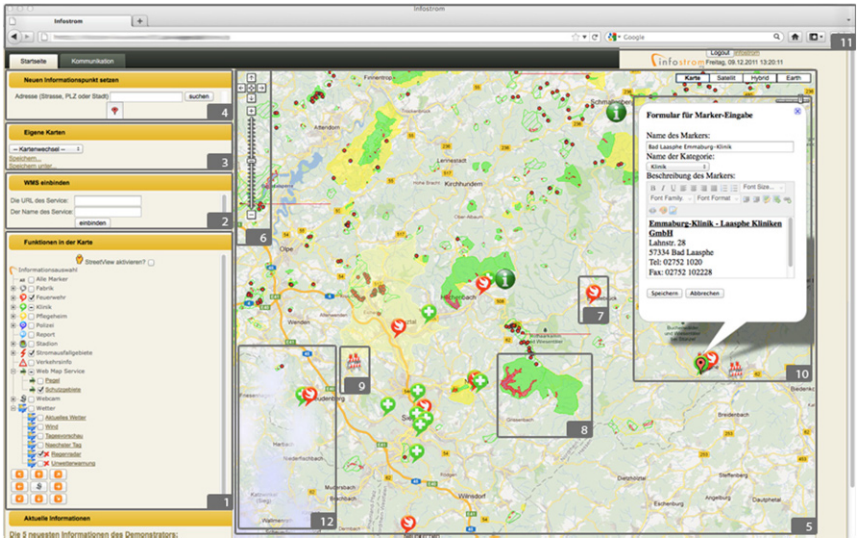

Figure 42: ISAC in 2011, the basis for the interim evaluation

The module *Inter-Organizational Information Repository (IOIR)*, which will not be presented as a contribution in this thesis, extends the functionality of ISAC as a web-based information pool (Ley et al., 2013).

12.4 Scenario B: Mobile Collaboration Application (MoCo)

12.4.1 Challenge: Ad Hoc Participation and Collaboration

The rigid, pre-defined BOS structures cannot satisfy the complexity and unpredictability of an emergency and therefore require a high level of informal communication and improvisation (Reuter et al., 2014). Besides radio, for on-site units (mobile) phones are the primary work equipment – especially when dealing with volunteer forces or when cooperating on an inter-organizational level through liaison officers (Reuter & Ritzkatis, 2013). This communication technique enables ad hoc involvement of individual actors during an emergency, but does not provide for awareness of other units and makes noticing a situation harder than through radio. The *living-in-a-situation*, which is necessary to get an overview of the situation, is no longer possible due to the frequent fallbacks to mobile phone use. When a unit participates in an ad hoc manner, the on-site units use a workaround with Google Maps on their smartphones to get a better overview and enhance the communication with visualization options. However, just using those maps cannot fulfill all the requirements, such as annotations or map sharing. These options support the informal mobile phone calls and pave the way for a fast involvement of the units into coping and recovery work (Reuter et al., 2014).

12.4.2 Concept and Implementation: Mobile Collaboration App 'MoCo'

In order to address the challenges of ad hoc participation and collaboration we designed *Mobile Collaboration (MoCo)*, a native Android application (chapter 8). MoCo is based on ISAC, which functions are adapted for mobile devices such as smartphones and tablets and extended to special mobile needs.

The main part of the application (Figure 43) is a map on which the user has the possibility to add, change or delete information markers, including multimedia data (photo, video, audio), or make annotations in the form of lines, circles or freehand drawings in different colors like in ISAC. At the left side the user has the possibility to slide in an *information repository* for integrating external and internal information. Internal information can be added manually on the map by clicking onto, or searching for a location, assigning information to a specific category (e.g. a police unit or a fire department) and giving them a short description. Similar to ISAC external information can be integrated in two ways: it is possible to insert an URL for a WMS to use geo-referenced map images from the Internet generated by a map server using data from a GIS database. The second way is to add a KML layer, a XML notation for expressing geographic annotation and visualization within Internet-based maps.

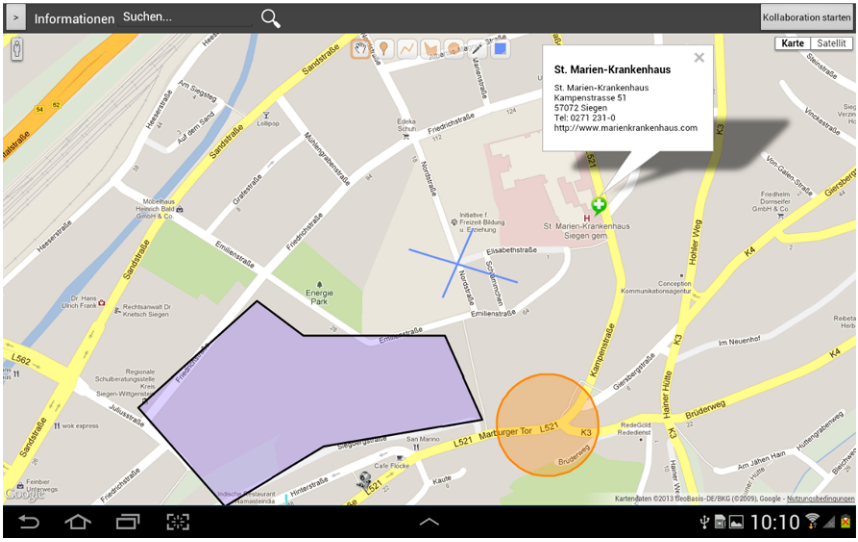

Figure 43: Mobile Collaboration App (MoCo)

The main functionality called *collaboration mode* can be displayed in the right border. Because of the need to do improvisational work, it is also possible that multiple people, who are registered in SiRena, can collaborate on a situation map. The WebSocket-based collaboration mode allows bi-directional, full-duplex communication. It lets the user make changes on his current map and everyone invited to this session can see the changes in sync, using the smartphone application MoCo or the browser version ISAC. When starting the collaboration mode, a dialog appears showing a list of the SiRena participations, which can easily be extended to involve other participants. The creator of the session (manager) can invite as many

users (participants) as needed to discuss a situation in a dispersed manner. This gives the manager the possibility to address several units in an ad hoc and dynamical way – also inter-organizationally, including on- or off-site units. After accepting the invitations, only the manager has write access, but he has the option to assign someone else these rights and force it back. This restriction ensures that the map will not be overloaded. In addition to mobile phone calls, the collaboration mode offers a multilateral communication environment instead of bilingual calls and the visualization aims to overcome verbal limitations, especially when talking about geo-referenced information. Every annotation, which represents e.g. a collection point, a road barrier or any other point of interest, can be shared with all participants of the collaboration session and can thus enhance awareness. The collaboration mode offers the option of making mobile calls so that more than one person or distributed entire units can participate in the process of situation assessment. A common picture of a situation can therefore be created.

To be able to use the collaboration mode, the support of web sockets is necessary; a web technology providing full-duplex communication channels over a single TCP connection. Web sockets have been available in web-browsers since mid-2011 and now a secure version of the web socket protocol is implemented in Mozilla Firefox 6, Google Chrome 14 and Internet Explorer 10. The collaboration server is not established on the device of the inviting actor due to the possibility of losing the Internet connection.

Functionality	Description
Mobile map application	Mobile application using Android 4, can be used on smartphones as well as tablets. Implementation is based on ISAC, whose functions are adopted for mobile devices and extended to special mobile needs (display, interactivity, sensors, and connection) allowing ad hoc participation.
Mobile annotation	Possibility to add, change or delete information markers, including multimedia data (photo, video, audio), or make annotations in the form of lines, circles or freehand drawings in different colors.
Collaboration mode	WebSocket-based collaboration mode using full-duplex communication. Allow the user to make changes on the current map and to easily invite someone ad hoc into the session to see the same view and all changes on the map in sync using the smartphone application (MoCo) or the browser version (ISAC).

Table 35: MoCo - functionalities at a glance

12.5 Scenario C: Mobile Reporting Application (MoRep)

12.5.1 Challenge: Reporting and Articulation

Control centers are mainly interested in gathering impressions from the incident location supported by visual multimedia data in order to get a situation overview (Ludwig et al., 2013b). If the written or verbal on-site reports do not satisfy their needs, the control center needs to have the option to actively articulate information needs. This dynamic requesting activity is currently not supported. Having to use the radio, the control center complains about being flooded with information and the on-site units are left with much room for interpretation. A mechanism, which allows semi-structured information requests and does not leave as much space for interpretations, could therefore support their cooperation. Because information needs to be tailored to each individual, reports should be easy to modify by each user. Some

context information, though, always needs to be captured automatically: the coordinates of the location, the source and the time that identify the information as a whole (Ludwig et al., 2013a).

12.5.2 Concept and Implementation: Mobile Reporting and Articulation App 'MoRep'

In order to address the challenges of reporting and articulation, we designed *Mobile Reporting (MoRep)*, a native Android application (chapter 9), that works in cooperation with MoCo. MoRep allows to report or request information. Determining the needs of the addressees of requests is possible by requesting information by location or role: location-based requests give a location overview of all subordinates from whom information can be requested. Due to privacy reasons it is also possible to turn off this function and to not submit information about position. This enriches the awareness between the control center and the on-site units. For role-based requests, the addressee can be determined the unit's role (e.g. sub section leader).

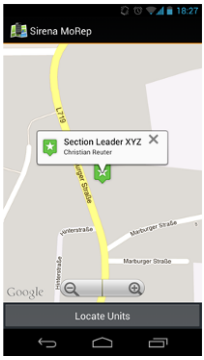

Figure 44: Localizing the response units

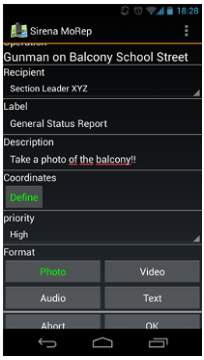

Figure 45: Request form

Figure 46: Content of the report, here: picture

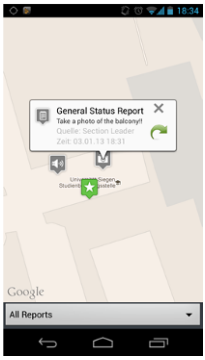

Figure 47: See reports

Our supportive mechanism guarantees proficient handling, including the following rights: *Requesting information* allows response units to finely specify and articulate the information needed. Using this, transmitting a destination location for a remote-navigation of the unit and setting the priority for a more appropriate assessment of the task's urgency is supported. The *independent sending of information* allows authorized units to send information directly, without previously having received a request. For instance, this permission is relevant for section leaders, as their information does not have to be authorized anymore. *Sending information by previous request* allows a unit to send information to the section leader, but only as an answer to a previous request. This restriction should help to avoid an *information overload* for decision makers due to information needs being requested first. If a user receives a request, a written and voice notification using Google Cloud Messaging appears.

Functionality	Description
Mobile reporting application	Mobile application using Android 4, can be used on smartphones as well as tablets. The technical concept is based on REST architecture as a form of the SOA-paradigm, where the services are implemented by HTTP-servlets.
Requesting reports	Allows fine-specifying and articulating what kind of information is needed. Transmitting a destination location for a remote-navigation of the unit and setting the priority for a more appropriate assessment of the tasks.
Independent sending of information	Allows authorized units to send information directly, without previous requests. Relevant for section leaders, as their information does not have to be authorized anymore.
See requests	Open requests are displayed for the user, sorted by priority and time. A request can directly be answered with a report. A form appears, in which the text fields have already been pre-determined by the creator of the request. If a target location was transmitted, the coordinates-button will be shown that offers the possibility of navigating to that location.
Sending information by previous request	Allows a unit to send information (picture, video, audio, text) as an answer to a previous request. This restriction should help to avoid an information overload for decision makers due to information needs to be requested first.
See reports	Previously created reports are shown with icons that indicate the data format. The user can view all reports or only those he requested.
Notifications	Using modern communication technologies, such as Google Cloud Messaging, innovative notification mechanisms are implemented that simplify communication and allow a parallel use to radio communication.

Table 36: MoRep - functionalities at a glance

13 Evaluation

The concepts and ICT artifacts SiRena, ISAC, MoCo and MoRep described in the previous chapter have been evaluated following the methodology described in chapter 3.3.3 and according to the aim of measuring potential organizational effects of such collaboration infrastructures on the ability to deal with emergence. Our initial empirical work explored *points of infrastructure*, related to both collaboration and emergence. This chapter addresses these initial points in order to evaluate the usefulness of our artifacts. This constitutes the third phase of the design case studies structure in the following three scenarios: information aggregation and visualization (scenario A), ad hoc participation in mobile collaboration (scenario B) and mobile reporting and articulation (scenario C).

13.1 Basic Infrastructure: Awareness and Networking with SiRena

In our empirical study we observed the need to foster inter-organizational social networks. We have perceived points of infrastructure in inter-organizational collaboration, when actors did not know whom to contact. SiRena helps to make these networks visible. It was used by more than 350 members of BOS, starting with about 15 users, who successively invited their colleagues and contacts. The following quote from a SiRena online discussion illustrates the general motivation for using SiRena:

> *"I appreciate this tool. There is an independent, not really public network of all the forces that are involved in some form of crisis management. [...] What this tool can accomplish in total is not quite open up to me, but I think that the future will show this. Whether through informal discussions or exchange of ideas, suggestions and knowledge or through a real crisis. Possible are also target agreements and collaboration. But 'thinking outside the box' within the discussions with the other professional groups is also possible. Let's make the best out of it!"* (Voluntary Fire Chief, Fire Department, Region A, 18.06.2013)

We also observed that organizations, which do have sophisticated ICT support, need such a system less than others:

> *"Our [Police] situation is different from the fire department. We are internally connected [existing intra-organizational groupware] and have individual contact points as well as group structures. We therefore do not need the SiRena as a community tool – but it might be good for cooperation between BOS and maybe later with the population."* (Head of Agency Strategy, Police, Region A, 04.12.2012)

Cooperation between forces that do not have formal connections is especially fostered.

13.2 Scenario A: Information Aggregation and Visualization with ISAC

The first scenario for the evaluation had to do with information retrieval in situation assessment (details in chapter 7.6). Some breakdowns occurred when the information necessary to

C. Reuter, *Emergent Collaboration Infrastructures,*
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overcome the situation was not available in the system and had to be looked up somewhere else. Based on this observation, we designed ISAC to allow information aggregation and visualization with web-based geospatial mashups. Participants saw the additional value of the system primarily in the visualization of a bigger picture for major incidents and disasters:

> *"It would be good for larger operations, to quickly create a situation overview […] The only possibility is to work together - fire department, Malteser [aid agency in Germany] and Red Cross - the breakdown of the telecommunication operator has shown this again. In cases like that, I could mark an area on the map and share it, to express, that I will take care of this area."* (E13)

For situations of imminent danger, *"it is not feasible enough. Here the system is still too sluggish. The situation is different for incidences evolved over multiple days, like a flood. For that it would be fantastic"* (E17). Due to security reasons, current IT infrastructures of the participating organizations are characterized by full isolation. The interviews emphasized that there are nearly no concerns about sharing information with others:

> *"During a major situation we have to exchange information. In this case we dispatch a liaison officer to them [fire department] and they send one to us. From then on there are no more secrets anyway."* (E24)

However, especially on the police side, there is confidential information that has to be kept under wraps, but this kind of information cannot be shared anyway, neither via our application nor via phone or radio:

> *"For example during a violent demonstration, we also work together with the fire department and ambulance services. But there is tactical information on police side that will not get outside. […] Every operation where special forces are involved."* (E21)

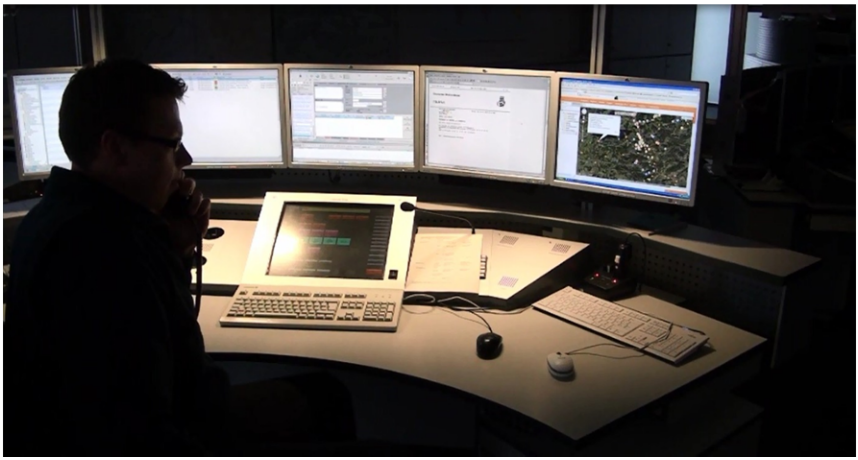

Figure 48: Use of ISAC in the control center (2013)

In summary, the evaluation in scenario A illustrated that ISAC allows aggregating and sharing information ressources that are not part of official systems, in order to connect organizations in emergent situations.

13.3 Scenario B: Ad Hoc Participation and Collaboration with MoCo

Further points of infrastructure occurred in our second scenario, which had to do with ad hoc participation in mobile collaboration with MoCo. Due to unexpected situations, like all situations in crisis management by definition, new actors have to be involved in situation assessment (details in chapter 8.6). We therefore designed MoCo. The biggest improvement for working practices was the possibility to "*include people into situation illustration that were previously left out*" (E16-25:44). Our participants mentioned that currently it is possible to talk to each other or to send photos from phone to phone, but not to actively and easily collaborate and exchange information independent of the existence of sophisticated infrastructures. For ad hoc collaboration, several cases were mentioned.

The first case was the need to include people that had previously been left out in cooperation between the spatially distributed services of the control center and the forces on-site. This kind of cooperation would be especially important in a synchronic way. For such situations the use of the smartphone version of our system was recommended:

> *"You should certainly use something like that on a tablet PC or a notebook when the colleagues are on-site. Here, for instance, you could add regions for a search for missing persons. The on-site forces could be divided based on this information."* (E20-50:41)

Such cooperation could in some ways replace phone calls:

> *"We get information from the fire service when, for example, there is a fire somewhere […]. [Using an] App for the smartphone, we could just add the disturbance instead of taking a call from someone, we could just directly add it to the map."* (E22-19:15)

The transmission of coordinates was also an issue mentioned in order to support cooperation between the control center and the on-site units:

> *"Especially since there are often areas that don't have a name or number at the houses and are somewhere in the open field. In this case I can also imagine that, rather than discussing it for a long time, you could add a marker and share it."* (E23-26:30)

A second case for light-weight tools to share digital representations ad hoc is cooperation among organizations, e.g. with new forces from other regions:

> *"I could provide an on-site overview. For instance, some people from Burbach [another city] arrive, who know where our city is of course but do not know where the Bismarckstraße [street] is."* (E13-32:19)

Other examples mentioned were rescue dog forces:

> *"You could implement the entire situation and create search maps. The rescue dogs are the ones who need the most map material because they run criss-cross."* (E13-21:24)

The third case of emerging cooperation scenarios affects temporal collaboration scenarios outside of office hours:

> *"Disturbances do not just happen during office hours but also for example on a Saturday night and in that case it would be useful […] A) Maybe some data is already in the system, blackout areas and so on. And B) I could show some-*

> *thing by marking it and saying: 'Here we have this and that problem'. Then I could […] upload pictures, or other material I've got relating to an object to make the situation more transparent, because today we do all that via telephone. Sometimes with difficulties."* (E23-24:00)

Figure 49: Use of MoCo on-site (2013)

In summary, the evaluation in scenario B illustrated, that MoCo allows to collaborate not only verbal, but also visually supported, with people of other organizations, with people outside office hours (without sophisticated infrastructures) and with people from other regions.

13.4 Scenario C: Mobile Reporting and Articulation with MoRep

Further points of infrastructure occurred in reporting, when the normal reports from on-site units did not arrive or did not contain the information necessary for judging the situation (details in chapter 9.7). MoRep allows the articulation of information demands and therefore works the other way around. Mobile reports can extend articulation work. MoRep cannot cover emergencies over their entire duration, but it can easily be used for "*basic information and a common understanding of the situation*" (EM08). In contrast to phone calls, it is an additional way of communication and articulation, enriching reports with visual data (EM09). Nevertheless, the articulation of coordinates may also contain risks:

> *"If I support new coordinates for a unit, than that's a process where I direct; then you have to think, if that is useful, or if you are allowed to do that.*" (EM11)

The extension of articulation work might improve situation awareness in two dimensions: First: it supports (organized) volunteers that know the location, but do not necessarily have experience in judging the importance of information for the control center (EM06). Second: semi-structured requests also support professional units from other counties, who assess the importance of information better than volunteer units do, but who do not know the location. For example, the head of the police station we studied mentioned that they will have new recruits starting very soon and the majority of them are not familiar with the region. They are already using GoogleMaps and their private smartphones (EM10).

> *"Of these 29 officers probably more than the half is not from this region. They will search for streets just on their smartphones."* (EM06)

Structuring of requests nevertheless has limits. Even though it was mentioned as very useful that communication paths are predefined by the application, there were still doubts whether the on-site units will utilize this feature (EM07). The predefined communication path versus the allowance of improvisation work therefore has to be judged. All participants were aware that mobile applications "*support an additional way of communication and that in case of emergencies you can still make a call*" (EM09).

Figure 50: Use of MoRep on-site (2013)

In summary, the evaluation of scenario C illustrated, that MoRep supports reporting, when information is not provided as planned. Therefore, the process is turned over, these information demands are specified, and information is requested.

14 Towards Emergent Collaboration Infrastructures

To contribute to the research on emergent collaboration infrastructures, collaboration practices have been empirically researched in order to design, implement and evaluate ICT artifacts. This chapter answers the research questions posed in chapter 1.2. While studies in the field of inter-organizational crisis management provide the answer to the first three questions, the answer to the fourth question provides general conclusions applicable to other domains:

1. Where do emergent collaboration practices reveal work infrastructure limitations?
2. What kind of novel concepts and artifacts are appropriate for improving work infrastructures towards enabling emergent collaboration?
3. What are the potential organizational effects of such collaboration infrastructures on the ability to deal with emergence?
4. What are the methodological implications for technology design towards emergent collaboration infrastructures in inter-organizational settings?

14.1 Emergent Collaboration Practices

The empirical study (chapter 11) provided material to answer the first question:

> *"Where do emergent collaboration practices reveal work infrastructure limitations?"*

Various empirical work, based on amongst others observations, group discussions, and interviews, illustrated several emergent collaboration practices (P) that reveal work infrastructure limitations (Table 37). Regulations and work processes frame inter-organizational practices; nevertheless, improvisation is a common practice and emergent collaboration occurs, as observed in the field of crisis management (P01). The uniqueness of each situation requires ad hoc decisions. Restricted technical infrastructures and terminological differences in IOIS also lead to the need for improvisation (P02). Improvisation appears in the use of unofficial ICT and informal contacts and relationships, but is partially based on formal procedures. It is sometimes performed in a collaborative way (P03). The actors perceive the necessity for improvisation in order to deal with emergent situations (chapter 5). In dealing with the situation, single official and additional sources of information are combined depending on the scenarios and the necessary tasks (P04) (chapter 6). Varying, improvised and ad hoc activities reveal work infrastructure limitations, which usually support a limited range of actions. Different scenarios imply specific practices and points of infrastructure. In the following, exemplary practices are used to illustrate three descriptive scenarios: information aggregation and visualization in situation assessment (scenario A), ad hoc participation in mobile collaboration (scenario B) and articulation work in mobile reporting (scenario C) (Table 37).

C. Reuter, *Emergent Collaboration Infrastructures,*
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Part	No.	Specific practices in inter-organizational crisis management	Chapter
Improvisation Work	P01	*Improvisation in current management structures:* common practice, besides executing one or more response plans.	5.5.1 11.2.3
	P02	*Reasons for improvisation:* uniqueness of each operation, need for in-situ decisions, technical infrastructures and terminologies.	5.5.2 11.2.1
	P03	*Conditions for improvisation:* do not occur in a pure form, foster the use of unofficial ICT, informal contacts and relationships, based on trust, takes place also collaboratively.	5.5.3 11.2.5
Information Qualities	P04	*Measurement of information qualities:* single pieces of information are combined in different ways (weakest link, best shot and summation) depending on the necessary tasks.	6.3
Scenario A: Information and Expertise Sharing	P05	*Improvisation practices in coping and recovery work:* common among decision-makers when responding to uncertain circumstances under risk and with limited time available.	7.4.2
	P06	*Situation assessment practices:* based on several types of information resources from different organizations via different media channels.	7.4.2 11.2.4
	P07	*Handling information uncertainties:* often leads to an overload of information that is difficult to manage.	7.4.2
	P08	*Information retrieval and exchange processes:* existence of official and unofficial information; on-site units usually report their information to the control center.	7.4.2
	P09	*Restricted ICT infrastructures*: sometimes make it hard to share information properly.	7.4.2
Scenario B: Ad Hoc Collaboration	P10	*Unforeseen situations and complexity require informal communication:* mobile phones are used as additional communication infrastructures, but they do not support the logging of all actions as required.	8.4.2.1 11.2.6
	P11	*Informal communication enables ad hoc participation but lacks awareness:* the use of mobile phones involves new units, but other actors are not informed as when using the *public* radio.	8.4.2.2
	P12	*Lack of technical support precludes involvement of voluntary forces:* besides radio and private smartphones, voluntary forces do not have other sophisticated technology support available	8.4.2.3
	P13	*Missing situational awareness through the phone handicaps liaison officers:* forces outside the control center do not necessarily have connection to crisis management systems.	8.4.2.4
Scenario C: Mobile Reporting	P14	*Information and communication practices:* verbal communication via radio leads to a flood of communication and the permanent risk of information overload, while on-site teams complain about lack of information.	9.4.1
	P15	*Articulation of information needs:* the official communication path is radio based, smartphones are also already used. On-site teams are responsible for delivering relevant information (push mechanism), but they often do not know which information they have to transmit.	9.4.2
Emergent Volunteer Groups	P16	*Volunteers in the perception of the officials:* BOS appreciate the existence and the activities but complain about a decreasing willingness of citizens to get involved in such activities. They wish to encourage self-help mechanisms.	10.4.3

Table 37: Specific practices in inter-organizational crisis management

In situation assessment (scenario A), information retrieval requires both official and unofficial information resources, which are enhanced with verbal communication between on-site and off-site units. Due to the diversified information needs in decision-making, improvisation is common (P05) and situation assessment uses a wide range of information resources from different organizations via various media channels (P06). However, perceived information uncertainties and citizen-generated content can lead to information overload (P07). The study revealed that the (visual) situation overview is given only within the control center; off-site leaders are informed via radio (P08), because restricted and shrouded ICT infrastructures complicate sharing or displaying information properly (P09). Overall, current collaboration infrastructures reveal limitations in situation assessment caused by a set of information and information needs, which are not foreseeable (chapter 7).

In mobile collaboration (scenario B) outside the control center, mobile phones are used as an (unofficial) communication infrastructure in addition to the official radio although they often lead to problems in logging (P10): the one-to-one use enables ad hoc involvement of units, but fails to create awareness among all participants unlike the *public* one-to-many transmission in radio (P11). The lack of technical support for (organized) voluntary forces precludes their *rich* involvement (P12). Likewise, a lack of sophisticated connection to crisis management systems handicaps liaison officers (P13). Overall, current collaboration infrastructures reveal limitations in inter-organizational ad hoc collaboration (with participants from other regions or volunteers) caused by the limited scope of the official infrastructure. Informal uses of technology try to span this gap (chapter 8).

In mobile reporting (scenario C) verbal communication via radio leads to a flood of communication. At the same time, on-site teams still complain about not having enough information (P14). On-site units are mostly responsible for providing information, but control center forces have the impression that volunteer forces sometimes do not know which information to report or external forces do not know the location of the respective objects (P15). Overall, current collaboration infrastructures reveal limitations in articulating information needs for on-site and off-site units (chapter 9).

Relating to emergent volunteers, although BOS appreciate their activities, they also complain about the decreasing occurrence of self-help mechanisms, at least during smaller incidents (P16). Overall, current work practices reveal limitations in including volunteers in collaborative crisis management (chapter 10).

14.2 Novel Concepts and Artifacts for Emergent Practices

The design of concepts and artifacts (chapter 12), which was informed by the empirical insights, made it possible to answer the second question:

> *"What kind of novel concepts and artifacts are appropriate for improving work infrastructures towards enabling emergent collaboration?"*

Emergent practices require collaboration infrastructures, which allow spontaneous and informal collaboration to enhance official work procedures. The design aims at both flexible and robust ICT artifacts that help users to overcome points of infrastructure and to support unforeseeable situations (Table 38, Figure 51). Therefore lightweight and interoperable tools seemed

to be applicable in order to combine the respective local systems towards an emergent inter-organizational collaboration infrastructure:

- The *Inter-Organizational Social Network* (SiRena), a web-based social network exclusively for BOS, supports awareness and networking among BOS. It allows for information exchange, self-organized inter-organizational working groups and contact management. This is especially important for scenarios without a common infrastructure, such as inter-organizational settings or the support of organized volunteers. It also acts as a basic infrastructure, to allow the inclusion of new modules, such as ISAC, MoCo or MoRep. Furthermore, it has been used for the continuous participation of end-users within the following studies (chapters 7 and 12.2).
- The *Inter-Organizational Situation Assessment Client* (ISAC), a web-based geo-collaboration mashup using Google Maps, supports information aggregation and visualization (scenario A). It allows for individual information retrieval including the possibility to create and add new information and to allow individual map compositions (chapters 7 and 12.3).
- *Mobile Collaboration* (MoCo), a native mobile application based on ISAC, supports ad hoc participation and collaboration (scenario B). Its *collaboration mode* allows for sharing map compositions by spatially distributed teams, e.g. in the control center and on-site, in order to include new, external and unforeseen actors in the situation assessment (chapters 8 and 12.4).
- *Mobile Reporting* (MoRep), a native mobile application, supports reporting and articulation (scenario C). It extends the directions of communication and allows for (multimedia-based) requests and reports, e.g. pictures provided by on-site units to the control center, when the available information is not sufficient (chapters 9 and 12.5).

Figure 51: Novel concepts and artifacts to support emergent collaboration

The artifacts are adapted to the emergent character of crisis management allowing improvisation work and also helping to overcome organizational, spatial and temporal boundaries. The support for emergent collaboration, for ad hoc participation, and for individual practices based on inter-operable tools is appropriate and, I argue, necessary, to improve emergent collaboration.

Part	Prototype	Chapter
Basic Infrastructure	Inter-Organizational Social Network (SiRena)	12.2
Scenario A: Information and Expertise Sharing in Situation Assessment	Inter-Organizational Situation Assessment Client (ISAC) (Ley et al., 2014, 2012a, 2012b).	7.5 12.3
Scenario B: Ad hoc Collaboration in Mobile Collaboration	Mobile Collaboration Application (MoCo) (Reuter et al., 2014; Reuter & Ritzkatis, 2013).	8.5 12.4
Scenario C: Articulation Work in Mobile Reporting	Mobile Reporting Application (MoRep) (Ludwig et al., 2013a, 2013b; Ludwig & Reuter, 2014).	9.5 12.5

Table 38: Novel concepts and artifacts to support emergent collaboration

14.3 Effects of Emergent Collaboration Infrastructures

The various evaluations (chapter 13) of the concepts and designed artifacts provided data about possible organizational effects of such infrastructures, to answer to the third question:

> *"What are the potential organizational effects of such collaboration infrastructures on the ability to deal with emergence?"*

They illustrate their consequences (C) for the ability to deal with emergent situations (Table 39, Figure 52): The evaluation of ISAC (scenario A) outlined BOS' motivations for as well as restrictions on sharing information. Unless all applications have been designed for a variety of technical infrastructures, the evaluations of ISAC showed that the artifacts were not as independent from the technical infrastructure as we wished them to be: police browsers (Internet Explorer 6 and 7), for example, did not allow for the use of all collaborative functions. The consideration of *old* local technical infrastructures therefore has to be considered (C01). Nevertheless, during the use of ISAC, the users were satisfied to be able to create a situation overview. Even so, they perceived a lack of predefined templates, shapes and tactical insights addressing their local specific needs (C02). We observed no concerns about sharing information with others, except where crime relevant issues were concerned (C03). ISAC should facilitate situation assessment by allowing all participants to collect and share information resources which are not part of the official systems. This is in addition to existing infrastructures and therefore helps to connect the respective organizations, even in scenarios of emergent collaboration, when information and expertise sharing is more important (chapter 7).

The evaluation of MoCo (scenario B) illustrated interesting dimensions, boundaries and breakdowns for ad hoc participation. Control center and on-site units are enabled to collaborate and overcome spatial boundaries (C04). New forces from other regions or organizations can collaborate by using (private) smartphones to overcome organizational boundaries (C05). Forces in the control center and off site experts can collaborate during an emergency outside the office hours, who do not work according to schedule, to overcome temporal boundaries (C06). As an additional perspective, BOS mentioned the possibility of providing such information to the public (C07). The overall organizational effect of MoCo is to help overcome boundaries for emergent participation in different dimensions and to include people in situation assessment who have previously been left out. It therefore helps to extend the scope of the infrastructure (chapter 8).

The evaluation of MoRep (scenario C) showed points of infrastructure such as breakdowns in reporting practices and improvisational possibilities which support articulation work. Actors

can request any information not provided by using semi-structured mobile requests in MoRep, therefore extending articulation work (C08). This especially helps to support voluntary forces who are sometimes not as experienced in reporting as their professional counterparts (C09). The organizational structures as well as the reporting practices are different at police and fire departments and the use of such an application therefore differs (C10). Reports help to enhance debriefing (C11), but fail if the communication path is too restricted and does not allow improvisation work (C12). The overall organizational effect of MoRep is to help overcome reporting and articulation breakdowns and to request information when on-site reports are not provided as previously planned and defined in work processes (chapter 9). By including emergent volunteers, requesting information may be further extended (C13) (chapter 10).

Part	No.	Specific practices in inter-organizational crisis management	Chapter
Scenario A: Information and Expertise Sharing with ISAC	C01	*Integration with existing infrastructures:* lack of technical infrastructures does not allow the use of all collaborative functions within the police.	7.6.2.1
	C02	*Shared content and collaboration scenarios:* lack of predefined templates, shapes, and tactical sights.	7.6.2.2
	C03	*Information visibility concerns in inter-organizational information sharing:* no concerns about sharing information with others, neither from the police nor the fire department nor from any other involved organization, with the exception of crime relevant issues.	7.6.2.3
Scenario B: Ad hoc Collaboration with MoCo	C04	*Control center and coordination of on-site units:* possibility to extend improvisational verbal communication on mobile phones with visualization and synchronous view.	8.6.2.1
	C05	*Including new forces from other regions:* possibility to extend improvisational communication by integrating cheap and often already existing (private) technical devices in order to include additional organizations, especially volunteer forces.	8.6.2.2
	C06	*Collaboration outside the office / office hours:* sharing information independently from work environments like a fixed desktop PC or situation map of a control room - therefore beyond office hours.	8.6.2.3
	C07	*Perspective: Sharing with the public:* map sharing and crisis communication to the public is a perspective for BOS.	8.6.2.4
Scenario C: Mobile Reporting with MoRep	C08	*Extending articulation work with semi-structured mobile requests:* reporting basic information to create a common understanding of the situation.	9.7.1
	C09	*Improving situation awareness through semi-structured requests*: supports (organized) volunteers who know the location but lack experience in judging the importance of information; or professionals who do not know the location.	9.7.2
	C10	*Taking organizational specifics and improvisational practices into account*: different organizational structures of the police and fire department lead to different uses of the application.	9.7.3
	C11	*Enhancing debriefing with multimedia-based documentation*: after an emergency the automatically saved requests and transmitted information can be used for the documentation.	9.7.4
	C12	*Predefined communication path vs. improvisation work:* despite the predefined command and reporting structure, the concept has to be flexible enough to cover all improvisational activities during emergencies.	9.7.5
Emergent Volunteers	C13	*Volunteers:* installation of virtual contact points in order to be able to request information from authorities or volunteers.	10.5.5

Table 39: Effects of emergent collaboration infrastructures

Figure 52: Effects of emergent collaboration infrastructures

14.4 Infrastructuring and Emergent Collaboration

The empirical study presented in this work illustrated emergent collaboration practices and work infrastructure limitations (chapter 14.1). They have been addressed with novel concepts and artifacts (chapter 14.2) to illustrate solutions as well as to research their appropriation and their effects on the ability to deal with emergence (chapter 14.3). The results facilitate the discussion of the fourth question:

> *"What are the methodological implications for technology design towards emergent collaboration infrastructures in inter-organizational settings?"*

Ackerman's (2000) article on the intellectual challenge of CSCW outlines the *social-technical gap* between the "social requirements" and the "technically feasible". Pipek and Wulf's (2009) *infrastructuring* (chapter 2.5) aims to allow the users to reduce (at least their perception of) this gap (partially) by themselves, using "appropriation activities as infrastructural work" as opposed to "productive work that end-users consider their main area of work" (Pipek, 2005). Infrastructuring covers all efforts "that contribute to the successful establishment of an information system usage" (Pipek & Wulf, 1999). Accordingly, the gap and the infrastructure usually become visible at the *point of infrastructure* either when new uses emerge or desired activities ("social requirements") are not possible ("technically feasible"). The concept contains both user and designer activities, and provides methodologies for reducing use breakdowns divided into appropriation (use activity) and tailoring (design activities). To discuss infrastructuring for emergent collaboration, the specifics of the subsets, namely *collaboration infrastructures* and *emergent infrastructures,* need to be elaborated.

14.4.1 Collaboration Infrastructures

A number of the theoretical, empirical, conceptional and practical findings reported here are related to the design or use of collaboration infrastructures. *Collaboration infrastructures* are work infrastructures supporting collaborative work. In a jubilee issue of the CSCW journal, Schmidt and Bannon (2013) summarized that, influenced by the technological possibilities of the respective times since CSCW's occurrence in 1984, a range of technologies has emerged, such as collaborative working environments, computer conferencing or social software. However, fundamentally and according to the definitions (chapter 1.1), *collaboration* occurs if at least two actors work on the same task beyond the coordination of their sub-tasks. I argue that collaboration infrastructures are challenged to support the collaborators, who are each embed-

ded in a specific socio-spatio-temporal context, in their effort to overcome the distance between them and to create a common ground for collaboration. "Computer systems meant to support cooperative work in real world settings must support cooperation through the joint construction of a common information space in such settings" (Schmidt & Bannon, 1992). The infrastructure aims to enable collaboration despite the context of the individuals might be rather different. *Distance* is the "amount of space between two things or people" (Oxford University Press, 2014). Consequently, collaboration infrastructures aim to support their users to overcome their contextual distances. According to one definition collaborative work is "enacted in space as well as in time which becomes significant on close analysis of what takes place" (Bardram & Bossen, 2005). For the design of CSCW applications it is beneficial if the current and prospective contexts of the collaborators as well as the distance between them are known in order to consider these constraints in design. However, due to the possibilities of use which go beyond those planned (Orlikowski, 1997), the exact *scope of the infrastructure* (Star & Ruhleder, 1996), defined as the "either spatial or temporal" reach beyond a single event or one-site practice, is often not fully known by its users and designers. Bardram and Bossen (2005, p. 158) posit the concept of *mobility work* as "the attempt to accomplish tasks and work within a setting where everything is distributed, some things are stationary and many other things move around". My case studies, often dealing with mobile actors and resulting in geo-collaborative functionalities, illustrate the mobility of work in the chosen application field. Bardram and Bossen (2005) label mobility work as the spatial parallel to *articulation work*, which they claim to mainly focus on temporal aspects. Independent of the consideration whether articulation work focuses more on temporal or spatial dimension, the question arises:

> *Are 'time' and 'space' the only dimensions that enact or edge collaboration and define the possible distances and therefore the scope of the infrastructure?*

It seems more reasonable that work infrastructures, visibly or invisibly, support collaborative work in defined distances across a number of dimensions. The term *distributed work* does not just refer to the spatial dimension. Temporal, spatial, social, organizational, cultural, professional, intellectual, lingual or technical differences (or distances) do also have to be bridged. These dimensions differ depending on the general type of collaboration. Still, opposing to automated IOIS, for CSCW applications the distance between collaborators is not always fully known during design. If the distance between collaborators is too large or outside the limitations of the infrastructure, a user's desired collaboration is not supported and the user will be aware of the *boundary* of at least one dimension (equivalent to the point of infrastructure). Then either use breakdowns occur or the known scope of the infrastructure is enhanced using appropriation activities (Pipek, 2005; Stevens et al., 2009). Of course, it is impossible to determine all dimensions and breakdowns before use. Still, some obvious collaboration boundaries can be dissolved by identifying at least some dimensions.

To summarize: Collaboration infrastructures are work infrastructures supporting collaborative work and support the collaborators in overcoming dimensional *distances* (e.g. temporal, spatial, social, organizational, cultural, professional, intellectual, lingual or technical) within the known scope of the infrastructure to create a common ground for collaborative activities. If the scope is perceived, points of infrastructure occur.

14.4.2 Emergent Infrastructures

As mentioned in the previous section, the use of an infrastructure sometimes differs from the one planned by the designers. Independent of the type of infrastructure, the emergence of different uses might lead to the need to exceed the scope of the infrastructure. According to Goldstein (1999) *emergent* practices make it harder to anticipate necessary activities (chapter 2.1). When social requirements differ depending on the non-anticipatable tasks necessary in the arising situation, the social-technical gap (Ackerman, 2000) increases. As opposed to static and pre-planned processes, with the emergence of the work context, points of infrastructure probably occur more often, if the infrastructure is not able to adjust to all other contextual conditions. In order to avoid these points, it is proposed that infrastructures should be prepared for the unforeseeable (Waugh & Streib, 2006) and their design therefore needs to be both evolutionary and participatory, leading towards technical flexibility (Wulf, 1999). If these infrastructures are seen as critical infrastructures, not only the emergence of the infrastructure, but also fallbacks will need to be considered. This should provide an infrastructure allowing improvisation work (chapter 2.2), defined as "unforeseeable work", which is "necessary when planned decision-making as the main managerial activity does not fit the conditions the practice provides" (Ley et al., 2012a). Improvisation occurs in both "productive work that end-users consider their main area of work" (if the infrastructure is not improved with that work), as well as in "appropriation activities as infrastructural work" (Pipek, 2005) and therefore infrastructure improvements (Pipek & Wulf, 1999). Although Star and Bowker (2002) indicate that infrastructure is dynamic, prospective evolvements are not necessarily prepared during design.

To summarize: Emergent infrastructures are infrastructures that allow improvised uses beyond the ones planned, therefore enhancing the known scope of the infrastructure. Emergent infrastructures are prepared for infrastructuring.

14.4.3 Emergent Collaboration Infrastructures

The term *emergent collaboration infrastructure* describes the synthesis of collaboration infrastructures (work infrastructures aiming to support the collaborators in overcoming dimensional distances within the known scope of the infrastructure) and emergent infrastructures (infrastructures aiming to support improvised uses and in enhancing the scope of the infrastructure). *Emergent collaboration infrastructures* are challenged to provide a collaboration scope prepared for emergence. However, what does that mean?

The design case studies focusing on the three scenarios (chapters 7-9) provided exemplary perspectives on emergent collaboration. The designed ICT artifacts aim to allow improvisational collaboration in various forms. The artifacts have in common that they support *exceptional* situations, which however are constituted in some typical features in emergent contexts and are expected to happen. Technology design for emergence therefore needs to consider such exceptions and unusual uses.

- *SiRena* (basic infrastructure; social networking in crisis management) offers support in collaboratively discussing topics or editing documents and requests the use of a related ICT artifact even outside regular meetings. In form of a basic social collaboration infrastructure it therefore allows extending the time and place for negotiations. SiRena

also helps participants to learn about other organizations, their working practices and terminologies.

- *ISAC* (scenario A, information and expertise sharing in situation assessment) supports situation assessment by allowing the collaborative creation, maintenance and use of information resources, which are not part of the official systems. It therefore facilitates the extension and self-organization of the information infrastructure used in crisis management.
- *MoCo* (scenario B; ad hoc participation in mobile collaboration) supports the inclusion of those people in situation assessments who were previously left out by not being able to be in the control center; or those who are not usually responsible for crisis management, e.g. independent experts or volunteers. It therefore increases the possible number of participants and therefore the human infrastructure involved in crisis management.
- *MoRep* (scenario C; articulation in mobile reporting) supports the need to articulate information requests when on-site reports are not provided as usually defined in work processes. It therefore extends the directions of communication, especially the reporting between on- and off-site units, and improves articulation.

The three scenarios yield exemplary dimensions to identify boundaries in the use of work infrastructures. They enact the collaboration sphere. I define the *collaboration sphere* as the known scope of the collaboration infrastructure that is visibly or invisibly limited in an infinite number of dimensions. The term *known* refers to the individual user: if he or she is not aware of some kind of supported collaboration, it will not be likely to occur. ICT is usually designed for specific use cases and therefore only supports limited (e.g. socio-spatio-temporal) contexts. However, new applications emerge during use, which emergent collaboration infrastructures should allow.

- *Spatial context:* Usually applications are designed for specific purposes, regardless of time and place. Inter-spatial collaboration refers to multilateral support for actors at the same place (here: internal control center communication) and at various other places (here: on-site units in different places). The design of MoCo or MoRep allowed the improvisational verbal communication already in existence to be enhanced by the ubiquitous use of smartphones as collaboration infrastructures with the visualization and synchronous view on a situation map (MoCo) or reports from on-site to the control center (MoRep), to span spatial distances and overcome the spatial boundaries.
- *Organizational context*: Sometimes collaboration is enacted in organizational and social boundaries. Inter-organizational collaboration refers to the integration of external units (here: inter-organizational forces or volunteer units). The design of SiRena, ISAC or MoCo allows the improvisational communication and situation assessment practices to be extended in such a way that the existing heterogeneous infrastructures are used. Examples include inter-organizational networking (SiRena) or web-based situation illustration (ISAC) as well as utilizing the technical devices which often already exist (in private use) for the integration of additional organizations and especially volunteer forces (MoCo), in order to span organizational distances and overcome organizational boundaries.
- *Temporal context*: Collaboration is sometimes enacted in time. Inter-temporal collaboration refers to time-independent cooperation mechanisms, which are available outside office hours. The design of MoCo or MoRep allows contracting actors independence not only from working environments like a fixed desktop PC or a sophisticated situa-

tion map inside a control room (MoCo), but also from typical office hours (MoRep). BOS also have to be time-independent in order to span temporal distances and overcome temporal boundaries since emergencies do not occur according to time schedules.

Possible infrastructural dimensions are all the parameters that might differ among collaborators, which might change during collaboration or are necessary for the collaboration infrastructure itself.

- *Language context*: Collaboration may be enacted within terminological boundaries, e.g. terminological ambiguities can lead to misunderstandings. Collaboration infrastructures that foster information exchange, like ISAC, support the management or interpretation of different terminologies. Through concepts like SiRena, it is possible to learn about other organizations as well as the terminology they use. ISAC allows tactical signs to be displayed in different ways at the respective organizations according to their local meaning (Reuter, Pipek, et al., 2012; Reuter, Pohl, et al., 2011) to overcome language boundaries.
- *Radio network context:* Collaboration may also be restricted by electrical or radio network boundaries, e.g. if the connection of some of the collaborators is partially unavailable, this may lead to a breakdown in collaboration (Reuter & Ludwig, 2013; Reuter, 2013, 2014). Concepts like MoCo deal with this by sidestepping the set-up of the collaboration server on the inviting actor's device. This precaution is taken in case the internet connection is lost to overcome radio network boundaries.
- *Hardware and software context:* The availability of specific technical requirements, as detected in scenario A, may also be a boundary for collaboration. The installed web browsers in the control centers were outdated (e.g. one police station is still using Internet Explorer 6, which was released in 2001) and did not support important computer technology like JavaScript or Web-Sockets, which are necessary to run our application. It therefore failed to overcome all hard- and software boundaries, unless it was intended.
- *IT skill context*: Technical skills differ a lot among people. Concepts like ISAC can help to share inofficial information ressources, which have previously been accessable in a complicated way (individual collection with various bookmarks) and are now available and accessable in an easy way for all.

Many other dimensions are possible, depending on the kind of infrastructure. However, it is important to elaborate on the scope of the infrastructure and possible limitations in use in order to allow for boundless collaboration and collaborative resilience (B. E. Goldstein, 2011).

14.4.4 Methodological Implications

The previous section elaborated the collaboration sphere as the collaboration possibilities provided by the infrastructure, limited by the respective dimensions. In order to support *infrastructuring* for emergent collaboration infrastructures, the challenge is to design ICT prepared for its emergence and therefore for dimensional flexibility. The methodologies of infrastructuring describe five groups of activities: (1) infrastructural background work with regard to work development or (2) technology development, (3) preparatory design work, (4) preparatory work development and (5) in-situ design work (Figure 1 in chapter 2.5). Infrastructuring tries to "support a search process leading to the [...] points of infrastructure" (Pipek & Wulf, 2009, p. 460). This might be successful for non-emergent practices, as with Orlikowski and

Hofman's (1997) "improvisational model for change management" which outlines the existence of anticipated, emergent and opportunity-based changes in groupware use. As illustrated in the empirical study, official processes and actual practices are not necessarily similar. Official processes are usually more stable and less emergent than actual practices (Hess et al., 2012); they are therefore in theory easier to support with ICT; however, actual practices have to deal with emergence, therefore beforehand defined constraints may not be adequate. Ciborra and Hanseth (2000) even postulate that "infrastructures tend to *drift*, i.e. they deviate from their planned purpose for a variety of reasons often outside anyone's influence" which leads towards an "understanding of infrastructure as an embedded and drifting institution". This substantiates the elaboration of an emerging collaboration sphere but require methodologies for infrastructuring in such settings.

Emergent collaboration infrastructures are challenged to support the collaborators in overcoming dimensional distances in (spontaneous) collaboration. They therefore allow the collaboration sphere (as the known scope of the infrastructure) to expand (or to drift). Emergent collaboration infrastructures in its greatest extent, as opposed to fully automated IOIS, would no longer only comprise specialized tools to support specific practices but generalized tools to fit to most conditions. They are therefore in some cases less adequate. Hence, creating fully emergent infrastructures may neither desirable nor reasonable for all kinds of collaboration. However, ICT should also not create barriers, which limit work practice adaption or improvement but find a compromise between the support of specifics and allowance for improvement and improvisation.

Points of infrastructure can initiate infrastructure development in normal settings, but designers for emergent collaboration infrastructures should not only focus on the support of these specific points, but on the analysis of the underlying characteristics of the collaborators during the occurrence of this point. Hence, requirements engineering, should focus on the observation of contextual distances in the relevant dimensions of collaboration and possible limitations of the infrastructure. Information about arising limitations may be provided by use-cases, empirical studies but may also be inspired by Star and Ruhleder's (1996) characteristics of infrastructure (Table 3 in chapter 2.5). I argue that, based on the detection of typical practices, the challenge is to detect relevant differences among the collaborators and *adequate* infrastructural dimensions (probably besides time, space and organization). This should allow designing ICT artifacts without (too) specific presumptions about these dimensions allowing designing a bit more independent from these constraints and thus a bit more emergent in order to support various contingencies. The move from the point of infrastructure to the point of established use, which is usually reached after appropriation or tailoring, could be minimized by providing emerging infrastructures. The occurrence of a point of infrastructure can therefore help to identifying *dimensions of infrastructure* connected to the point of infrastructure.

Collaborative work, especially on an inter-organizational level, has further specifics opposed to the individual use of work infrastructures. CSCW applications are only part of the work infrastructure, if they are used. Respective collaborators therefore have to be aware of possible uses that may ease the flow of their work. Particularly in the case of emergent (inter-organizational) collaborative infrastructures, this only happens if actors create awareness about the functionalities in use as opposed to the usual invisibility of infrastructures. The concrete usage of a particular application should therefore be made visible in order to create *resonance activities* (Pipek & Wulf, 2009, p. 459):

> *"Each point of infrastructure […] creates resonance activities involving observing and communicating aspects of what has become visible. […] Through resonance activities, the social appropriation of certain technology usages can be captured, and the relations between different points of infrastructure become clear."*

The display indicating when the use of a particular application on the SiRena dashboard begins or the successful conduct of the collaboration mode in ISAC and MoCo can contribute to shaping this awareness, therefore creating resonance activities.

Besides very easy-to-use, lightweight technologies allowing improvisation (Ciborra, 1996), a very important aspect for emergent collaboration infrastructures is self-organization. Highly flexible software applications (Wulf et al., 2008) and support of the appropriation processes associated with them (Pipek, 2005) are therefore required. While the fields of applications differ, the boundary dimensions of the work infrastructures will also differ. Thus the design of ICT in such situations should engage with practices (Wulf et al., 2011), allowing for in-depth knowledge of the application field before the design of ICT. This knowledge might be used to create specific tools supporting this; but even better, the practices identified should be observed from an infrastructure perspective to allow the analysis of the different dimensions this kind of collaboration has to overcome. Basic communication infrastructures as a technical and social basis for tools, such as our implemented social network SiRena, can provide a structure that allows discussions about the ICT artifacts to create resonance activities because "much critical knowledge is never made explicit in materials that can be computerized" (Pipek et al., 2002). Nevertheless, the more emergent an infrastructure becomes, the less it is possible to plan its progression (Pipek & Wulf, 1999) and conflicts may occur (Wulf, 1995). Overall, there is some way to go towards the establishment of infrastructures, which are fully able to deal with emergences while still being useful for the specific situation and prevent breakdowns in collaboration while providing new infrastructure uses.

14.4.5 Towards Infrastructuring for Emergent Collaboration

Collaborative infrastructures should not only support distributed actors with respect to the spatial dimension. Besides the "either spatial or temporal" defined *scope of the infrastructure* (Star & Ruhleder, 1996) I argue that also social, organizational, cultural, professional, intellectual, lingual or technical differences (or *distances*) have to be bridged. With emergent phenomena, that cannot be anticipated in their full richness before they actually manifest themselves (J. Goldstein, 1999, see chapter 2.1), the exact distances are not known during design. In order to design emergent collaboration infrastructures the identification and consideration of relevant distances between the collaborators, based on case studies, leading towards related *dimensions* is crucial. Points of infrastructure should therefore be analyzed regarding their underlying characteristics to identify restricting *dimensions of infrastructure* and to address these constraints in technology design. Examples for emergent technologies allowing improvisation and emergence with regard to some parameters have been presented in this thesis, e.g. the self-organized information infrastructure for situation assessment (scenario A), the ad hoc human infrastructure in situation assessment (scenario B), or the flexible articulation infrastructure for mobile reporting (scenario C). The consideration of emergent dimensions will lead towards more emergent and resilient infrastructures that are reasonable in crisis management, but also for organizations, businesses and individuals in other contexts.

15 Summary

This PhD dissertation has researched technology design for *emergent collaboration infrastructures*. It contributes practically to the research on how ICT can support inter-organizational cooperation practices in emergent contexts using the example of crisis management. The results represent contributions to the fields of CSCW, HCI and IS at four interrelated levels. The thesis (1) provides insights into emergent work practices; (2) presents novel concepts and ICT artifacts to support these practices; (3) evaluates the designed artifacts in order to capture their effects and (4) presents methodological implications for technology design towards emergent collaboration infrastructures in inter-organizational settings.

The advances in ICT have made it possible to support cooperation beyond spatial, temporal and organizational boundaries. Networks of companies exchange information about the flow of goods using supply chain management systems, universities collaborate in joint research using file hosting services, but also BOS (organizations and public authorities with security responsibilities) need to exchange information and need to collaborate. ICT can support this. However, ICT needs to reflect the dynamic nature of cooperation and collaboration in order to improve work infrastructures. The notion of *emergence* as coined by Lewes (1875) and interpreted by Goldstein (1999) refers to dynamic contexts that cannot be anticipated to their full extent before they actually occur. The cooperation in crisis management, which by definition contains the unforeseeable, is probably one of the most suitable examples of the need and occurrence of emergent collaboration and has therefore been chosen as the application field for this research (chapter 1). According to related work (chapter 2), a combination of emergence and self-organization is common (De Wolf & Holvoet, 2005). CSCW is appropriate for dealing with emergent situations, because it aims at "supporting self-organization of cooperative ensembles as opposed to disrupting cooperative work by computerizing formal procedures" (Schmidt & Bannon, 1992) (chapter 2.1). Caused by the *emergent* characteristics of the application field (such as uncertainty, time pressure and complexity) (Mendonça, 2007) information systems for crisis and emergency management have to be highly flexible (Turoff, 2002) and have to support improvisation (Ciborra, 1996) (chapter 2.2). There has already been previous work on inter-organizational CSCW (chapter 2.3) as well as on social software for public participation in crises (chapter 2.4). Nevertheless, published work does not explicitly focus on emergent collaboration infrastructures (chapter 2.5), empirically considering the actual collaboration practices in order to also technically support improvisation work and informal practices and focusing on the appropriation of ICT artifacts and their impact on collaborative practices (chapter 2.6).

This thesis therefore researched this topic theoretically, empirically, conceptually and practically. *Design case studies* (Wulf et al., 2011; Wulf, 2009), inspired by *action research* (Lewin, 1958) and following Hevner and Chatterjee's suggestion (2010) to integrate action research with *design research* (chapter 3.1), were applied at BOS in the two German districts of Siegen-Wittgenstein and Rhein-Erft (chapter 3.2). The research considered the *infrastructuring* perspective (Pipek & Wulf, 2009), to let user-driven innovation emerge from IT breakdowns. The methodology followed a strong user involvement (Rohde, 2007) and contained qualitative methods such as document analyses, observations, group discussions, interviews,

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social media analyses, the development of ICT, empirical evaluations and regular user workshops (Randall et al., 2007) (chapter 3.3).

Based on the analysis of CSCW applications and social software use during crises and in order to specify the research efforts, a classification matrix for crisis management with four different types of cooperation was derived: (1) *Inter-organizational crisis management* – e.g. the exchange of information between the police and fire services: (2) *crisis communication* – e.g. the provision of information to citizens; (3) the *integration of citizen-generated content* – e.g. the selection of citizen-generated information in social media and (4) *self-help communities* – e.g. to foster emergent volunteer groups and neighborhood aid (chapter 4). This matrix interprets the communication relationships mentioned by Quarantelli (1988) and has already been used to classify research efforts (e.g. Birkbak, 2012; Díaz et al., 2010). Furthermore it has been extended to the needs of command and control (Grant et al., 2013; Jongejan & Grant, 2012). The main focus of this thesis is the first type of cooperation: *(inter-)organizational crisis management*.

The empirical study on inter-organizational improvisation work analyzed information exchange, situation assessment, collaboration and reporting practices and illustrated the emergent character of crisis management. Among other aspects, it highlights the necessity of informal contacts as well as the use of private ICT and the subordinate role of formal correctness (chapters 5 and 11). The exploration of the interconnections between single pieces of information in collaborative work resulted in different types and respective design implications (chapter 6). These results contribute to the answering of the first question:

> *"Where do emergent collaboration practices reveal work infrastructure limitations?" (chapter 14.1).*
>
> Emergent collaboration practices as a result of the uniqueness of each situation lead to improvisational practices. Communication challenges (such as different terminological ambiguities), inflexible regulations (one-sided reporting and articulation options) or encapsulated technical infrastructures foster the use of informal contracts, private ICT and information resources. They have been identified as main properties, where emergent collaboration practices revealed limitations of the existing work infrastructure.

Based on these empirical and conceptual foundations three related scenarios have been identified and researched. In particular, the design case studies led to the following concepts:

- *Scenario A*: The research on information and expertise sharing (chapter 7) led to the conception, implementation and evaluation of the *Inter-Organizational Social Network* (SiRena), a social network for BOS (as suggested by White et al., 2009) (chapter 12.1), and the *Inter-Organizational Situation Assessment Client* (ISAC), a web-based map mashup for crisis management (chapter 12.2).
- *Scenario B*: The research on ad hoc participation in mobile collaboration (chapter 8) led to the conception, implementation and evaluation of *Mobile Collaboration* (MoCo), a mobile application allowing map based ad hoc participation and an extension of ISAC (chapter 12.3).
- *Scenario C*: The research on articulation work in mobile reporting (chapter 9) led to the conception, implementation and evaluation of *Mobile Reporting* (MoRep), a mobile application allowing the articulation of information needs and connected to MoCo (chapter 12.4).

They contribute to the answer of the second question:

> *"What kind of novel concepts and artifacts are appropriate for improving work infrastructures towards enabling emergent collaboration?" (chapter 14.2).*
>
> Novel concepts and artifacts aim to span distances among the collaborators to overcome boundaries of collaboration in various dimensions (e.g. temporal, spatial, social, organizational, cultural, professional, intellectual, lingual or technical). The concepts ISAC, MoCo and MoRep have in common to be based on identified constraints and distances between the actors, to design independent from these dimensions and to enhance the *collaboration sphere*. Examples are to enable self-organized information gathering and exchange (ISAC), to include people in situation assessment (MoCo) and to extend requesting and reporting structures (MoRep). This enables emergent collaboration opposed to situations, which lead towards work infrastructure limitations and use breakdowns.

The evaluations of these artifacts (chapter 13) offer different implications for emergent collaboration: It is necessary to create lightweight, flexible and independent infrastructures for inter-organizational information exchange (chapter 7). ICT should also provide possibilities for ad hoc enhancement to the group of people participating in collaboration in different dimensions: spatial, organizational and temporal (chapter 8). ICT can also support improvisation work to enable information to be requested when the formal provision of information fails (chapter 9). It is especially the people outside the official structures (in this case: organized volunteers, such as volunteer fire departments who ought to be considered as important actors). Further work demonstrates possibilities to additionally integrate spontaneous volunteers (chapter 10). These results allow the third question to be answered:

> *"What are the potential organizational effects of such collaboration infrastructures on the ability to deal with emergence?" (chapter 14.3).*
>
> The main organizational effect of emergent collaboration infrastructures is the connection of different actors in emergent contexts by reducing the boundaries between them, e.g. by allowing all participants to collect and share information resources and to connect the respective actors in different dimensions. The result is to overcome spatial boundaries (e.g. between control center and on-site units), organizational boundaries (e.g. new forces from other regions or organizations) and temporal boundaries (e.g. collaborate during an emergency outside the office hours), but also boundaries in other dimensions relevant for the selected case.

Finally, this thesis provides a methodological discussion on infrastructuring for emergent collaboration. Emergent collaboration infrastructures should support the collaborators in detecting and overcoming dimensional *distances* (e.g. time, space, organization, language, electricity, technology) in spontaneous collaboration and therefore allow enhancing the *collaboration sphere* as the known scope of the infrastructure. This answers the fourth question:

> *"What are the methodological implications for technology design towards emergent collaboration infrastructures in inter-organizational settings?" (chapter 14.4).*
>
> In order to design emergent collaboration infrastructures the identification and consideration of relevant *distances* between the collaborators, based on case studies, leading towards related *dimensions*, is crucial. Points of infrastructure

should therefore be analyzed in regards to their underlying characteristics to identify restricting *dimensions of infrastructure* in that particular case and to address these constraints in technology design. I do not argue to aim towards the support of emergence in its full extend, which would resemble arbitrarily tools, but to allow improvisation without yielding towards use breakdowns.

Embedded in the project *InfoStrom* about information infrastructures for inter-organizational crisis management (Balduin et al., 2010; Wiedenhoefer et al., 2011, 2013) this work provides different published contributions:

- Empirical findings on inter-organizational collaboration practices in crisis management (Ley et al., 2012a, 2012b; Mueller et al., 2010; Reuter, Pipek, et al., 2012; Reuter, Pohl, et al., 2011) (chapters 5, 11 and 14.1).
- Empirical findings on the use of social media and the role of the citizen in crisis situations (Heger & Reuter, 2013; Reuter et al., 2013; Reuter, Heger, et al., 2012; Reuter & Ludwig, 2013; Reuter, Marx, et al., 2011a, 2011b, 2012; Reuter, 2013) (chapters 4 and 10).
- Theoretical findings on the interconnection of information in CSCW (Christofzik & Reuter, 2012, 2013; Reuter, 2009) (chapter 6).
- Concepts, implementations and evaluations of concepts and ICT artifacts to address these topics and improve infrastructures for emergent collaboration (Ley et al., 2014; Ludwig et al., 2013a, 2013b; Ludwig & Reuter, 2014; Pipek et al., 2013; Reuter et al., 2014, 2009b; Reuter & Ritzkatis, 2013; Reuter, 2011; Thamm et al., 2013) (chapters 7, 8, 9, 12, 13, 14.2 and 14.3).
- A notion of emergent collaboration infrastructures including methodological implications (chapter 14.4).

This work highlights areas for exploration in further work. Firstly, emergent collaboration infrastructures may be faced with disruptions in the underlying technical communication infrastructure. The research of robust mobile infrastructures and ad hoc networks will therefore increase the resilience of mobile tools addressing emergence. Secondly, the ICT applications have been evaluated only with BOS. The integration of citizens or spontaneous (unorganized) volunteers has not yet been proven and needs to be researched in more detail. Thirdly, the emergence of the software infrastructure itself has not been researched yet, either. It is therefore necessary to elaborate opportunities for providing feedback during use in order to let the infrastructure emerge.

Appendix

Empirical Methods

A Scenario District A: Siegen-Wittgenstein (2010)

Beschreibung: Wettersituation, ausgegeben vom Deutschen Wetterdienst am Donnerstag, 07.01.2010, 13:29 Uhr (Winterferienzeit):

> *„Am morgigen Freitag muss in ganz Deutschland im Tagesverlauf mit schwerem Weststurm gerechnet werden. Vor allem im Westen und in höheren Lagen besteht Unwettergefahr durch Böen bis zur Orkanstärke, deren Ausprägung gegen Abend am stärksten sein wird. Dabei gibt es bei rasch wechselnder bis starker Bewölkung verbreitet sehr kräftige Schauer und schwere Gewitter. Die Tageshöchstwerte liegen zwischen 10 Grad im Nordosten und 13 Grad im Südwesten. In der Nacht zu Samstag gibt es weitere sehr kräftige Schauer. Die Luft kühlt sich auf Tiefstwerte zwischen 0 und 3 Grad ab. Örtlich Gefahr von Eisregen! Der Wind weht weiterhin stark bis stürmisch aus westlichen Richtungen, mit Unwettergefahr durch orkanartige Böen, im höheren Bergland sind Orkanböen möglich."*

Vorbereitungen: Auf Grund der Vorwarnung werden folgende Maßnahmen getroffen:

- Für den nächsten Tag wird das Personal in der Kreisleitstelle aufgestockt, darüber hinaus wird die Verfügbarkeit weiterer Kräfte abgeklärt.
- Der Kreiskrisenstab sowie die Einsatzleitung werden informiert und halten sich für den kommenden Tag bereit.
- Die Leiter der Feuerwehren in den einzelnen Kreiskommunen erhalten entsprechende Informationen um ihre Feuerwehren entsprechend aufstellen zu können.

Phase 1: Freitag 13:00 - vor Eintritt der Störung - keine wetterbedingten Einsätze

Phase 2: Freitag 13:15 - 16:00 Uhr: Der SAE (Stab außergewöhnliche Ereignisse) trifft sich um 16:00 Uhr in der Kreisleitstelle und beobachtet die Lage sowie die Wetterentwicklung.

Phase 3: Freitag 16:30 - 19:00 Uhr

- Kreisleitstelle
  - Etliche Meldungen über umgefallene Bäume und Sturmschäden sowie vollgelaufene Keller.
  - Anfragen wegen Stromausfällen durch besorgte Bürger.
  - Auf Grund der Vielzahl eingehender Anrufe wird das Leitstellenpersonal gegen Abend aufgestockt.
- Einsatzleitung
  - In der Kreisleitstelle erweitert sich der SAE zur Einsatzleitung unter der Leitung des Kreisbrandmeisters.

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  - In den kreisangehörigen Gemeinden werden zwischen 17:00 Uhr und 18:00 Uhr Meldeköpfe der Feuerwehren installiert, die die Einsätze in ihrem Gebiet selbstständig abarbeiten.
  - Um 18:00 Uhr wird der zuständige Dezernent in die Einsatzleitung gerufen
- Kreiskrisenstab
  - Um 19:00 Uhr ruft der Kreisbrandmeister den Krisenstab des Kreises ein
  - Der RWE-Verbindungsmitarbeiter wird informiert

Phase 4: Freitag 19:00 - 20:00 Uhr - Meldungen -

- In der Kreisleitstelle melden sich mehrere Landwirte, darunter ein großer landwirtschaftlicher Betrieb mit ca. 200 Milchkühen in Emilienhof, die Ihre Kühe nicht melken können.
- In der Kreisleitstelle melden sich besorgte Bahnkunden, die mit ihrem Zug in einem längeren Bahntunnel zwischen Wilnsdorf-Rudersdorf (im Kreisgebiet) und Hessen steckengeblieben sind. Es befinden sich ca. 500 Personen im Zug.
- Auf Grund von Unpassierbarkeit von Straßen durch umgefallene Bäume können erkrankte und verletzte Patienten nicht mehr in angemessener Zeit erreicht werden.
- Ausfall aller Mobilfunknetze in den betroffenen Gebieten

Phase 5: Freitag 20:00 - 22:00 Uhr: keine zusätzlichen Aktivitäten

Phase 6: Freitag 22:00 - 00:00 Uhr

- In der Kreisleitstelle melden sich mehrere Alten- und Kinderheime aus dem Bereich Burbach, Neunkirchen und Wilnsdorf, deren Bewohner auf Grund der ausgefallenen Heizung frieren. Seitens des Kreiskrisenstabs wird eine Evakuierung geprüft.
- Insbesondere betroffen sind folgende Einrichtungen:
  - Altenheim Haus Höhwäldchen, Höhwäldchen 3, Wilnsdorf
  - Senioren- und Pflegeheim Burbach, Steinhardstr. 4
  - Kinderzuhause, Burgweg 14, Burbach
- In der Kreisleitstelle melden sich Beatmungs- und Dialysepatienten, die in den nächsten Stunden Hilfe benötigen.
- Auf Grund der massiven Regenfälle der letzten Tage führt die Sieg Hochwasser. Aus Sicherheitsgründen muss daher in der städtischen Kläranlage Siegen (Geisweid, Ferndorfsteg 33) sowie im Krankenhaus Weidenau (Weidenauer Straße) der Strom abgestellt wird.
- Mehrere Straßen müssen auf Grund von Hochwasser gesperrt werden.

Phase 7: Samstag 02:00 Uhr - keine zusätzlichen Aktivitäten

Phase 8: Samstag 08:00 Uhr - keine zusätzlichen Aktivitäten

Phase 9: Samstag 18:00 Uhr

- Durch den langen Ausfall im Bereich Burbach ist der Siegerlandflughafen betroffen. Dort sind mehrere Umsetzer für den BOS-Funk nicht mehr versorgt, wodurch der Funk in diesem Bereich am Samstagnachmittag ausgefallen ist.
- Ausfall der Richtfunkstrecken zu den Rathäusern im südlichen KSW, dadurch auch Einschränkung der Telefonie in den betroffenen Verwaltungen.
- Lebens- und Arzneimittelversorgung im Bereich Burbach nur noch stark eingeschränkt.
- Keine Kraftstoffversorgung im Bereich Burbach mehr möglich.
- Festnetztelefonie teilweise gestört.

Phase 10: Sonntag 18:00 Uhr

- Das Hochwasser der Sieg ist zurückgegangen, die Kläranlage sowie das Krankenhaus sind wieder versorgt.
- Die meisten Straßensperrungen wurden aufgehoben.
- Der Kreiskrisenstab sowie die Einsatzleitung lösen sich auf.

Phase 11: Montag 13:00 Uhr - keine zusätzlichen Aktivitäten

B Scenario District B: Rhein-Erft (2010)

Beschreibung: Wettersituation, Donnertag, 6. Januar, 13:30 Uhr: Der Deutsche Wetterdienst gibt eine Unwetterwarnung für den Rhein-Erft-Kreis heraus. Es wird vor Sturm mit Orkanstärke und Eisregen gewarnt:

> *„Am morgigen Freitag muss in ganz Deutschland mit schwerem Weststurm gerechnet werden. Vor allem im Westen und in höheren Lagen besteht Unwettergefahr durch Böen bis zur Orkanstärke, deren Ausprägung am Nachmittag am stärksten sein wird. Dabei gibt es bei rasch wechselnder bis starker Bewölkung verbreitet sehr kräftige Schauer und schwere Gewitter. Die Tageshöchstwerte liegen zwischen 10 Grad im Nordosten und 13 Grad im Südwesten. In der Nacht zu Samstag gibt es weitere sehr kräftige Schauer. Die Luft kühlt sich auf Tiefstwerte zwischen 0 und +3 Grad ab. Örtlich Gefahr von Eisregen! Der Wind weht weiterhin stark bis stürmisch aus westlichen Richtungen, mit Unwettergefahr durch orkanartige Böen, im höheren Bergland sind Orkanböen möglich."*

Vorbereitende Maßnahmen: Aufgrund der Vorwarnung werden folgende Maßnahmen getroffen:

- Für den nächsten Tag wird das Personal in der Kreisleitstelle aufgestockt, darüber hinaus wird die Verfügbarkeit weiterer Kräfte abgeklärt.
- Der Kreiskrisenstab sowie die Einsatzleitung werden informiert und halten sich für den kommenden Tag bereit.
- Die Leiter der Feuerwehren in den einzelnen Kreiskommunen erhalten ausführliche Informationen um ihre Feuerwehren entsprechend aufstellen zu können.

Phase 1: Freitag, 13.00 Uhr: - vor Eintritt der Störung - Keine wetterbedingten Einsätze.

Phase 2: 13.15 bis 13.45 Uhr

- Leitstelle
    - Ab 13:15 Uhr Meldungen über umgefallene Bäume und Sturmschäden.
    - Anfragen wegen Stromausfällen durch besorgte Bürger.
    - Aufstockung des Leitstellenpersonals.
    - Das Gruppenklärwerk Kenten ist spannungslos geworden. Mehrere Pumpen sind ausgefallen. Anfrage des Betreibers wie lange der Ausfall voraussichtlich dauern wird.
    - Lokale Ausfälle von Mobilfunknetzen wegen Überlastung.
- Krisenstab
    - Einrichtung von Meldeköpfen in den betroffenen kreisangehörigen Kommunen.
    - Bildung der Kreis-Einsatzleitung unter der Leitung des Kreisbrandmeisters.
    - Der Krisenstabsleiter des Rhein-Erft-Kreises steckt im Bahnhof Horrem im Aufzug fest.

Phase 3: 14.05 Uhr: Ausfall von 110 kV-Leitungen in Sinsdorf Nord und Süd

- Leitstelle wird kurz spannungslos. USV arbeitet.
- Kreiskrisenstab nimmt um 14:30 Uhr seine Arbeit auf, Anforderung RWE-Verbindungsmitarbeiter.

Phase 4: 14.35 Uhr: Ausfall Wasserwerk Sindorf

- Wasserversorgung in Teilen der Gemeinden Kerpen, Bergheim und Elsdorf nicht mehr sicher-gestellt! (Auch Löschwasserversorgung betroffen!)

Phase 5: 15.00 Uhr: Ausfall Umspannanlage Hürth

- Die zuständigen Behörden sowie die Rettungsleitstelle wurden über die Fackeltätigkeit im Industriepark Hürth informiert.

Phase 6: 15.20 Uhr: Krankenhaus Brühl

- Krankenhaus Brühl (Mühlenstraße) ist spannungslos geworden, Notstrom funktioniert nicht (Versorger: Stadtwerke Brühl).

Phase 7: 15.45 Uhr: Ausfall Mobilfunknetz

- Ausfall des letzten Mobilfunknetzes.

Phase 8: 15.55 Uhr: Liegen gebliebener Zug

- Liegengebliebener Zug mit ca. 400 Fahrgästen wegen Bäumen auf der Schiene bei Kerpen-Horrem.

Phase 9: 16.00 Uhr: Lagebericht

- Keine zusätzlichen Aktivitäten.

Phase 10: 17.00 Uhr: Lagebericht

- Störung Wasserwerk: Eine Einspeisung wurde entstört und wieder zugeschaltet, das Wasserwerk kann den Betrieb wieder aufnehmen.
- Meldung in Kreisleitstelle: Aufgrund von ausgefallenen Ampeln ist es an der Ampelkreuzung an der Auffahrt Kerpen zur A4 (L122) zu einem schweren Verkehrsunfall mit mehreren Schwerverletzten gekommen.
- Meldung durch die Polizei: An gefährlichen Kreuzungen wird die Verkehrsregelung aufgrund der ausgefallenen Ampeln durch die Polizei übernommen.

Phase 11: 18.00 Uhr: Lagebericht: Meldung der Kreisleitstelle: Ausfall der Alarmierung im Bereich Kerpen.

Phase 12: 21.00 Uhr: Lagebericht: Keine zusätzlichen Aktivitäten

Phase 13: Freitag, 22.00 bis Samstag, 05.00 Uhr: weitere Meldungen von Bürgern

- Leitstelle
    - Vielzahl von Anrufen frierender Bürger wegen Ausfällen der Heizung aus den betroffenen Gebieten.
    - In den Abendstunden mehrere Zimmerbrände aufgrund von umgefallenen Kerzen.
    - Anfrage des Dialysezentrums Horrem nach weiterem Vorgehen, samstags morgens müssen Patienten behandelt werden.
- Krisenstab
    - Meldung durch Polizei: Meldungen von Plünderungen in einigen Ortsteilen seit Anbruch der Dunkelheit.
    - Teilausfall des Festnetzes.

Phase 14: Samstag, 19.00 Uhr: Lagebericht: Keine zusätzlichen Aktivitäten

Phase 15: Sonntag, 19.00 Uhr: Lagebericht: Der Kreiskrisenstab sowie die Einsatzleitung lösen sich auf.

C Interviews: Work Practices and IT Support (2010-2011)

Interviewers: Christian Reuter, Torben Wiedenhoefer and Benedikt Ley.

Teil I: Analyse des Nutzungskontextes

1. Was ist Ihre Rolle?
2. Wie lange nehmen Sie diese Rolle bereits ein?
3. Beschreiben Sie Ihre Qualifikation.
4. Beschreiben Sie bitte in ihre Tätigkeit in einem oder zwei Sätzen
5. Aus welchen Aufgaben ist Ihre Tätigkeit zusammengesetzt? (Typische Kern-Aufgaben aufführen, d.h. wenn großer Zeitanteil oder häufig wiederkehrend oder sehr wichtig)? Welche dieser Kern-Aufgaben werden durch Software unterstützt?
6. Wie ist Ihre Tätigkeit organisiert?

7. Welche Qualifikationen sind zum Ausüben ihrer Arbeit notwendig (Arbeitsausübung/Softwarenutzung)? Welche Vorkenntnisse fehlen?
8. Wer (bzw. welches Ereignis) bestimmt, was zu tun ist? (Wer trifft die Auswahl?, Selbständigkeit der Bearbeitung, Arbeitsteilung, externe Datenquellen)
9. Welche Hilfsmittel sind erforderlich (für die Aufgabenbewältigung / zur Softwarenutzung)? Nennen Sie auch Hilfsmittel, die Sie sich selbst geschaffen haben. Welche davon fehlen ggf., welche sind zusätzlich gewünscht?
10. Welche Arbeitsschritte sind durchzuführen?
11. Welche weiteren Personen sind an Ihren Arbeitsschritten beteiligt?
12. Arbeiten mehrere Personen an einem Vorgang, Disposition, etc.?
13. Welche Abhängigkeiten bestehen von Personen/Arbeitsergebnissen oder Systemen?
14. Können Sie Arbeitsschritte selbst beeinflussen/gestalten oder werden diese vorgegeben?
15. Welche (Teil-) Ergebnisse entstehen und wie werden diese ggf. verwertet/weitergeführt?
16. Welches Feedback bekommen Sie in Bezug auf die Arbeitsergebnisse und die Wirkung ihrer Arbeit?
17. Welche Unterbrechungen gibt es und warum? Welche Störungen treten auf (organisatorisch/sozial/technisch)?
18. Welche Stressfaktoren gibt es und wie wird damit umgegangen?
19. Gibt es informelle Kommunikations- und Arbeitswege, die Sie nutzen? Wenn ja, wann nutzen Sie diese?
20. Wie werden Fehler zurückgemeldet und behoben (organisatorisch/sozial/technisch)?
21. Welche wichtigen Sonderfälle müssen berücksichtigt werden (Was fällt Ihnen spontan ein; z.B. zur Arbeitsteilung/Zusammenarbeit)?
22. Welche Organisationsziele gibt es im Hinblick auf die Tätigkeit?
23. Welchen Überblick hat der Benutzer im Hinblick auf die Gesamttätigkeit?
24. Welche Veränderungen wird es in den kommenden 5-10 Jahren Ihrer Meinung geben, die auch Ihre Arbeit beeinflussen werden?

Teil II: Analyse der Nutzung von Anwendungs- und Kommunikationssysteme

1. Welche Anwendungs- und Kommunikationssysteme verwenden Sie zur Ausübung Ihrer Tätigkeit und wie werden diese von Ihnen genutzt? (Wenn möglich, Demonstration der einzelnen Systeme wie sie real verwendet werden – zumindest Kernaktivitäten)
2. Welche Probleme treten bei Nutzung von Anwendungs- und Kommunikationssystemen auf?
3. Haben Sie ggf. eigene Strategien/Hilfsmittel um diese Probleme zu umgehen?
4. Auf welche Besonderheiten bei der Nutzung muss geachtet werden?

5. Gibt es Ihrer Meinung weitere Unterstützungsmöglichkeiten durch Anwendungssysteme oder weitere Funktionen (auch intra- und interorganisational)?
6. Auf welche Besonderheiten sollte hier geachtet werden?
7. Wäre für Ihre Arbeit eine Erweiterung der Unterstützung durch Bürger (Senden von Bildern, Melden von Ereignissen) hilfreich?
8. Welche Unterstützungsmöglichkeiten erhalten Sie für die Erlernung von Anwendungssystemen (Schulung, Rückfragen, etc.)?
9. Welche Möglichkeiten bietet Ihre Institution, wenn Probleme mit Anwendungssystemen auftreten?
10. Wie gehen Sie vor, wenn Probleme mit ihren Anwendungssystemen auftreten (z.B. Kollegen fragen)?
11. Treten bei Ihnen unsichere Informationen auf und wie gehen Sie damit um? Könnten Ihnen Programme hierbei helfen?
12. Wäre eine verbesserte Aktivitätswahrnehmung anderer Beteiligter auch anderer Organisationen durch ein System für Ihre Arbeit hilfreich?
13. Wie wird bei Ihnen mit Anpassungswünschen umgegangen?
14. Haben Sie Ihre genutzten Systeme an Ihre Bedürfnisse angepasst? (Wenn möglich zeigen lassen, ansonsten Beispiele nennen lassen)
15. Können Sie Anpassungen selbst übernehmen oder wird dies von anderen Personen oder Institution übernommen? Wenn selbst übernommen: Wie haben die Anpassungen durchgeführt. Wenn andere Person/Institution: Wer ist dafür zuständig?

D Interviews: Mobile Collaboration and Reporting (2012)

Interviewers: Christian Reuter, Thomas Ludwig and Michael Ritzkatis.

1. Wissen die Einsatzkräfte vor Ort was sie, wie wann zurückmelden müssen?
2. Welche Rolle spielen verschiedene Formate von Informationen? Gibt es Präferenzen der einzelnen Akteure bei den Formaten?
3. Wäre es interessant bei schlechter/unzureichender Rückmeldung Informationen selbst anzufordern?
4. Wäre es interessant vorzudefinieren, wie man Informationen erwartet?
5. Von wem und wie sollte man die Informationen anfordern?

E Evaluations: Inter-Organizational Situation Assessment (2011)

Interviewers: Christian Reuter, Torben Wiedenhoefer and Benedikt Ley.

Einleitung: Basierend auf den Ergebnissen aus den Interviews und Recherchen möchten wir Ihnen nun einen ersten technischen Output zeigen. Unser System stellt eine Lagekarte dar, auf der relevante Informationen, wie Wetterkarten, Pegelstände, Webcams, Stromausfallgebiete, Polizei- und Feuerwehrwachen, Kontaktdaten, eingebunden und dargestellt werden können.

Diese Karten können individuell konfiguriert werden und untereinander geteilt werden. Der *Lageillustrator* ist ein webbasiertes Tool auf der Basis von Google Maps und ermöglicht einen Zugriff von überall.

Ziel der Evaluation:

1. Bewertung der Funktionalitäten und deren Umsetzung.
2. Anregungen hinsichtlich der weiteren Entwicklung.
3. Es handelt sich um einen frühen Prototyp. Alle Funktionen und Informationsressourcen stehen noch nicht zur Verfügung, um damit Aufgaben lösen zu können. Wichtig für uns ist, dass wir die Zielsetzung des Systems verständlich machen und Sie uns Anregungen geben.
4. Es soll kein Leistungstest sein. Probleme die mit der Bedienung auftreten können sind nicht schlimm und sind auf Defizite in der Softwareentwicklung nicht auf die Person zurückzuführen. Deshalb wollen wir frühzeitig testen.

Szenario: Stellen Sie sich vor, Sie erhalten per E-Mail eine Unwetterwarnung des Deutschen Wetterdienstes. Für den nächsten Tag wird ein schwerer Weststurm vorhergesagt. Um darauf entsprechend vorbereitet zu sein, wollen Sie sich ein genaueres Bild über den Sturm machen. Kommentieren Sie bitte im Folgenden Ihre Handlungen, so dass wir auch die Gründe für Ihre Handlungen erfahren sowie Probleme leichter nachvollziehen können.

1. Wie würden Sie mit Hilfe dieser Lagekarte und den darin verfügbaren Informationsressourcen, vorgehen, um sich ein Bild der Wetterlage zu verschaffen?
2. Wie können Sie sich Wetterinformationen anzeigen lassen?
3. Wie können Sie sich Stromausfallgebiete anzeigen lassen? (Beispielinformationen - sich selbst Informationen einbinden)
4. Sie haben bemerkt, dass die Information … noch nützlich sein könnte. Wie würden nun vorgehen, diese in die Lagekarte zu integrieren?
5. Was für weitere Informationen könnten noch in der Karte nützlich sein?
6. Demonstration der Einbindung einer aus der vorherigen Frage genannten Information oder Markierung eines Gebäudes mit Eingabe eines Ansprechpartners im Editorfeld
7. Demonstration der Einbindung eines WMS (GeoServer NRW, Keyword: *Wasser*, zweiter Webservice gut geeignet)
8. Sie haben des Weiteren die Möglichkeit ihre Karte zu speichern und anderen Kollegen zur Verfügung zu stellen (abspeichern einer Kartenansicht, Aufrufen einer Karte eines anderen Benutzers)

Interview:

1. Wie ist generell Ihr erster Eindruck?
2. Funktionen: Wie würden Sie das System beschreiben? Was kann man mit dem System machen?
3. Nutzung: Wie hat das System im Allgemeinen das Erreichen Ihrer Ziele unterstützt? Wie war der Umgang mit dem System? War der Umgang mit vielen Problemen behaf-

tet? War der Umgang verständlich? Hat es Spaß gemacht mit dem System zu arbeiten? Wie wichtig ist Ihnen das?

4. Nutzen: Wie ist Ihre persönliche Meinung, sehen Sie das System als Bereicherung für Ihre Arbeit? Wie würde sich Ihrer Meinung nach, Ihre Arbeit verändern?
5. Ziel: Was müsste es noch gegeben sein, damit Sie dieses System nutzen? Gibt es technische/organisatorische/soziale Voraussetzungen die erfüllt sein müssen?
6. Gemeinsame Lageeinschätzung: Wie wird Ihrer Meinung nach die gemeinschaftliche Lageeinschätzung unterstützt? Wie kann das in Ihrer Arbeit helfen? Gibt es Besonderheiten zu beachten?
7. Welche Informationen fehlen? Wie ist Ihre persönliche Meinung zur interorganisationalen Integration von Informationsressourcen? Wie kann das in Ihrer Arbeit helfen? Welche Informationen wären für Sie in einer solchen Anwendung hilfreich? Gibt es technische/organisatorische/soziale Besonderheiten zu beachten?
8. Gibt es sonst noch etwas, was Sie sich wünschen würden?

F Evaluations: Mobile Collaboration and Reporting (2012)

Interviewers: Christian Reuter, Thomas Ludwig and Michael Ritzkatis.

Teil I: Mobile Collaboration

Schritt 1: Vorstellung und Erläuterung von MoCo auf einem Tablet durch ein Szenario

- Einloggen mit SiRena-Benutzerdaten
- Kurzübersicht der Hauptseite der Anwendung (Infoleiste, Karte, Kollaborationsleiste, Titelleiste)
- Demonstration der Toolbox (Marker anlegen und Freihandzeichnung)
- Demonstration von Informationsquellen (Web Services)
- Start und Demonstration des Kollaborationsmodus
- Erstellung eines mobilen Markers
- Demonstration der Navigation, indem der zweite Kollaborationsteilnehmer einen Marker hinzufügt und der Tablet-Nutzer diesen als Navigationsziel benutzt

Schritt 2: Fragen zur Anwendung MoCo

- Welche ihrer Erwartungen zu MoCo sind erfüllt bzw. nicht erfüllt?
- Wie ist ihr Eindruck zu der verwendeten Google-Maps Karte?
- Wie kann sich der dargestellte Informationsaustausch auf ihre Arbeitspraxis auswirken?

Schritt 3: Kurzdemonstration von MoCo auf einem Smartphone zur Überprüfung der Gebrauchstauglichkeit

- Anwendung starten und einloggen, kurze Pause, damit Befragter die Anwendung begutachten kann

- Wie ist ihr Eindruck zu dieser Anwendung auf dem Smartphone, insbesondere in Bezug auf die veränderte Bildschirmgröße?

Teil II: Mobile Reporting

Schritt 1: Intention von MoRep erklären

Schritt 2: Unterschiede zu vergleichbaren Apps deutlich machen

- Vorstellung von MoRep auf zwei Smartphones durch ein kleines Szenario

Schritt 3: Leitfragen zu MoRep

- Sie und Ihre Kollegen haben in dem letzten Interview bereits Erwartungen an einen Mechanismus, welcher die entfernten Einheiten mit Informationen versorgt, formuliert. Welche dieser Erwartungen sind erfüllt bzw. nicht erfüllt?
- Ist MoRep relevant für Ihre Arbeitspraxis?
- Was denken Sie von einer reinen Informationsanforderung über mobile Geräte?
- Haben Sie konkrete Tipps und Verbesserungsvorschläge?

G Evaluations: Information and Expertise Sharing (2013)

Interviewers: Benedikt Ley, Thomas Ludwig, Christian Reuter and Torben Wiedenhoefer.

Teil I: Angaben zur Person

1. Was ist ihre Rolle?
2. Wie lange nehmen Sie diese Rolle bereits ein?
3. Beschreiben Sie Ihre Qualifikation (Lehrgänge etc.)
4. Beschreiben Sie bitte in ihre Tätigkeit in einem oder zwei Sätzen!

Teil II: Analyse der Gebrauchstauglichkeit von ISAC

5. Wie ist Ihr erster Eindruck von dem System?
6. Welche Probleme sind im Umgang mit dem System aufgetreten?
7. Würden Sie das System einem Kollegen empfehlen? (Wenn ja/nein, warum?)

Teil III: Analyse des Arbeitskontextes

8. Welche Tätigkeiten haben Sie mit dem System durchgeführt?
9. Welche Tätigkeiten können Sie sich in Zukunft vorstellen, die durch das System unterstützt werden können?
10. Waren noch andere Personen bei der Nutzung involviert?
11. Sind weitere Hilfsmittel für solche Tätigkeiten notwendig? (Telefon, Software, etc.)
12. Für welche (Einsatz-)Szenarien ist Ihrer Meinung das System geeignet und für welche nicht?

Teil IV: Analyse der inter-organisationalen Faktoren

13. Welche Organisationen könnten bei der Nutzung des Systems involviert sein?

14. Welche Chancen und Herausforderungen sehen Sie im Austausch von Informationen und Expertise mit anderen Organisationen?
15. Welche Informationen (eigene/Organisation) haben oder würden Sie Kollegen oder anderen Organisationen zur Verfügung stellen und welche nicht?

Teil V: Abschließende Fragen

16. Was müsste gegeben sein, damit Sie dieses System in Ihrem Arbeitsalltag nutzen können?
17. Welche weiteren Funktionen wären Ihrer Meinung nach noch wünschenswert?

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